DECEMBER 2022

2022 U.S. CLIMATE AMBITION REPORT

Eighth National Communication and Fifth Biennial Report of the United States of America to the United Nations Framework Convention on Climate Change

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ABBREVIATIONS AND ACRONYMS

AAAS	American Association for the Advancement of Science
ABC	Advanced Building Construction Initiative
ACEP	Agricultural Conservation Easement Program
AEO	Annual Energy Outlook (EIA)
AESP	Appliance and Equipment Standards Program (DOE)
AIM	American Innovation and Manufacturing Act
AML	Abandoned Mine Land program
AR4	IPCC Fourth Assessment Report
AR6	IPCC Sixth Assessment Report
AVTM	Advanced Technology Vehicle Manufacturing program
BIA	Bureau of Indian Affairs
BIL	Bipartisan Infrastructure Law
BLM	Bureau of Land Management (DOI)
BR	Biennial Report
BTU	British Thermal Unit
C	Carbon
CAFE	Corporate Average Fuel Economy
CASC	Climate Adaptation Science Center
CE	Committee on Environment
CEM	Clean Energy Ministerial
CEQ	Council of Environmental Quality
CES	Clean energy standards
CCS	Carbon capture and storage
CCUS	Carbon Capture, Utilization, and Storage
CDC	Center for Disease Control
CFCs	Chlorofluorocarbons
CFP	Community Forest Program
CH_4	Methane
CHMO	Climate and Health Monitor and Outlook
CHP	Combined Heat and Power
CIG	Capital Investment Grants
CLE	Conservation Legacy Effect
CLEAN	Climate Literacy and Energy Awareness Network
CLEEN	Continuous Lower Energy, Emissions and Noise Program
CM	centimeter
CMAQ	Congestion Mitigation and Air Quality program
CMOP	Coalbed Methane Outreach Program
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
CO	Carbon monoxide
COFIDE	Development Bank of Peru
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
CRA	Collaborative research action
CREAT	Climate Resilience Evaluation and Awareness Tool
CRF	Common reporting format
CRP	Conservation reserve program
CRSCI	Climate Ready States and Cities Initiative
CSP	Conservation Stewardship Program
CStP	Conservation Stewardship Program
CTA	Conservation Technical Assistance program
CTCN	Climate Technology Center and Network
CTSL	Clean and Advanced Technologies for Sustainable Landscapes Program
DFC	Development Finance Corporation
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DOS	Department of State
DOT	Department of Transportation
ECP	Environment and Culture Partners
ECV	Essential climate variable
ED	Emergency department
EECBG	Energy Efficiency and Conservation Block Grant Program
EERE	Energy efficiency & renewable energy

eGRID	Emissions and Generation Resource Integrated Database
EIA	Energy Information Administration (DOE)
EISA	Energy Independence and Security Act
EPA	U.S. Environmental Protection Agency
EPCA	Energy Policy and Conservation Act
EQIP	Environmental quality incentives program
ERDC	Engineer Research and Development Center
ESGF	Earth system grid federation
EVs	Electric vehicles
EXIM	Export-Import Bank of the United States
°F	Fahrenheit
FAA	Federal Aviation Administration
FARG	Federal Adaptation and Resilience Group
FASOMGHG	Forest and Agricultural Sector Optimization Model with Greenhouse Gases
FEMA	Federal Emergency Management Agency
FFII	Forest Finance and Investment Incubator
FHWA	Federal Highway Administration
FIA	Forest inventory analysis
FLP	Forest Legacy Program
FOROM	Forest Dynamics model, Land Use Change model, and Trade Model
FSA	Farm service agency
FSP	Forest Stewardship Program
FTA	Federal Transit Administration
FY	Fiscal year
G/MI	Gallons/mile
GAO	Government Accounting Office
GAOA	Great American Outdoors Act
GAW	Global atmosphere watch
GCF	Green Climate Fund
GCCS	Gas collection and control systems
GCIS	Global Change Information System
GCMS	General circulation models
GCOS	Global Climate Observing System
GCRA	Global Change Research Act
GDP	gross domestic product
GEB	Grid-interactive efficient buildings
GEF	Global Environment Facility
GEM	Greenhouse gas emissions model
GHG	Greenhouse gas
GHGRP	Greenhouse gas reporting program
GPP	Green power partnership
GSN	GCOS Surface network
GTM	Global timber model
GUAN	GCOS upper air network
GW	Gigawatts
GWF	Green Workforce Training program
GWP	Global warming potential
HBIIP	Higher Blends Infrastructure Incentive Program
HDV	Heavy duty vehicle
HEARTH	Health, Ecosystems and Agriculture for Resilient Thriving Societies
HECG	High energy cost grants
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
HPwES	Home Performance with ENERGY STAR
HUD	Department of Housing and Urban Development
HVAC	Heating, ventilation, and cooling
IAC	Interagency Council
IAC	Industrial Assessment Center
IAI	Inter-American Institute for Global Change Research
ICAO	International Civil Aviation Organization
ICED II	Indonesia Clean Energy Development II project
IGBZ	Integrated Gorongosa and Buffer Zone

IMLS	Institute of Museum and Library Services
IN	Inch
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
IOOS	U.S. Integrated Ocean Observing System
IRA	Inflation Reduction Act
ISEIS	Informal science education institutions
ISGAN	International Smart Grid Action Network
IWG	Interagency Working Group
JPSS	Joint polar satellite system
K	Kindergarten
KG	kilogram
KM2	Square kilometers
KW	kilowatt
KWH	kilowatt-hours
LACI	Latin America and the Caribbean Initiative
LDC	least-developed countries
LEDS GP	Low Emissions Development Strategies Global Partnership
LEDM	light-emitting diode
LGEP	Local government energy program
LRF	Land Legacy Restoration Fund
LMOP	Landfill Methane Outreach Program
LPO	Loan Program Office (DOE)
LULUCF	Land use, land use change, and forestry
LSR	Landscape Scale Restoration
LTS	Long-Term Strategy
LWCF	Land and Water Conservation Fund
MAC	Marginal abatement cost
MCC	Millennium Challenge Corporation
MDB	Multilateral development banks
MECCE	Monitoring and Evaluating Climate Communication and Education project
MI2	Square miles
MIPS	Model intercomparison projects
MMT	Million metric tonnes
$MMTCO_2e$	Million metric tonnes of carbon dioxide equivalent
MOU	Memorandum of understanding
MOVES	Motor Vehicle Emission Standards
MPG	Miles per gallon
MMRV	Measurement, monitoring, reporting and verification
MSHA	Mine Safety and Health Administration – Department of Labor
MSTRS	Mobile Sources Technical Review Subcommittee
MSW	Municipal solid waste
MW	Megawatts
MY	Model year
N_2O	Nitrous oxide
NAAEE	North American Association for Environmental Education
NAP	National adaptation planning
NAP-GN	National adaptation planning global network
NASA	National Aeronautics and Space Administration
NASEM	National Academies of Sciences, Engineering and Medicine
NBI	New Buildings Institute
NC	National Communication
NCA	National Climate Assessment
NCA4	Fourth national climate assessment
NCEI	National Centers for Environmental Information
NDC	Nationally Determined Contribution
NEI	National Emissions Inventory
NEMA	New England Museum Association
NEMS	National Energy Modeling System

NEON	National ecological observatory network
NESDIS	National Environmental Satellite Data and Information Service
NEVI	National Electric Vehicle Infrastructure
NF_3	Nitrogen trifluoride
NHTSA	National Highway Traffic Safety Administration
NICE FUTURE	Nuclear Innovation: Clean Energy Future initiative
NIWS	Natural Infrastructure for Water Security
NIST	National Institute of Standards and Technology
NMVOCS	Volatile organic compounds
NO	Nitrogen oxide
NO2	Nitrogen dioxide
NOX	Nitrogen oxides
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NREL	National Renewable Energy Laboratory
NRCS	Natural Resources Conservation Service
NSF	National Science Foundation
NSPS	New Source Performance Standards
NSTC	National Science and Technology Council
N/A	Not Applicable
O_3	Ozone
OAP	Office of Atmospheric Programs (EPA)
OBSIWG	Observation interagency working group
OCCHE	Office of Climate Change and Health Equity
OCOF	Our Climate Our Future
OCS	U.S. Outer Continental Shelf
ODS	Ozone depleting substances
OECD	Organization for Economic Development
OIB	Operation Icebridge
ODA	Official Development Assistance
OMEGA	Optimization Model for reducing Emissions of Greenhouse gases from Automobiles
OMG	Oceans melting Greenland
ONE-SL	Offset National Emissions through Sustainable Landscapes
OOI	Ocean Observatories Initiative
OSTP	Office of Science and Technology Policy - White House
PFC	Perfluorocarbon
PHMSA	Pipeline and Hazardous Materials Safety Administration
PIDP	Port Infrastructure Development Program
PIER	Private Investment for Enhanced Resilience
PMI	President's Malaria Initiative
PROTECT	Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation program
PV	Photovoltaic
QBtu	Quadrillion British thermal units
RAD	Resist-Accept-Direct
RCP	Representative Concentration Pathway
RCPP	Regional Conservation Partnership Program
RD&D	Research, design, and development
REAP	Rural Energy for America Program
REDD+	Reducing emissions from deforestation and forest degradation
RESP	Rural energy savings program
RFS	Renewable fuels standard
RGGI	Regional Greenhouse Gas Initiative
RPA	Resource Planning Act
RPS	Renewable portfolio standards

RRIF	Railroad Rehabilitation and Improvement Financing
RUS	Rural Utilities Service
SAEP	Southern Africa Energy Program
SCEP	Strategic Clean Energy Partnership
SEAN	Societal Experts Action Network
SEDAC	Socioeconomic Data and Applications Center
SEP	State Energy Program
SF_6	Sulfur hexafluoride
SFLR	Sustainable Forestry and African American Land Retention Program
SHADOZ	Southern Hemisphere ADditional OZonesondes
SHuFFLE	Support Hub for Forest Finance and Landscapes Engagement
SIDS	Small island developing states
SME	Small or medium enterprises
SNAP	Significant new alternatives policy
SO_2	Sulfur dioxide
SSP2	Shared socioeconomic pathway 2
START	System for analysis, research and training
STBG	Surface Transportation Block Grant program
STEM	Science, technology, engineering and math
SWAMP	Sustainable Wetlands Adaptation and Mitigation Program
TEC	Technology Executive Committee
TES	Thermal energy storage
TFI	Task Force on Greenhouse Gases
TIFIA	Transportation Infrastructure Finance and Innovation Act
TOD	Transit-oriented development
TRIPS	Trade-related aspects of intellectual property rights
UCF	Urban and Community Forestry program
UNEP	UN Environment Program
UNFCCC	UN Framework Convention on Climate Change
USAID	U.S. Agency for International Development
USCRN	U.S. Climate Reference Network
USCRP	U.S.-Caribbean Resilience Partnership
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USGCRP	U.S. Global Change Research Program
USGEO	U.S. Group on Earth Observations
USGS	U.S. Geological Survey
VMT	Vehicle miles traveled
VOC	Volatile organic compound
VPP	Virtual Power Plant
VRE	Variable renewable energy
WAC	Weighted average cost
WAP	Weatherization Assistance Program
WCRP	World climate research program
WHEJAC	White House Environmental Justice Advisory Council
WM	With measures
WMO	World Meteorological Organization
WTO	World Trade Organization
ZERH	Zero Energy Ready Homes
ZEV	Zero-Emission Vehicle

U.S. CLIMATE AMBITION REPORT

Chapter 1.
EXECUTIVE SUMMARY

Chapter 1. EXECUTIVE SUMMARY

OVERVIEW

This 2022 U.S. Climate Ambition Report – the Eighth National Communication and Fifth Biennial Report of the United States to the UN Framework Convention on Climate Change – reports that the United States achieved its target of net economy-wide emissions reductions in the range of 17 percent below 2005 levels in 2020. It summarizes a series of policies and measures the United States has taken that will contribute to achieving its nationally determined contribution (NDC) target to reduce economy-wide net greenhouse gas (GHG) emissions 50-52 percent below 2005 levels in 2030, as well as to achieving net-zero emissions no later than 2050. These targets and actions align with the goal to limit global temperature rise to no more than 1.5 degrees Celsius above pre-industrial levels. The report also provides information regarding a range of actions undertaken by the United States to support adaptation and build resilience to the impacts of climate change in the United States, and to support climate action internationally. It reflects not only actions by the federal government, but those of a wide range of stakeholders engaged in taking action, building awareness, and advancing cutting-edge science and technology to enhance global climate efforts.

While this report includes preliminary assessments of the GHG mitigation impacts of the 2022 Inflation Reduction Act (IRA) and the 2021 Bipartisan Infrastructure Law (BIL), the United States also plans to submit a voluntary supplement to this report in 2023 to provide more complete estimates of these impacts.

CONTEXT

Combatting the climate crisis is perhaps the most urgent and important task facing humanity today. The United States, like so much of the world, faces unprecedented wildfires, drought, floods, and hurricanes, intensified by climate change. Glaciers are melting, and sea-level rise threatens low-lying coastal communities. The most vulnerable communities suffer from extreme heat and extreme cold, while smoke from fires endangers the health of millions of people across the continent. Farmers, fishers, and foresters see their livelihoods threatened by changes in weather patterns and extreme weather events. In 2021 alone the United States experienced 20 separate billion-dollar weather and climate disasters; many of these were made worse by climate change.[1] The United States is far from alone. People, ecosystems, and economies around the world are suffering from catastrophic floods, monstrous

[1] https://www.ncei.noaa.gov/access/billions/time-series.

hurricanes, unrelenting drought, wildfires, and disappearing coastlines. Humanity must rise to this challenge and the United States has stepped forward to lead.

As President Joseph Biden said at the UN General Assembly in September 2022:

> *From the day I came to office, we've led with a bold climate agenda. We rejoined the Paris Agreement, convened major climate summits, helped deliver critical agreements on COP26. And we helped get two thirds of the world GDP on track to limit warming to 1.5 degrees Celsius.*
>
> *And now I've signed a historic piece of legislation here in the United States that includes the biggest, most important climate commitment we have ever made in the history of our country: $369 billion toward climate change. That includes tens of billions in new investments in offshore wind and solar, doubling down on zero emission vehicles, increasing energy efficiency, supporting clean manufacturing.*
>
> *Our Department of Energy estimates that this new law will reduce U.S. emissions by one gigaton a year by 2030 while unleashing a new era of clean-energy-powered economic growth.*
>
> *Our investments will also help reduce the cost of developing clean energy technologies worldwide, not just the United States. This is a global gamechanger — and none too soon. We don't have much time.*
>
> *We all know we're already living in a climate crisis. No one seems to doubt it after this past year. As we meet, much of Pakistan is still underwater; it needs help. Meanwhile, the Horn of Africa faces unprecedented drought.*
>
> *Families are facing impossible choices, choosing which child to feed and wondering whether they'll survive.*
>
> *This is the human cost of climate change. And it's growing, not lessening.*
>
> *So, as I announced last year, to meet our global responsibility, my administration is working with our Congress to deliver more than $11 billion a year to international climate finance to help lower-income countries implement their climate goals and ensure a just energy transition.*
>
> *The key part of that will be our PREPARE plan, which will help half a billion people, and especially vulnerable countries, adapt to the impacts of climate change and build resilience.*
>
> *This need is enormous. So let this be the moment we find within ourselves the will*

to turn back the tide of climate devastation and unlock a resilient, sustainable, clean energy economy to preserve our planet.

ACCELERATED ACTION

To avoid the most catastrophic impacts of climate change, we must put the world on a pathway to limit global temperature rise to no more than 1.5 degrees Celsius above pre-industrial levels. In April 2021, the United States communicated an ambitious NDC target in line with this goal: to reduce economy-wide net GHG emissions 50-52% below 2005 levels in 2030. This target is in line with a trajectory to reach net-zero emissions no later than 2050.

To achieve this target, President Biden has spearheaded the most significant domestic climate actions in U.S. history. The United States has set out a framework of policy actions and investments designed to drastically reduce GHG emissions in this critical decade by accelerating clean energy deployment, investing in clean transportation and infrastructure solutions, modernizing our industrial sector, weatherizing and electrifying our buildings, conserving and restoring our ecosystems, and supporting our lands in sequestering carbon while producing food, feed, fiber and fuel. At the same time, we will invest in jobs, communities, and infrastructure that are resilient to the impacts of climate change.

Building the clean energy economy is an opportunity to support high-quality jobs, restore American manufacturing leadership, spur innovation, and deliver cleaner air and water, while ensuring benefits for disadvantaged communities. Reflecting this, President Biden established the Justice40 Initiative to deliver 40% of overall benefits from federal investments in climate and clean energy to disadvantaged communities that are marginalized, underserved, and overburdened by pollution.

The IRA is key to accelerating the implementation of this climate agenda. The IRA is expected to reduce GHG emissions by about one gigaton annually in 2030 by, among other measures:

- More than doubling U.S. deployment of solar, wind, and battery storage by 2030, with new and extended tax incentives for clean energy;
- Accelerating the transition to energy-efficient appliances, electric vehicles, and energy-efficient buildings;
- Advancing clean energy projects at rural energy cooperatives that reach 42 million people;
- Conserving and strengthening the resilience of nearly 2 million acres (809,000 ha) of forests and coastal ecosystems; and
- Supporting the widespread adoption of climate-smart agricultural and forestry practices.

This complements the BIL, which provides historic levels of support for upgrading the U.S. power grid to transmit more clean energy and withstand extreme weather; building a nationwide network of electric vehicle chargers; improving public transit and passenger rail; deploying zero-emission school and transit buses; weatherizing low-income homes; cleaning up legacy pollution; supporting demonstration projects and research hubs for next-generation clean technologies; and boosting resilience to intensifying climate impacts.

The United States also took action to reduce GHG emissions through a phase-down of the production and consumption of hydrofluorocarbons (HFCs), super-polluting chemicals that are hundreds to thousands of times more powerful than carbon dioxide, by enacting the American Innovation and Manufacturing Act of 2020 and ratifying the Kigali Amendment to the Montreal Protocol in 2022.

These legislative milestones complement strong executive action. In January 2021, President Biden issued an Executive Order on Tackling the Climate Crisis at Home and Abroad, mobilizing the full capacity of the federal government to reduce domestic emissions while creating good-paying jobs, delivering environmental justice, and protecting public health. Since then, the Biden-Harris Administration has taken new actions to fast-track clean energy projects, accelerate electric transportation and strengthen vehicle emissions standards, tackle super-pollutants like methane and HFCs, advance industrial decarbonization and clean manufacturing, cut emissions and energy costs in buildings, support climate-smart agriculture and forestry, conserve U.S. lands and waters, lead by example across federal operations, increase resilience to extreme weather, and more – all while empowering workers and revitalizing communities.

Building on our commitment to address climate change at home, the United States remains focused on supporting partners around the world in enhancing resilience and curbing GHG emissions. The Biden Administration has pledged to work with Congress to quadruple U.S. annual public climate finance to developing countries by 2024.[2] Part of this overall quadrupling goal, as reflected in the President's Emergency Plan for Adaptation and Resilience (PREPARE), is a commitment to work with Congress to provide $3 billion in adaptation finance annually to developing countries by 2024 – a six-fold increase in adaptation finance. The Plan to Conserve Global Forests: Critical Carbon Sinks further reflects the intention to dedicate up to $9 billion of international climate funding by 2030 to support the objectives of the Plan, which seeks to catalyze and coordinate U.S. contributions

[2] Relative to the average level during the second half of the Obama-Biden Administration (FY 2013-2016).

to these global objectives to collective goals of ending natural forest loss by 2030 and significantly increasing the rate of global restoration of degraded landscapes and forestlands to restore at least an additional 200 million hectares by 2030.

These federal actions complement the intense work undertaken throughout the United States by a range of other stakeholders. U.S. states, territories, cities, and tribal governments remain at the forefront of combatting climate change, with ambitious climate targets consistent with the Paris Agreement temperature goals, clean energy and zero emission vehicle goals, and plans to enhance resilience. Thousands of U.S. companies have similarly committed to deep reductions in their own value chains on a trajectory to net zero, and to supporting mitigation actions far beyond their own supply chains. U.S. financial institutions are increasingly incorporating climate-related financial risk into their portfolios, and also financing a range of climate investments around the world. U.S academics lead cutting-edge research and development efforts that will deliver the next generation of climate technologies. And U.S. civil society has been at the forefront of advocating for, and supporting, climate action in the United States and around the world.

It is largely because of the sustained efforts of this diverse set of actors that the United States met our target of achieving economy-wide emissions reductions in the range of 17 percent below 2005 levels in 2020. And because of this sustained action – by the public, private, and civil society sectors – we are well placed to achieve our ambitious NDC target in 2030 and to achieve net-zero emissions no later than 2050.

STRUCTURE

This 8th National Communication and 5th Biennial Report reflects the efforts of the United States to combat climate change with the urgency it deserves, reducing GHG emissions aggressively, adapting to the impacts of climate change, and assisting partners around the world in taking action to do the same.

Following this Executive Summary, Chapter 2 outlines the national circumstances of the United States. This chapter highlights trends in the economy, demographics, energy profile, and land use, and summarizes some of the drivers behind these shifts: national and subnational policies, investments in renewable energy technologies, cost reductions in renewables, advances in fuel efficiency, increased demand for natural gas as a transitional fuel, the shift to a service economy, and changes in forests and land use that are affecting emissions and removals.

Chapter 3 summarizes the Inventory of U.S. Greenhouse Gas Emissions and Sinks that the United States submitted in April 2022, covering the years 1990-2020, with accompanying summary tables and charts. This national GHG inventory report showed a 17.4 percent decrease in U.S. net GHG emissions from 2005 to 2020.

Chapter 4 summarizes information on policies and measures that mitigate climate change. This chapter focuses primarily on developments since the beginning of 2021, though it also includes a selection of previously reported policies and measures. These policies and measures reflect an intensive effort to address GHG emissions from all sources, by advancing clean energy, transportation, buildings, and industrial processes as well as climate-smart agriculture and forestry. Chapter 4 also includes a sample of the broad range of policies and programs put into place by non-federal governments, including U.S. states, territories, Tribal Nations, and local governments, to combat the climate crisis.

Chapter 5 includes projections of expected GHG emissions and removals associated with current policies and measures based on our baseline model utilizing data available as of November 2021, extending through 2035. As with previous reports, these projections include a range reflecting the uncertainty around the future of the terrestrial carbon sink. This chapter also includes preliminary assessments of the GHG mitigation impact of recently enacted legislation such as the BIL and the IRA.

Chapter 6 summarizes efforts by the federal government, subnational governments, tribes, businesses, and civil society to increase the resilience of American communities, the economy, infrastructure and landscapes to impacts from extreme events and changing conditions, including those related to climate change. It also highlights the findings of recent scientific assessments of U.S. vulnerability to climate change and its impacts.

Chapter 7 contains information on U.S. support to developing country partners on finance, technology, and capacity building to assist in implementing and achieving ambitious climate goals, reduce vulnerabilities and adapt to climate change impacts, curb GHG emissions and increase sequestration, and monitor implementation and results.

Chapter 8 includes highlights of research and systematic observation programs in the United States. Historically, the United States has contributed substantially to a better understanding of issues including climate systems, GHG fluxes, and land use change, and developed systems to predict and plan for extreme weather. These efforts continue, delivering benefits for communities on the ground and scientists worldwide.

Chapter 9 reflects programs designed to enhance climate change education, training, and public awareness throughout the country. While many of these programs are supported by the federal government, many others have been designed and implemented by a diverse set of stakeholders committed to helping to combat climate change.

Annex 1 contains the 5th Biennial Report of the United States, which includes all required information not reported elsewhere in the National Communication. Annex 1 includes data showing that the United States met the goal of achieving economy-wide emissions reductions in the range of 17 percent below 2005 levels in 2020. Annex 2 provides information on mitigation policies and measures in a tabular format. Annex 3 provides the methodology used for policies and measures with quantified GHG mitigation estimates. Annex 4 describes the methodology for projected GHG emissions. Annex 5 presents tables on public financial support provided to developing countries to support climate action. Annex 6 provides methodological information related to financial support.

Estimating Future Impacts of Recent Legislation

This report's projections on GHG emissions focus primarily on policies and measures implemented through November 2021, based on the U.S. Energy Information Administration's Annual Energy Outlook 2022, consistent with relevant UNFCCC reporting guidelines. Where quantitative or narrative information on new policies adopted in 2022 is available, such information has been included in the report. However, major policy developments such as the enactment of the BIL in November 2021 are not fully reflected in the GHG emission projections in the report and the impact of the transformational IRA enacted in August 2022 is not yet incorporated into this report's projections. These policies, and the associated programs, are expected to have a substantial impact on U.S. emissions and the achievement of the United States' 2030 NDC.

Chapter 5 provides projections of U.S. GHG emissions through 2035, including the effects of policies and measures implemented as of November 2021 in a "With Measures" scenario. Chapter 5 presents information from a preliminary assessment by the U.S. Department of Energy (DOE) that finds that the IRA—in combination with the BIL, as well as other enacted policies and past actions—will help drive 2030 economy-wide GHG emissions to 40% below 2005 levels. The legislation would play a major role in enabling the United States to achieve its NDC of 50-52% GHG emission reductions below 2005 levels in 2030, together with continued executive branch, state, local, and private sector actions.

To provide a more current and complete understanding of expected future emissions and removals, the United States plans to submit a voluntary supplement to this report in 2023 that will include projections with a "With Measures" scenario that fully incorporates the BIL and IRA, and a "With Additional Measures" scenario that will show how the United States can go beyond existing measures to further reduce its emissions and meet the NDC economy-wide target of reducing net GHG emissions by 50-52 percent below 2005 levels in 2030.

Chapter 2.

NATIONAL CIRCUMSTANCES

Chapter 2. NATIONAL CIRCUMSTANCES

NATIONAL CONTEXT

The United States is the largest economy in the world and the third largest country in terms of population and geographic area. As such, it faces a unique set of domestic circumstances, and plays a singular role in global systems. National circumstances that affect greenhouse gas (GHG) emissions and removals include market dynamics, technological innovation, economic growth, energy production and consumption, population and density trends, use of land and natural resources, and climate and biogeographic conditions. This chapter outlines key circumstances relevant to the United States, including the structure of the government, economic profile, and energy production and use, and identifies factors that significantly impact GHG emissions and removals. It also reflects significant changes to national circumstances and trends since the 2021 A Review of Sustained Climate Action Through 2020 (2021 7th National Communication (NC) and 2021 3rd and 4th Biennial Reports (BR)).

GOVERNMENT STRUCTURE

The United States is a federal republic of 50 states, plus the District of Columbia and U.S. territories. The Constitution of the United States assigns certain powers to the federal government, with other responsibilities entrusted to the states. Local governments, as well as Native American tribal governments, are charged with governance responsibilities at the corresponding level of subnational government. Indian tribal governments exercise governmental authority over a broad range of internal and territorial affairs. This shared responsibility for policy in areas such as economic growth, energy development, transportation, land use planning, and natural resource use creates the opportunity for action and coordination at multiple levels.

The U.S. federal government is divided into three branches: executive, legislative, and judicial. Each branch of government is assigned specific authorities and plays distinct roles in creating, implementing, and adjudicating laws and regulations. This same three-branch structure is also replicated at the state level, and often at lower levels of government as well. This structure creates a system of “checks and balances” which shapes the development and implementation of policy. Jurisdiction for addressing energy, environment, and climate change-related issues within the federal government cuts across each of the three branches.

FEDERAL GOVERNMENT

EXECUTIVE BRANCH

The executive branch of the federal government is responsible for implementing and enforcing the laws of the United States. The scope of its responsibility covers a wide range of areas including enacting regulations through the rulemaking process, supporting innovation and research and development, implementing foreign policy, maintaining federal highway and air transit systems, and managing federal lands.

The President of the United States is the head of the executive branch and is advised by the Vice President and a Cabinet of senior officials. This Cabinet is composed of the heads of 15 executive agencies – the Departments of Agriculture, Commerce, Defense, Education, Energy, Health and Human Services, Homeland Security, Housing and Urban Development, Interior, Justice, Labor, State, Transportation, Treasury, and Veterans Affairs, as well as the White House Chief of Staff, the U.S. Ambassador to the United Nations, the Director of National Intelligence, the U.S. Trade Representative, and the heads of the Environmental Protection Agency, Office of Management and Budget, Council of Economic Advisers, Office of Science and Technology Policy, and the Small Business Administration.

For the first time, under the Biden Administration the President is advised by a National Climate Advisor and a Special Presidential Envoy for Climate. In recognition of the seriousness of the climate crisis, these positions were newly created to lead and coordinate the development and implementation of domestic and international climate change policy, respectively. The Executive Office of the President includes several offices with relevance to environmental and energy policy including the new office of Office of Domestic Climate Policy and the Office on Clean Energy Innovation and Implementation, in addition to the National Security Council, the Domestic Policy Council, and the Council on Environmental Quality.

Within the executive branch, the purview for energy, environment, and climate-related issues fall under some two dozen federal agencies and executive offices, as well as a number of independent commissions, boards, and agencies such as the Federal Energy Regulatory Commission. Relevant agencies and offices work together to advise, develop, and implement policies that help the U.S. government understand the workings of the Earth's climate system, increase innovation related to clean energy and energy efficiency, work towards low GHG energy systems, enhance the sustainability of land and natural resource management, and assess and respond to the adverse effects of climate change. The actions of these agencies are described in relevant chapters of this report.

LEGISLATIVE BRANCH

The federal legislative branch is the U.S. Congress which is composed of two chambers: the Senate and the House of Representatives (House). The Senate includes 100 elected members, two from each state; Senators serve six-year terms of office. The House is made up of 435 elected members, each representing a single congressional district of an average of approximately 760,000 people.[3] Representatives serve two-year terms of office. The bicameral nature of Congress is intended to balance representation based on population, and representation based on statehood.

Both the Senate and the House have the authority to develop legislation; a completed bill must receive a majority of votes in each chamber. Congress is also responsible for raising revenue through taxation and authorizing the use of public funds by the executive branch through the budget and appropriations process. Any difference between House and Senate bills must be reconciled before the bill can be sent to the President for signature. Legislation becomes effective upon signature by the President. As new legislation must be approved by a majority in both chambers of Congress and signed by the President, the threshold of support required to enact new laws remains high.

Committees within each Chamber of Congress are tasked with considering and developing draft legislation on specific topics. In the House, the Committees on Appropriations; Agriculture; Science, Space, and Technology; Ways and Means; Natural Resources; and Energy and Commerce, among others, consider topics relevant to climate, environment, energy and land use. In the Senate, the Committees on Environment and Public Works; Finance; Foreign Relations; Agriculture; Commerce, Science, and Transportation; Energy and Natural Resources; and Indian Affairs develop legislation on these topics and are similarly critical venues for debate.

JUDICIAL BRANCH

The judicial branch of the federal government is responsible for interpreting the U.S. Constitution, among other duties. The Supreme Court is the highest Court in the United States. The judicial branch plays a significant role in defining the jurisdiction of the executive branch departments and interpreting laws, including those related to energy, environment, and climate policy.

[3] https://www.census.gov/newsroom/press-releases/2021/2020-census-apportionment-results.html.

SUBNATIONAL ACTORS

As a federal system, jurisdiction for issues related to energy, environment, and climate change is shared by federal, state, local, and tribal governments. For example, while the Federal Energy Regulatory Commission regulates wholesale sales and transportation of natural gas and electricity, economic regulation of energy distribution is the responsibility of the states. Within the scope of their authorities, States may establish energy-sector standards, mandate building energy efficiency standards, set emissions targets, plan and build transportation and energy infrastructure, establish state or regional carbon markets, and determine land use practices on state lands, among other actions. Cities may also set emissions targets; together with states, they determine how non-federal transportation systems and other infrastructure are planned and implemented. Native American tribal governments have similar authorities for tribal lands. Many states, cities, and tribes in the United States are implementing policies relevant to climate change mitigation and adaptation. Examples of these activities are provided in Chapter 4.

POPULATION PROFILE

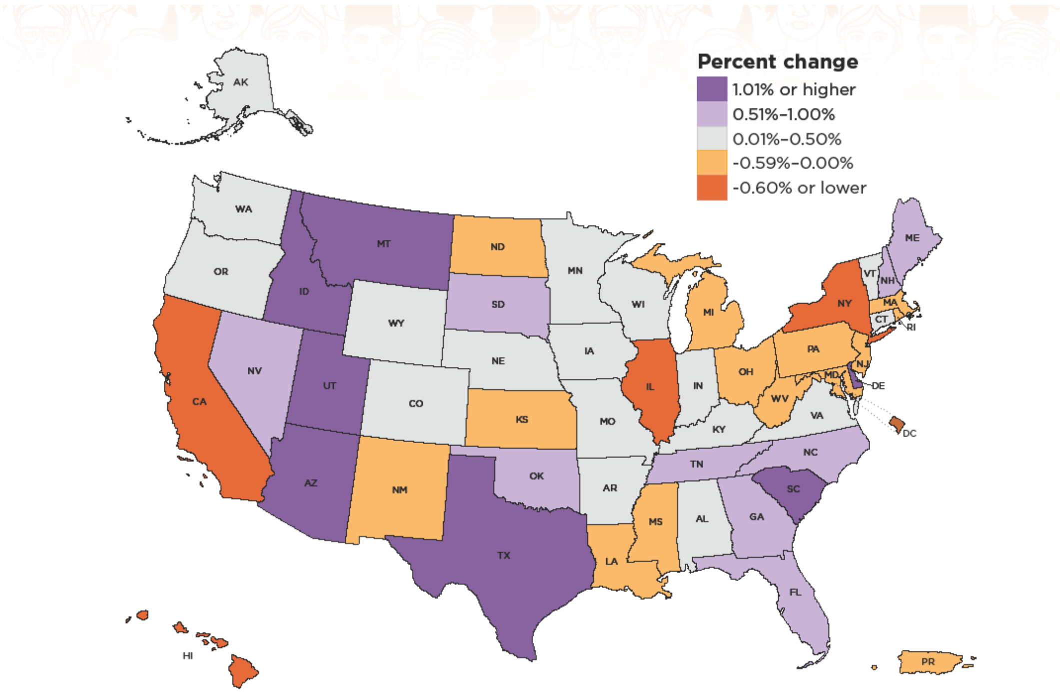
The estimated population of the United States as of July 1, 2021, was approximately 331.9 million,[4] making the U.S. the third most populous country in the world. While this represents an increase of over 30 percent above 1990 levels, the U.S. population grew at a rate of only 0.1 percent from 2020 to 2021,[5] the lowest rate since the country's founding, which reflected decreased net international migration, decreased fertility, and increased mortality stemming in part from the Covid-19 pandemic. Thirty-three states saw population increases while seventeen states and the District of Columbia declined in population - a historically large number of states to lose population in a year.[6]

[4] https://www.census.gov/quickfacts/fact/table/US/PST045217.

[5] *Ibid*.

[6] https://www.census.gov/newsroom/press-releases/2021/2021-population-estimates.html.

Figure 2-1: Population Change for States (and Puerto Rico) From July 2020 to July 2021



Source: U.S. Census Vintage 2021 Population Estimates.[7]

By 2050, the total population of the United States is expected to reach approximately 400 million people,[8] an estimate reflecting U.S. Census Bureau assumptions that growth rates will decline slightly over the coming decades.[9]

Trends in population growth and density shape energy consumption, land use, transportation, housing density, and other factors which have a significant effect on U.S. GHG emissions.

ECONOMIC PROFILE

Following a decade of steady growth, the U.S. experienced its worst economic downturn since World War II in 2020 due to the global outbreak of Covid-19. After a sharp contraction

[7] *Ibid*.

[8] https://census.gov/data/tables/2017/demo/popproj/2017-summary-tables.html.

[9] https://www.census.gov/library/publications/2015/demo/p25-1143.html.

during the Great Recession from late 2007 to mid-2009, the U.S. economy grew at an average annual rate of 2.3 percent from mid-2009 through 2019,[10] before shrinking precipitously by 3.4 percent in 2020 as the pandemic ravaged factories, businesses, and households. U.S.[11] gross domestic product (GDP) dropped from $21.37 trillion in 2019 ($65,056 per capita) to $20.89 trillion in 2020 ($63,285 per capita),[12] with unemployment spiking to over 14 percent – its highest on record since 1948 – in April 2020.[13]

The economy began to rebound during the second half of 2020 with the easing of lockdown restrictions, reopening of businesses, and introduction of a national vaccination campaign. Output reached its pre-pandemic size in mid-2021,[14] with annual GDP growth of 5.7 percent for the year and average unemployment dropping to 5.3 percent[15] (a fifty-year low) in November 2021.[16]

Due in part to reduced travel and other factors resulting in reduced energy consumption during the pandemic, U.S. energy-related carbon dioxide (CO_2) emissions in 2020 dropped 11 percent from 2019 levels–the largest annual decrease on record–falling to their lowest level since 1983.[17] CO_2 emissions then rose significantly in 2021 from 2020 levels, along with the nation's economic recovery, but remained lower than 2019 levels,[18] and lower than would have been expected without the effects of increased efficiency and a rapid shift towards cleaner and renewable energy.

GEOGRAPHICAL PROFILE

With a mainland bounded by the Atlantic Ocean to the east, the Pacific Ocean to the west, Canada to the north, and Mexico and the Gulf of Mexico to the South, the United States is a

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[10] https://www.census.gov/library/visualizations/2021/dec/2020-resident-population-map.html.
[11] https://www.bea.gov/news/2021/gross-domestic-product-4th-quarter-and-year-2020-advance-estimate.
[12] *Ibid*.
[13] https://www.bls.gov/opub/ted/2020/unemployment-rate-rises-to-record-high-14-point-7-percent-in-april-2020.htm.
[14] https://www.bea.gov/news/2021/gross-domestic-product-second-quarter-2021-advance-estimate-and-annual-update.
[15] https://www.bls.gov/news.release/pdf/srgune.pdf.
[16] https://www.usnews.com/news/national-news/articles/2021-11-24/weekly-jobless-claims-fall-sharply-now-below-200-000-and-a-50-year-low.
[17] https://www.eia.gov/tODAyinenergy/detail.php?id=48856.
[18] https://rhg.com/research/preliminary-us-emissions-2021/#:~:text=Based%20on%20preliminary%20data%20for,year%20GDP%20growth%20at%205.7%25.

large and diverse country. Its 9,192,000 square kilometers (km2) (3,548,112 square miles [mi_2]) are spread across six time zones.

Given the size and extent of U.S. territory, its biogeophysical profile is diverse. Ecosystems range from the Arctic tundra of northern Alaska to the tropical forests of Hawaii and the overseas U.S. territories. Temperate rainforests in the Pacific Northwest give way to Mediterranean landscapes and then deserts of the Southwest. The middle of the country includes the majestic Rocky Mountains, with Alpine ecosystems on peaks more than 4,390 meters (14,400 feet) tall. Vast grassland prairies transition into rich swathes of agricultural land interspersed with temperate deciduous and coniferous forests. The Great Lakes, the largest freshwater system in the world, and great rivers such as the Mississippi and Missouri, are important features defining the middle of the country. Along the Gulf coast, riverine estuaries and wetlands gradually melt into the sea, while further inland swamps such as the Everglades create unique habitats. The Appalachian Mountains mark a boundary between central and eastern lands, with temperate deciduous and coniferous forests pushing up against the beaches and marshes of the Eastern seaboard.

Approximately 60 percent of land in the United States is privately owned. Another 28 percent is owned and managed by the federal government. This area includes protected areas such as national parks, wilderness areas, wildlife refuges, and monuments; national forests; rangelands; and other public lands. Approximately 8 percent of land is owned and managed by state and local governments, and 3 percent is held in trust for Native Americans by the Bureau of Indian Affairs.[19] Currently 13 percent of lands and 26 percent of waters have permanent protections.

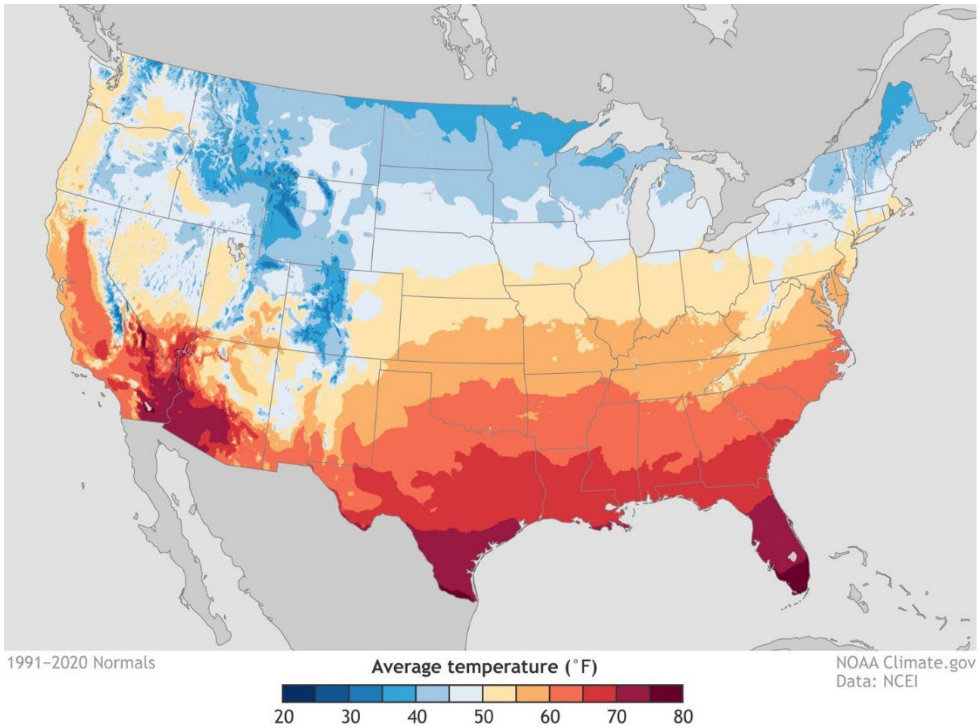
CLIMATE PROFILE

The climate of the United States reflects its geographic diversity. Average annual temperatures decrease dramatically from south to north in the continental United States, as seasonal variability increases. The average annual temperature in Florida exceeds 21 degrees Celsius (70.7 degrees Fahrenheit), while that of Alaska is just – 3 degrees Celsius (26.6 degrees Fahrenheit). Temperature ranges can be great, with some Great Plains states experiencing differences in temperature of as much as 50 degrees Celsius (90 degrees Fahrenheit) over the course of a year. Figure 2-2 illustrates the range in average temperatures over the past three decades across the contiguous United States. As very high or low temperatures require cooling or heating of buildings, average temperatures have a correlation to energy usage. A mild winter or a cool summer may correspond to lower energy

[19] https://www.ers.usda.gov/publications/pub-details/?pubid=84879.

usage, and thus to somewhat lower GHG emissions. This is reflected in annual estimates in the national GHG inventory, discussed in Chapter 3.

Figure 2-2: U.S. Temperature (1991-2020)

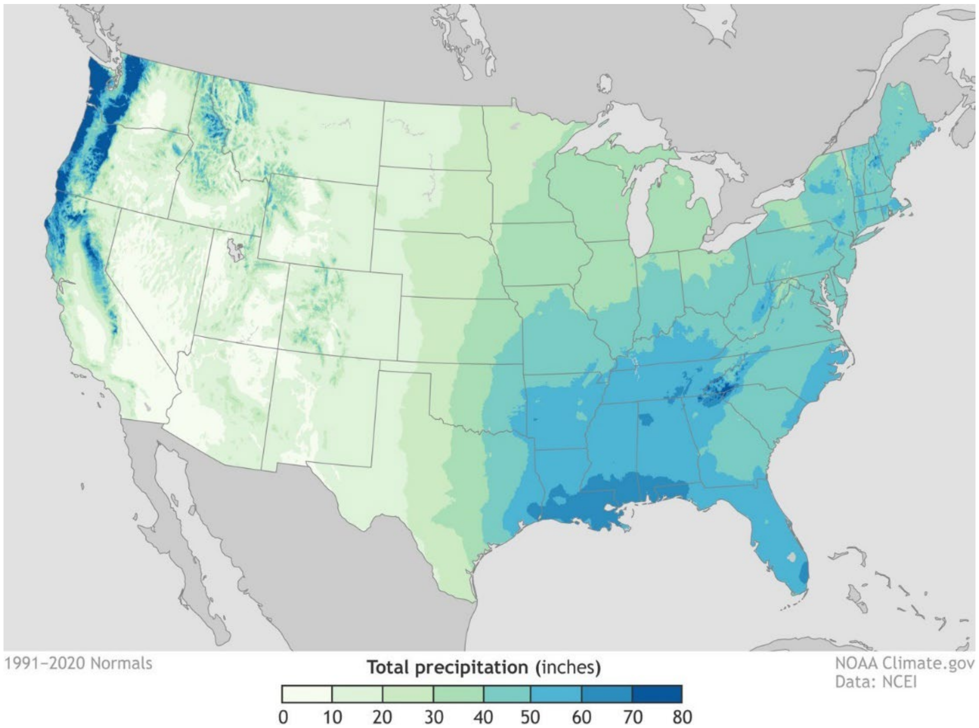


Source: U.S. National Oceanic and Atmospheric Administration (NOAA), National Centers for Environmental Information (NCEI) [20]

Similarly, precipitation varies across the United States in terms of quantity and seasonality. As Figure 3 depicts, while communities along the Gulf of Mexico may experience more than 127 centimeters (50 inches) of precipitation per year, parts of the Intermountain West and Southwest may receive less than 30 cm (12 in). The peak rainfall season also varies by region, though the seasonality has varied in recent years. Parts of the Great Plains and Midwest typically receive the greatest rainfall in the late spring, the West has a distinct wet season during the winter, the Deep South is affected by the North American monsoon, and many parts of the Gulf and Atlantic coastal regions see their greatest period of precipitation in the summer.

[20] https://www.climate.gov/news-features/featured-images/new-maps-annual-average-temperature-and-precipitation-us-climate.

Figure 2-3: U.S. Annual Average Precipitation (1991-2020)



Source: NOAA, NCEI[21]

Communities across the United States are already experiencing the impacts of climate change, including significant shifts in temperature and precipitation, as shown in Figure 4.[22] In 2021, for example, average annual temperature for the contiguous U.S. was 54.5 Fahrenheit (°F), which is 2.5°F above the 20th century average and the fourth-warmest year in the 127-year record. The six warmest years on record have all occurred since 2012.[23] While trends in precipitation vary by region, overall levels have increased (see Figure 2-4), and at least some of this is linked to climate warming and the "wetting" of the atmosphere that has occurred as rising temperatures cause more water to evaporate from the ocean and land surface.[24]

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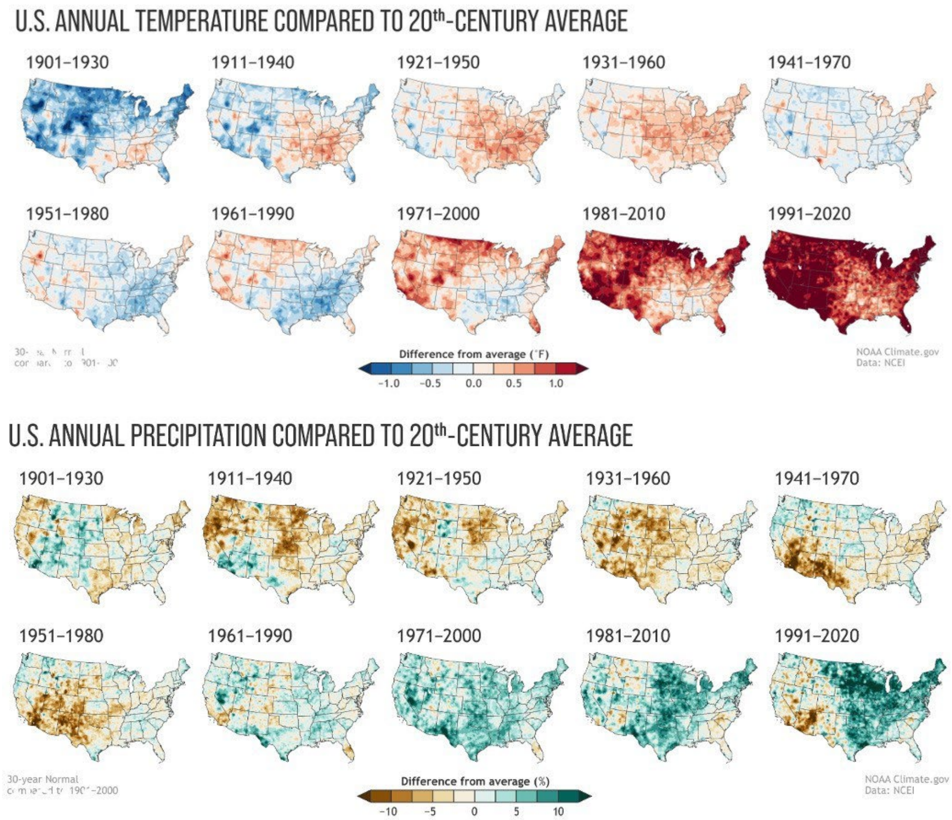
[21] https://www.climate.gov/media/13730.

[22] https://nca2018.globalchange.gov/downloads/NCA4_Report-in-Brief.pdf.

[23] https://www.ncei.noaa.gov/access/monitoring/monthly-report/national/202113.

[24] https://www.climate.gov/news-features/understanding-climate/climate-change-and-1991-2020-us-climate-normals.

Figure 2-4: Annual Temperature and Precipitation Compared to 20th Century Average



Source: NOAA [25]

At the same time, more frequent and intense extreme weather and climate-related events are damaging infrastructure, ecosystems, and the social systems that provide essential services.[26] In 2021 a cold-air outbreak across the central U.S. from February 10-19 brought frigid temperatures, snow, and ice from the Plains to southern Texas and into the Mississippi River Valley. It was the coldest event observed across the contiguous U.S. in more than 30 years and caused power outages for nearly 10 million people as well as other costly impacts across 15 states.

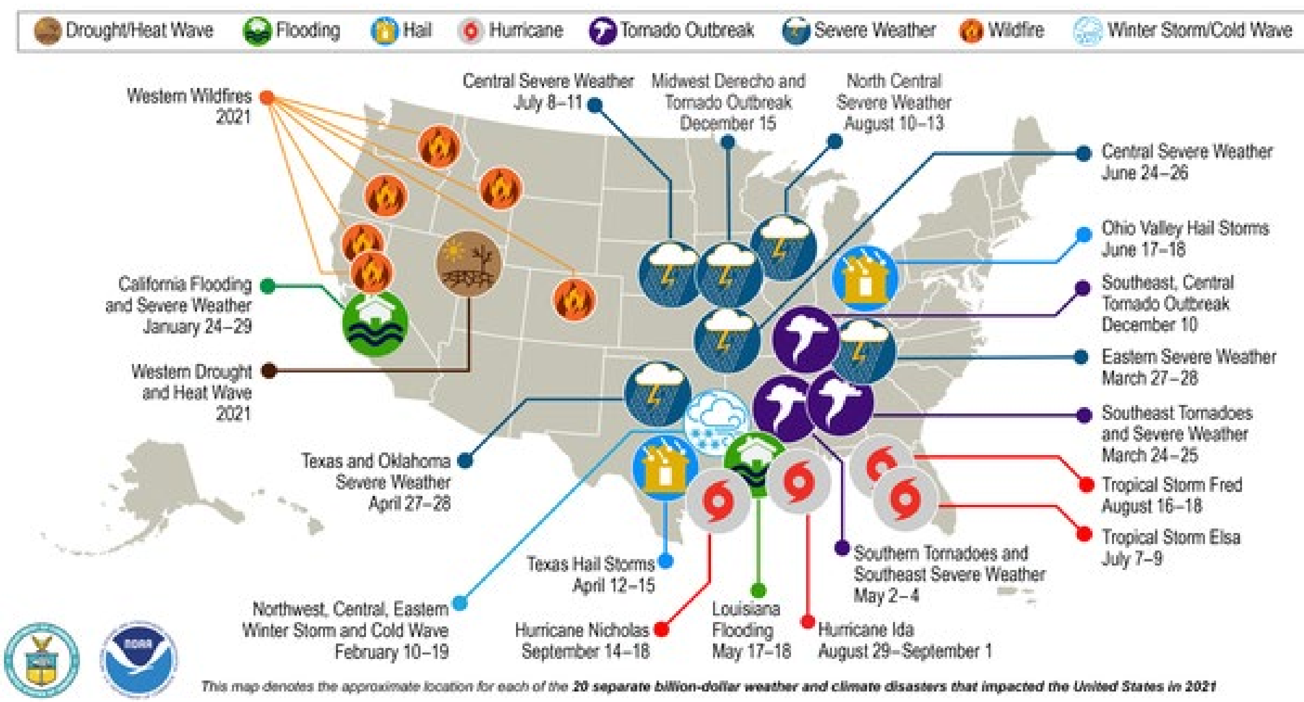
A record-warm June in 2021 across the contiguous U.S. ended with an unprecedented heat wave across the Pacific Northwest. Approximately 14.6 percent of the contiguous U.S. observed its warmest June on record. This is the largest extent of record warm temperatures

[25] https://www.noaa.gov/news/new-us-climate-normals-are-here-what-do-they-tell-us-about-climate-change.
[26] https://nca2018.globalchange.gov/downloads/NCA4_Report-in-Brief.pdf.

on record for the U.S. during June. The summer of 2021 tied with 1936 for the warmest summer on record. A record-warm December across the contiguous U.S. was accompanied by record-warm temperatures across 10 states from the central Plains to the Gulf Coast. An additional 21 states from the Rockies to the East Coast ranked among their top-five Decembers.[27]

Overall, the U.S. experienced 20-billion-dollar weather and climate disasters in 2021 (see Figure 2-5), just two events short of the record set in 2020. These caused at least 688 fatalities and included eight severe weather events, four tropical cyclone events, three tornado outbreaks, two flooding events, one drought/heat wave event, one winter storm/cold wave event, and one wildfire event, including the December 30 Marshall Fire in Boulder County, Colorado. In total, U.S. weather and climate-related disaster costs for 2021 exceeded $145 billion– the third-highest total on record.[28]

Figure 2-5: U.S. 2021 Billion-Dollar Weather and Climate Disasters



Source: NOAA, NCEI[29]

[27] https://www.ncei.noaa.gov/access/monitoring/monthly-report/national/202113.
[28] *Ibid*.
[29] https://www.climate.gov/news-features/blogs/beyond-data/2021-us-billion-dollar-weather-and-climate-disasters-historical.

ENERGY

The United States is the world's second-largest producer and consumer of energy. This creates significant opportunities to mitigate GHG emissions through energy efficiency, electrification of end-uses that currently burn fossil fuels, and carbon-free energy supply. The United States is a leader in clean energy innovation and deployment, with recent increases in investment into research, development, demonstration, and deployment of clean energy, other GHG-mitigating activities, and technologies to support resilience and adaptation to the changing climate.

- While U.S. population and GDP per capita have increased over the past three decades, the energy and carbon intensity of the U.S. economy have declined (see Figure 2-6).[30]
- Energy intensity (energy/GDP) has decreased relatively consistently across this 30-year time frame, largely as a result of demand-side efficiency gains and productivity improvements as well as economic trends, such as the changing profile of U.S. manufacturing industries and a shift toward greater commercial sector economic activity.[31] In 2020, U.S. energy intensity of GDP was about half of what it was in 1990, and in 2050, is projected to decline by a further one- third from today's levels.[32]
- Carbon intensity of energy consumption (CO_2 emissions per unit of energy used) has also decreased significantly since 1990 as the U.S. energy mix has evolved, shifting away from carbon-intensive and toward lower– and zero-carbon fuels. Key drivers include increases in natural gas production from shale and tight resources, which have lowered the cost of natural gas production and made it cost competitive with coal for electric power generation, as well as the plummeting cost of renewable energy, such as solar and wind.

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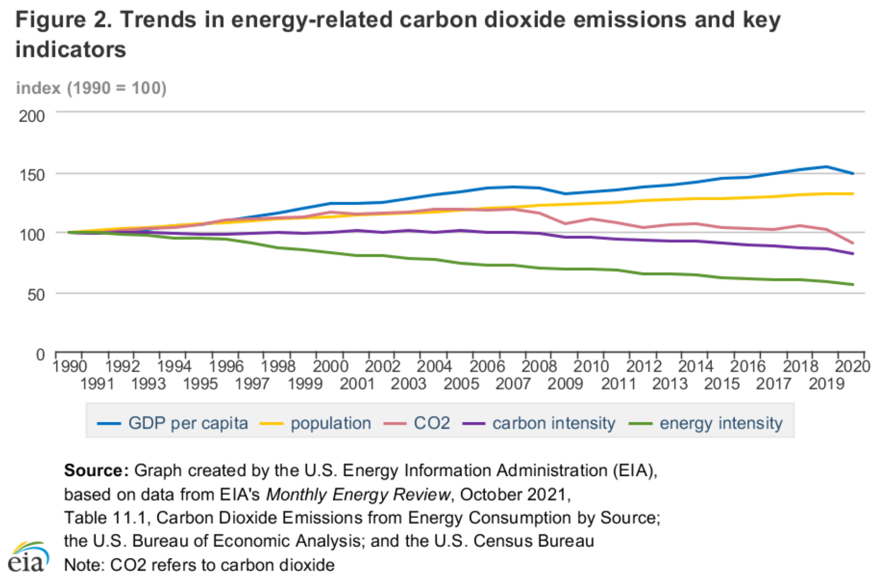
[30] https://www.eia.gov/environment/emissions/carbon/.
[31] https://www.eia.gov/outlooks/aeo/consumption/sub-topic-03.php.
[32] https://www.eia.gov/tODAyinenergy/detail.php?id=48896.

Figure 2-6: Index of Key Factors that Influence Energy-Related CO_2 Emissions



Source: U.S. Energy Information Administration (EIA)[33]

ENERGY PRODUCTION AND CONSUMPTION

In 2019, U.S. domestic energy production exceeded consumption on an annual basis for the first time since 1957, and production continued to exceed consumption in 2020 and 2021.[34] After record-high U.S. energy production and consumption in 2018, energy production grew by nearly 6 percent in 2019 while energy consumption decreased by about one percent. In 2020, largely due to the Covid-19 pandemic, total energy production and consumption both declined dramatically by a record 5 and 7 percent, respectively, to 95.75 and 92.94 quadrillion BTU.[35] Then in 2021, production increased to 97.78 and consumption to 97.33 quadrillion BTU, respectively.[36]

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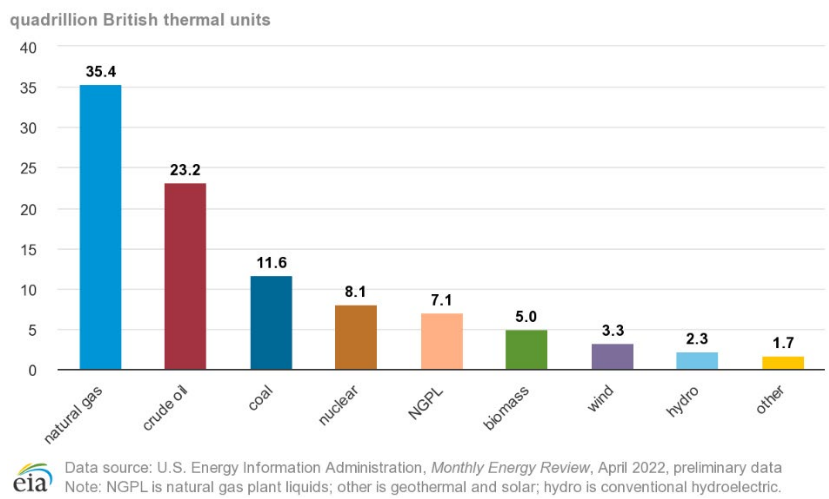
[33] This and material for rest of this section from https://www.eia.gov/environment/emissions/carbon/ unless otherwise noted.
[34] https://www.eia.gov/energyexplained/us-energy-facts/#:~:text=Production%20also%20exceed%20consumption%20in,primary%20energy%20production%20in%202021.
[35] https://www.eia.gov/totalenergy/data/monthly/pdf/sec1_4.pdf.
[36] https://www.eia.gov/energyexplained/us-energy-facts/#:~:text=Production%20also%20exceed%20consumption%20in,primary%20energy%20production%20in%202021.

In 2021, natural gas and natural gas plant liquids represented approximately 43 percent of energy produced. Crude oil and coal made up 23 percent and 12 percent of energy production, respectively. Renewable energy comprised 12 percent and nuclear energy the remaining 8 percent.[37]

Figure 2-7: U.S. Primary Energy Production by Major Sources, 2021



Source: U.S. EIA[38]

The energy sources consumed in the United States reflected a similar pattern, with petroleum (36 percent) and natural gas (32 percent) making up the majority of energy use, followed by renewable energy (12 percent), coal (11 percent), and nuclear energy (8 percent) in 2021.[39] In recent years the share of renewable energy sources, which includes solar, wind, biomass, hydropower, and geothermal, has increased substantially.

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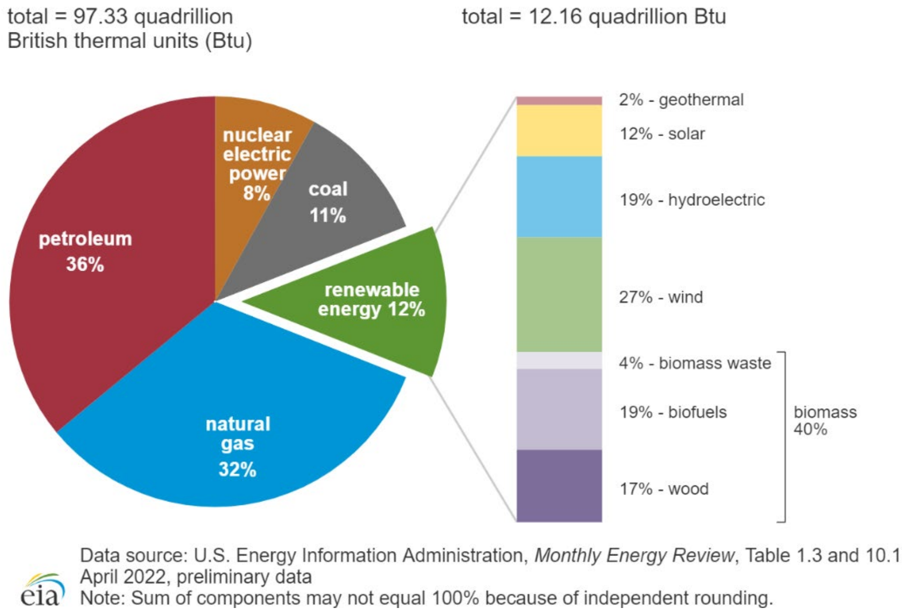
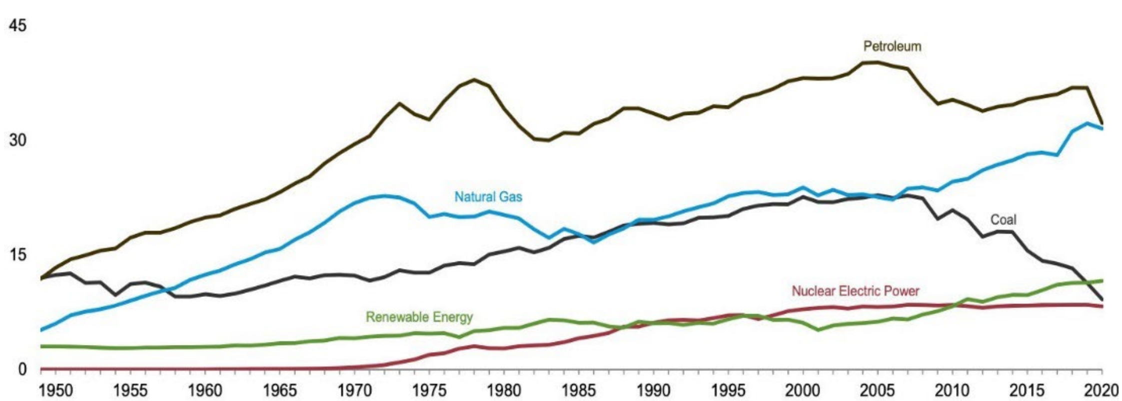
[37] *Ibid*.
[38] U.S. Energy Information Administration (EIA), *Monthly Energy Review,* April 2020, preliminary data.
[39] https://www.eia.gov/energyexplained/us-energy-facts/#:~:text=Production%20also%20exceed%20consumption%20in,primary%20energy%20production%20in%202021.

Figure 2-8: U.S. Primary Energy Consumption by Energy Source, 2021



Source: U.S. EIA[40]

Figure 2-9: U.S. Primary Energy Consumption



Source: U.S. EIA[41]

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[40] EIA, *Monthly Energy Review,* Table 1.3 and 10.1, April 2020, preliminary data.

[41] EIA, *Monthly Energy Review*, April 2020, preliminary data.

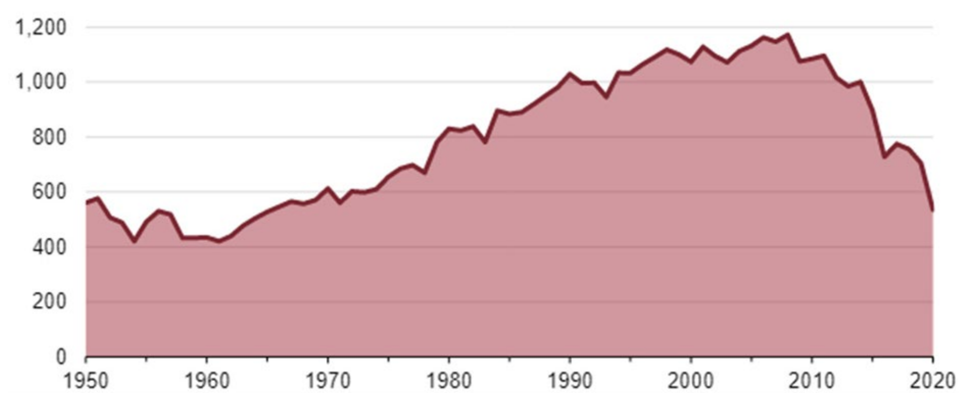
FOSSIL FUELS

Fossil fuels – petroleum, natural gas, and coal – accounted for the majority of total U.S. primary energy production and consumption in 2021. While they have dominated the U.S. energy mix for more than a century, the fossil fuel mix has shifted significantly over time toward less carbon- intensive sources.

COAL

Electric power generation has been the largest consumer of coal since the 1960s, while industrial sector use of coal has slowly declined since the 1970s. Coal consumption in the United States peaked in 2007 at about 1.13 billion short tons, and coal production peaked in 2008 at about 1.17 billion short tons. Due to weakening demand from the electricity sector, both have declined nearly every year since. Last year was a notable exception, with coal consumption increasing from 477 million short tons in 2020 to 546 million short tons in 2021. However, this was still the lowest amount since 1964 and the second-lowest percentage share after 2020 of total U.S. annual energy consumption since at least 1949.[42]

Figure 2-10: Annual U.S. Coal Production (1950-2020) Million short tons (>>st)



Source: U.S. EIA[43]

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[42] https://www.eia.gov/energyexplained/coal/use-of-coal.php#:~:text=In%202021%2C%20about%20546%20million,of%20total%20U.S.%20energy%20consumption.

[43] EIA, *Monthly Energy Review*, April 2020, preliminary data.

PETROLEUM

Following a general decline between 1970 and 2008, annual U.S. crude oil production began to rise in 2009. It reached a high of 12.2 million barrels per day in 2019,[44] largely driven by increasingly cost-effective drilling and production technologies. However, production declined to about 11.3 million barrels per day in 2020 – falling by over 8 percent, its largest decrease on record[45] – due to a large drop in demand resulting from the COVID-19 pandemic. In 2021, it dropped again slightly to 11.2 million barrels per day.[46]

NATURAL GAS

Natural gas production in the United States has generally increased over the past decade, as widespread adoption of horizontal drilling and hydraulic fracturing techniques has allowed operators to produce natural gas from shale formations more economically. These production increases have contributed to a decline in natural gas prices, which in turn has contributed to increases in natural gas use by the electric power and industrial sectors. In 2020, both natural gas consumption by the U.S. electric power sector and natural gas exports reached record highs. In 2021, consumption by the power sector dipped slightly,[47] while natural gas exports again reached a new high.[48] Natural gas has been the largest source of electricity generation in the United States since surpassing coal in 2016, and more than 100 coal plants have been replaced with or converted to natural gas since 2011.[49] This displacement of more carbon-intensive fossil fuels has had a significant impact on overall emissions from the energy sector.

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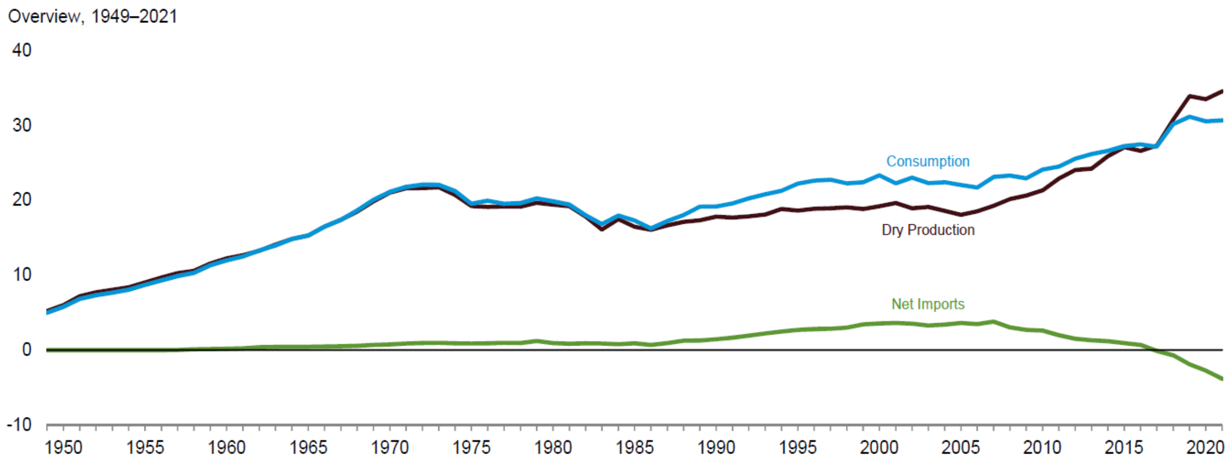
[44] https://www.eia.gov/tODAyinenergy/detail.php?id=47056.
[45] *Ibid*.
[46] EIA, https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=WCRFPUS2&f=W.
[47] https://www.eia.gov/energyexplained/natural-gas/use-of-natural-gas.php.
[48] https://www.eia.gov/energyexplained/natural-gas/imports-and-exports.php#:~:text=Natural%20gas%20exports%20reached%20a%20record%20high%20in%202021&text=In%202021%2C%20the%20United%20States,of%20natural%20gas%20since%202017.
[49] https://www.eia.gov/tODAyinenergy/detail.php?id=48256, https://www.eia.gov/totalenergy/data/flow-graphs/natural-gas.php.

Figure 2-11: U.S. Natural Gas Consumption and Production, 1949-2021



Source: U.S. EIA Monthly Energy Review

NUCLEAR

Nuclear energy production in commercial nuclear power plants in the United States began in 1957, grew each year through 1990, and slightly from 1990-2000, and generally leveled off after 2000.[50] The amount of nuclear energy production in 2021 was about 778 billion kilowatt hours (kWh), equal to about 8.13 quads. A combination of increased electric generation capacity upgrades and shorter refueling and maintenance cycles at nuclear power plants have helped to compensate for reductions in the numbers of nuclear reactors and to maintain a relatively consistent level of annual U.S. nuclear electricity generation for the past 20 years.[51]

Nuclear power plants have consistently provided about 20 percent of total U.S. electricity generation since the 1990s.[52] Of the 28 U.S. states with operating commercial nuclear power plants, 12 states generated more than 30 percent of their electricity from nuclear power, and three states (New Hampshire, South Carolina, and Illinois) generated more than 50 percent of their in-state electricity from nuclear power in 2019.[53]

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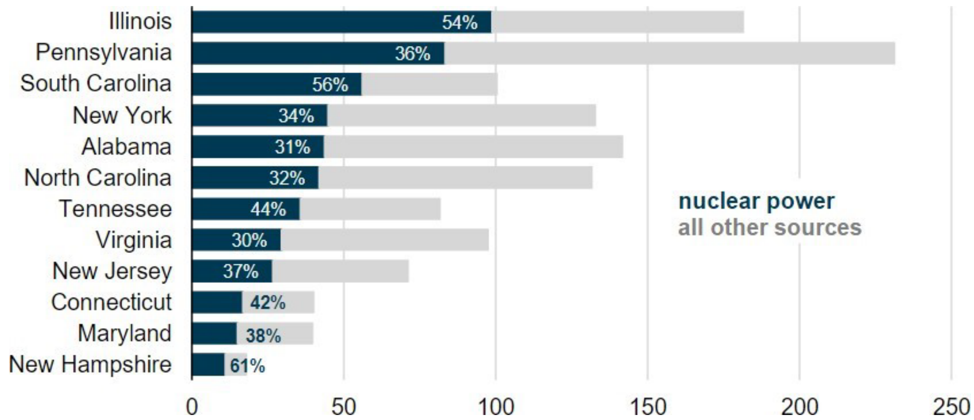
[50] https://www.eia.gov/totalenergy/data/monthly/.
[51] https://www.eia.gov/energyexplained/us-energy-facts/#:~:text=Production%20also%20exceed%20consumption%20in,primary%20energy%20production%20in%202021.
[52] https://www.eia.gov/tODAyinenergy/detail.php?id=43256.
[53] *Ibid*.

Figure 2-12: Nuclear Electricity Generation in Selected States (2019) (million megawatthours)



Source: U.S. EIA[54]

RENEWABLES

In 2021, renewable energy production and consumption both reached record highs of about 12.32 and 12.16 quads, respectively, driven mainly by record-high solar and wind energy production. Hydroelectric power production in 2021 was about 9 percent lower than in 2020 and about 19 percent lower than the 50-year average, primarily due to drought in the Western United States.[55] Total biomass production and consumption in 2021 were both higher than in 2020, but lower than the record highs in 2018. Geothermal energy use in 2021 was about 1.5 percent higher than in 2020, but lower than the record high in 2014.[56]

In 2021, renewables (including wind, hydroelectric, solar, biomass, and geothermal energy) produced about 20 percent of all electricity generated in the United States,[57] and renewable generation was approximately double what it was in 2010.[58]

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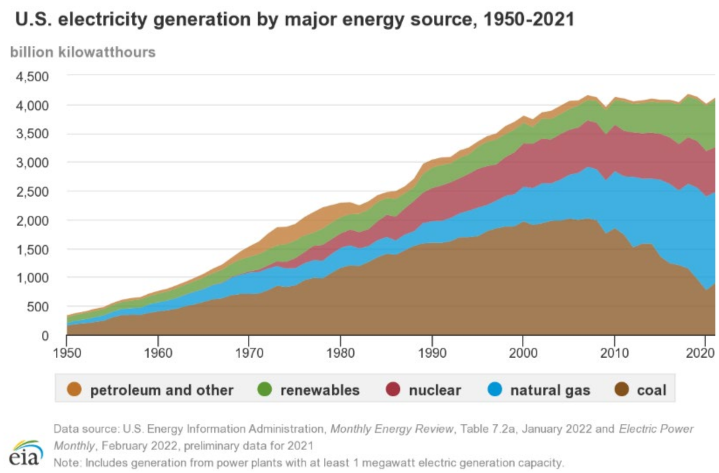
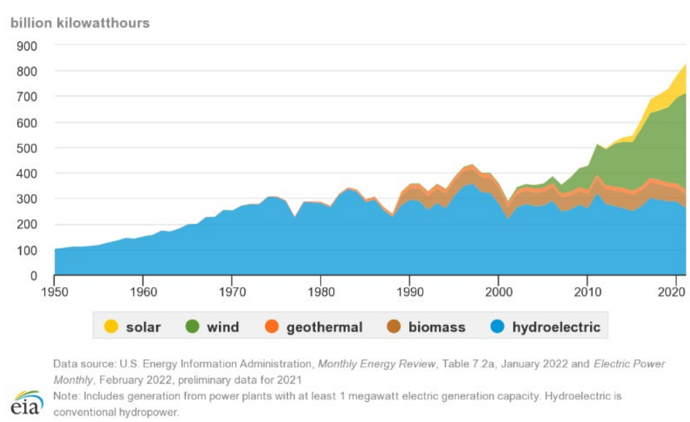
[54] *Ibid*.
[55] https://www.eia.gov/todayinenergy/detail.php?id=51839.
[56] https://www.eia.gov/energyexplained/us-energy-facts/#:~:text=Renewable%20energy%20production%20and%20consumption,than%20the%2050%2Dyear%20average.
[57] https://www.eia.gov/environment/emissions/carbon/.
[58] https://www.eia.gov/energyexplained/electricity/electricity-in-the-us-generation-capacity-and-sales.php#:~:text=In%202021%2C%20net%20generation%20of,solar%20photovoltaic%20(PV)%20systems.

Figure 2-13: U.S. Electricity Generation by Major Energy Source, 1950-2021



Source: U.S. EIA Monthly Energy Review[59]

Figure 2-14: U.S. Electricity Generation from Renewable Energy Sources, 1950-2021



Source: U.S. EIA Monthly Energy Review[60]

Wind, currently the most prevalent source of renewable electricity in the United States, grew over 12 percent from 2020 to 2021, while solar grew over 28 percent. Over the past decade,

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[59] EIA, *Monthly Energy Review,* January 2022, Table 7.2a.
[60] EIA, *Monthly Energy Review,* January 2022, Table 7.2a.

wind generation has seen a three-fold increase (120.18 billion kWh in 2011 to 379.77 billion kWh in 2021), while solar generation has increased by over a factor of 60 (1.82 billion kWh in 2011 to 114.68 billion kWh in 2021).[61]

Renewables are also expected to comprise most new U.S. electricity generating capacity in 2022, with solar accounting for the largest share of new capacity at 46 percent, followed by wind at 17 percent.[62] The addition of utility-scale solar capacity is expected to set a new record of 21.5 gigawatts (GW) added to the grid in 2022, surpassing a 15.5 GW increase in 2021. Another 7.6 GW of wind capacity is also scheduled to come online in 2022, following the addition of 17.1 GW in 2021.[63]

Average U.S. construction costs for renewable generation have fallen significantly in recent years, with costs for solar and wind dropping 50 percent and 27 percent, respectively, from 2013 to 2018.[64] The annual capacity-weighted average construction costs for solar photovoltaic systems in the United States continued to decrease in 2019, dropping by a little less than 3 percent, while the average costs for wind turbines remained relatively stable in 2019, increasing $9 per kilowatt (kW), or a little less than 1 percent from the 2018 average.[65] Falling costs are a big reason for the strong deployment trends for land-based wind and solar photovoltaic (PV). Median installed costs for standalone utility-scale PV plants have steadily fallen by more than 75 percent since 2010, to $1.35/weighted average cost (WAC) for plants completed in 2021.[66] Similarly, the capacity-weighted average installed project cost for land-based wind systems installed in 2021 was down more than 40 percent from 2010.[67]

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[61] https://www.eia.gov/energyexplained/electricity/electricity-in-the-us-generation-capacity-and-sales.php#:~:text=In%202021%2C%20net%20generation%20of,solar%20photovoltaic%20(PV)%20systems.

[62] https://www.eia.gov/todayinenergy/detail.php?id=50818#:~:text=In%202022%2C%20we%20expect%2046.1,%25%20and%20wind%20at%2017%25.

[63] https://www.eia.gov/todayinenergy/detail.php?id=50818#:~:text=In%202022%2C%20we%20expect%2046.1,%25%20and%20wind%20at%2017%25.

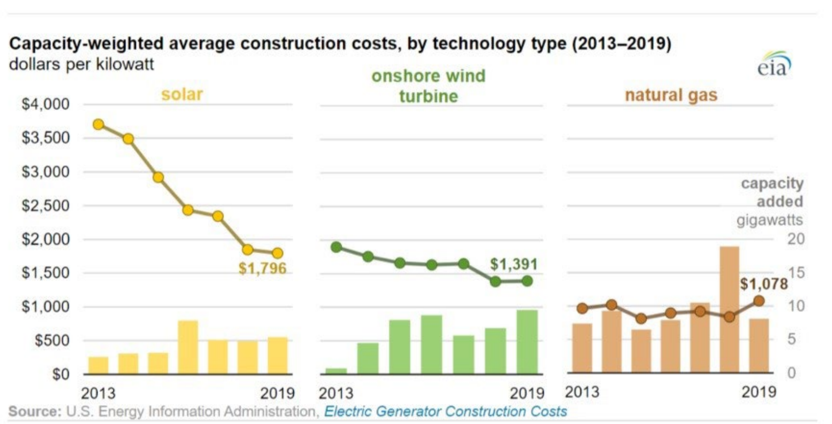
[64] https://www.eia.gov/tODAyinenergy/detail.php?id=48736.

[65] https://www.eia.gov/todayinenergy/detail.php?id=48736#:~:text=The%20average%20costs%20for%20wind,kW%2C%20or%20almost%2029%25.

[66] https://emp.lbl.gov/sites/default/files/utility-scale_solar_2022_technical_brief.pdf, p 3.

[67] https://emp.lbl.gov/sites/default/files/2022_land_based_wind_market_report.pdf, p 41.

Figure 2-15: U.S. Capacity-weighted Average Construction Costs, by Technology Type (dollars per kilowatt)



Source: U.S. EIA[68]

TRANSPORTATION

In 2016, the U.S. transportation sector overtook the power sector as the leading source of GHG emissions for the first time since the late 1970s and represented 27 percent of 2020 gross U.S. GHG emissions.[69] Transportation emissions have grown significantly since 1990, in large part due to increased demand for travel. Growth in air travel and freight transportation including trucking was particularly pronounced in recent years, with a more than 10 percent increase in for-hire freight shipments[70] and U.S. airline traffic[71] between 2015 and 2018.

In 2020, the majority of U.S. transportation sector GHG emissions (57 percent) came from light-duty vehicles, with the remainder from medium- and heavy-duty trucks (26 percent), aircraft (8 percent), rail (2 percent), ships and boats (2 percent), and other sources such as buses and motorcycles (5 percent).

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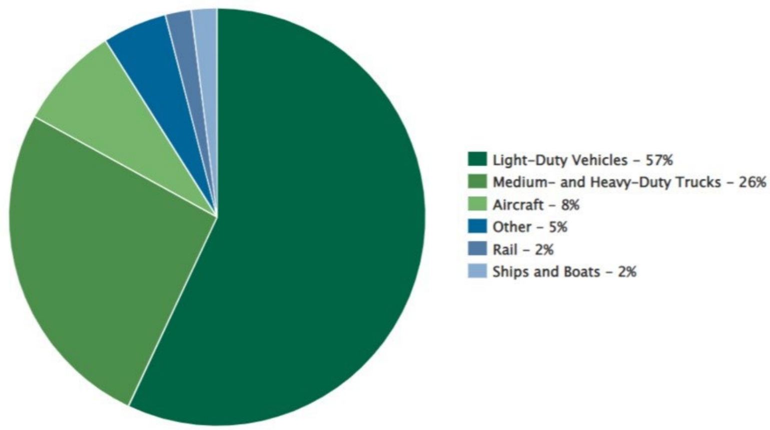
[68] EIA, Electric Generator Construction Costs.
[69] https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions.
[70] https://www.bts.dot.gov/newsroom/january-2019-freight-transportation-services-index-tsi.
[71] https://www.bts.gov/newsroom/estimated-october-2018-us-airline-traffic-data.

Figure 2-16: 2020 U.S. Transportation Sector Greenhouse Gas (GHG) Emissions by Source



Source: U.S. EPA[72]

Since 2020, the Covid-19 pandemic has had dramatic impacts on U.S. transportation sector trends. Energy-related CO_2 emissions fell by 15 percent in the transportation sector in 2020 compared to the previous year, largely because of reduced travel. Because of pandemic restrictions, working from home and online meetings frequently replaced commuting and in-person meetings, and both domestic and international air travel fell as well.[73] Transportation emissions are estimated to have rebounded sharply in 2021, reflecting high demand for freight transportation of consumer products and a modest recovery of passenger travel, though they did not return to pre-pandemic levels.[74]

In model year 2020, the average estimated real-world CO_2 emission rate for all new vehicles fell by 7 gallons/mile (g/mi) to 349 g/mi, the lowest ever measured. Fuel economy increased by 0.5 miles per gallon (mpg) to 25.4, achieving a record high. Since model year 2004, CO_2 emissions have decreased 24 percent, or 112 g/mi, and fuel economy has increased 32 percent, or 6.1 mpg. Over that time, CO_2 emissions and fuel economy have improved in thirteen out of sixteen years, and preliminary data suggest that CO_2 emissions and fuel economy in model year 2021 will remain near the levels achieved in 2020.[75]

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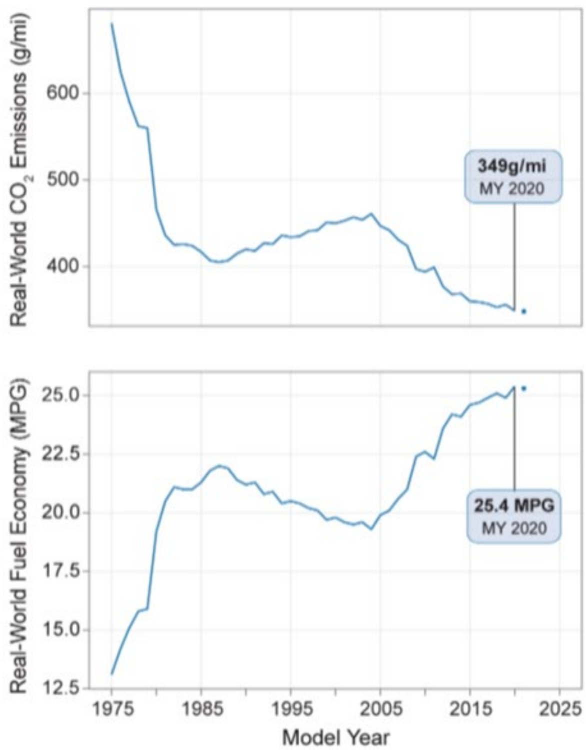
[72] https://www.epa.gov/greenvehicles/fast-facts-transportation-greenhouse-gas-emissions.
[73] https://www.bts.gov/data-spotlight/after-year-covid-19-view-bts.
[74] https://rhg.com/research/preliminary-us-emissions-2021/.
[75] https://www.epa.gov/automotive-trends/highlights-automotive-trends-report#Highlight1.

Figure 2-17: Estimated Real-World Fuel Economy and CO_2 Emissions



Source: EPA[76]

The overall new vehicle market continues to move away from the sedan/wagon vehicle type towards a combination of truck SUVs and car SUVs. Sedans and wagons fell to 31 percent of the market, well below the 50 percent market share they held as recently as model year 2013, and far below the 80 percent market share they held in 1975. Conversely, truck SUVs reached a record 39 percent of the market in model year 2020, and car SUVs reached a record 13 percent of the market. The trend away from sedan/wagons, which remain the vehicle type with the highest fuel economy and lowest CO_2 emissions, and towards vehicle types with lower fuel economy and higher CO_2 emissions has offset some of the fleetwide benefits that otherwise would have been achieved from the improvements within each vehicle type.[77]

Among heavy-duty vehicles, fuel economy has not improved significantly since 2010 but is projected to increase over the next decade across all vehicle classes (see Figure 2-18)[78] –

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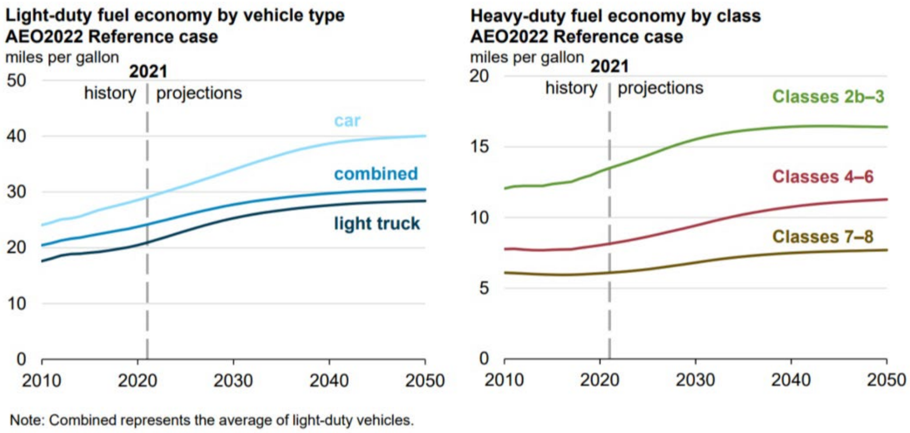
[76] https://www.epa.gov/automotive-trends/highlights-automotive-trends-report.
[77] https://www.epa.gov/automotive-trends/highlights-automotive-trends-report#Highlight1.
[78] https://www.eia.gov/tODAyinenergy/detail.php?id=29612.

including with the projected uptake of zero-emission heavy duty vehicles (HDVs). Note that these projections do not include the projected impact of the Inflation Reduction Act (IRA), Bipartisan Infrastructure Law (BIL), or the most recent EPA fuel economy standard, as these were adopted too late for inclusion in the Annual Energy Outlook (AEO) 2022 reference case.

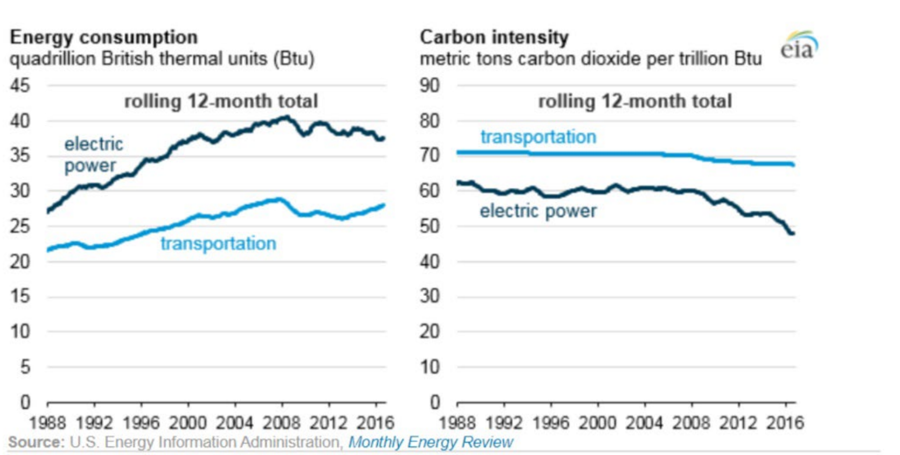
Figure 2-18: On-Road Vehicle Fuel Economy



Source: U.S. EIA[79]

Overall, carbon intensity of the transport sector has fallen only slightly over the past decade, and relatively less than the power sector.[80]

Figure 2-19: Evolution of Energy Consumption and Carbon Intensity



Source: U.S. EIA[81]

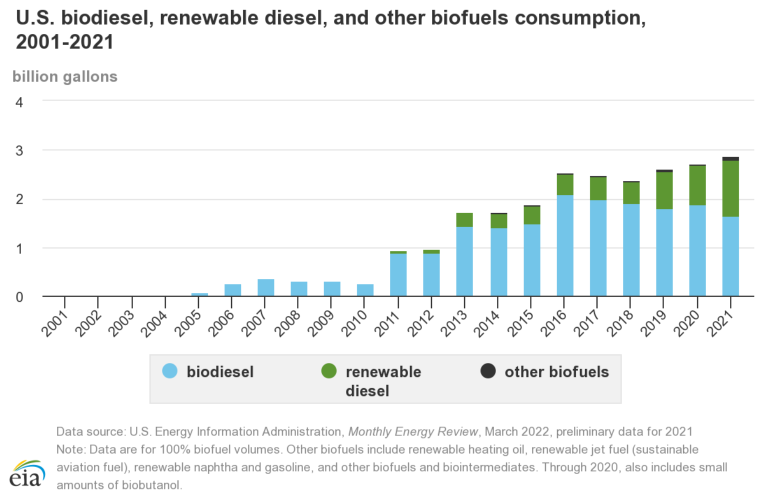
[79] EIA, Annual Energy Outlook 2022.

[80] https://www.eia.gov/todayinenergy/detail.php?id=29612.

[81] https://www.eia.gov/todayinenergy/detail.php?id=29612&src=email.

While fossil fuels continue to dominate U.S. transportation sector energy use, alternative sources have been gaining ground. Due in part to the availability of federal and state financial and other incentives, and the federal Renewable Fuels Standard (RFS) Program, biodiesel consumption grew dramatically from about 10 million gallons in 2001 to about 2 billion gallons in 2016.[82]

Figure 2-20: U.S. Biodiesel, Renewable Diesel, and other Biofuels Consumption, 2001-2021[83]

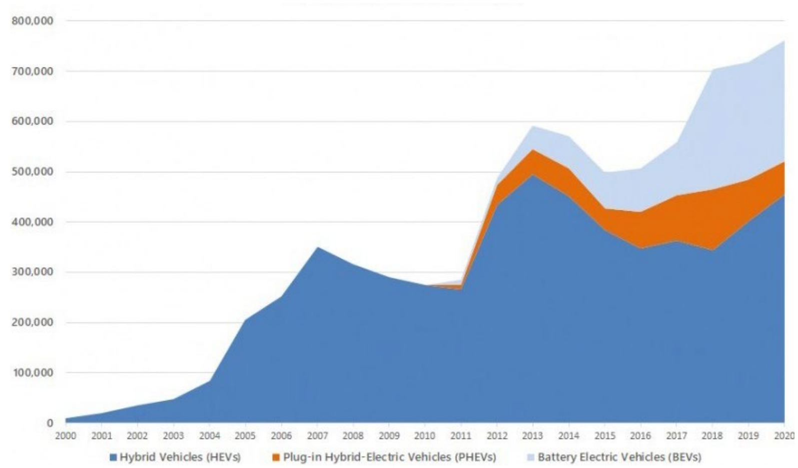


Source: U.S. EIA[84]

Moreover, the sale of electric vehicles (EVs) is growing quickly in the United States as a result of an ever-expanding supply of new models, improved infrastructure, tax incentives, and declining costs. The numbers of hybrid, plug-in hybrid, and battery powered EVs sold have increased steadily since 2018. This trend continues, as 2021 saw monthly record highs for combined sales of electric- drive vehicles.

[82] https://www.eia.gov/energyexplained/biofuels/biodiesel-rd-other-use-supply.php.
[83] EIA, *Monthly Energy Review*, March 2-22, preliminary data for 2021.
[84] EIA, *Monthly Energy Review*, March 2-22, preliminary data for 2021.

Figure 2-21: U.S. EV Sales Annual 2000-2020



Source: U.S. Bureau of Transportation Statistics[85]

Infrastructure to support an EV fleet shows similar strong growth. Between December of 2015 and 2019 alone, for example, the number of EV charging stations in the United States doubled.[86] The expected continued growth in the EV fleet (including models like pick-up trucks and SUVs) will continue to drive increases in average fuel efficiency over the fleet and drive down emissions from transportation over time–especially when combined with an ever-cleaner electricity profile.

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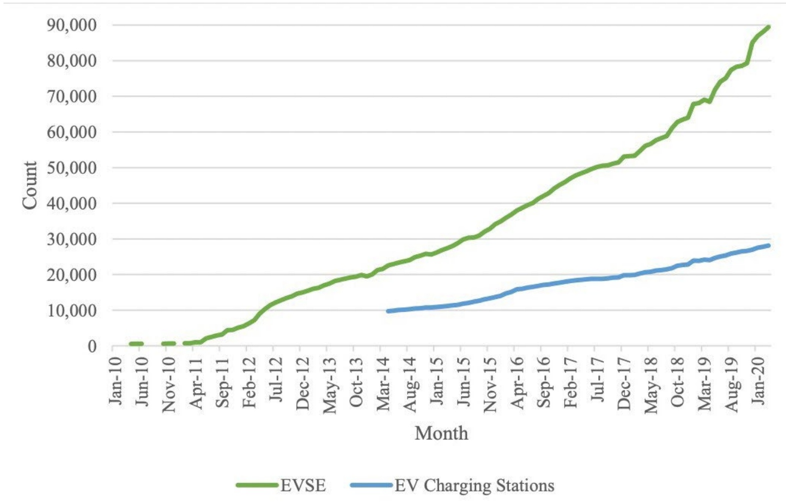
[85] U.S. Department of Transportation, https://www.bts.gov/data-spotlight/electric-vehicle-use-grows.
[86] Electric Vehicle Supply Equipment (EVSE) are charging points; there may be multiple EVSE at a single charging station.

Figure 2-22: Total Number of EV Supply Equipment and EV Charging Stations (2010-2020)



Source: U.S. Department of Energy[87]

INDUSTRY

Direct industrial sector GHG emissions accounted for 24 percent of total U.S. GHG emissions in 2020, making it the third largest contributor after the transportation and power sectors. Including both direct emissions and indirect emissions associated with electricity use, industry's share was 30 percent, the largest contribution from any sector.[88]

From 2019 to 2020, total energy use in the industrial sector fell by 5 percent, in part due to reductions in economic and manufacturing activity resulting from the COVID-19 pandemic. Since 1990, total U.S. GHG emissions from industry, including electricity, have declined by 22 percent[89] as a result of energy efficiency improvements and other structural factors, including shifts in industrial output away from energy-intensive manufacturing products to less energy-intensive products (e.g., from steel to computer equipment).[90]

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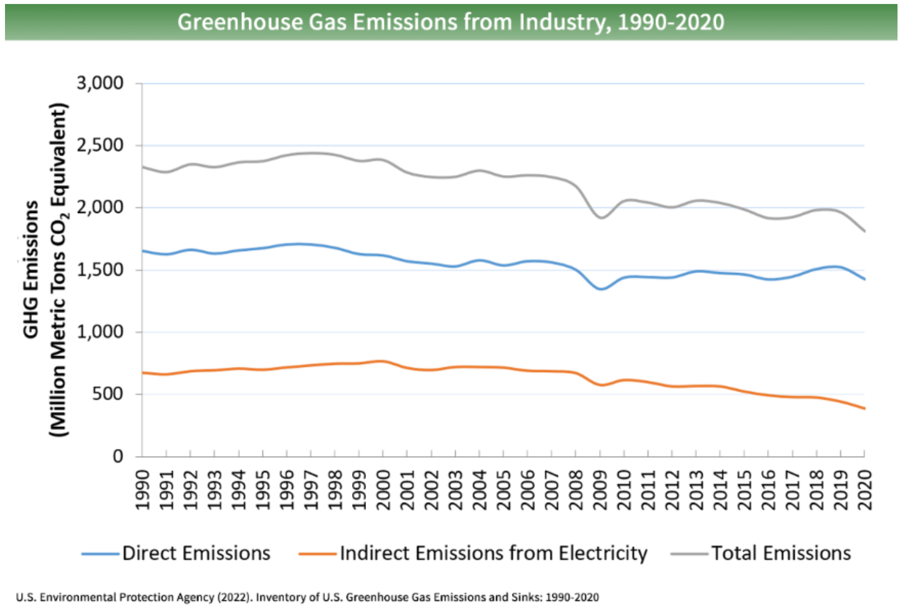
[87] U.S. National Renewable Energy Laboratory, www.nrel.gov/docs/fy20osti/77508.pdf.
[88] https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions.
[89] *Ibid*.
[90] *Ibid*.

Figure 2-23: Greenhouse Gas Emissions from Industry, 1990-2020



Source: U.S. Environmental Protection Agency[91]

WASTE

In 2018, the United States generated approximately 292.4 million short tons of municipal solid waste (MSW) – an increase from the 268.7 million tons generated in 2017 and the 208.3 million tons in 1990. Paper and paperboard products made up the largest component of MSW (about 23 percent), and food waste comprised the second-largest material component (22 percent). Yard trimmings and plastics constituted about 12 percent each, and the remaining amount of MSW generated was comprised of rubber, leather, and textiles, metals, wood, glass and other materials.

Recycling and composting have been the most significant change in waste management from a GHG perspective. In 2018, Americans composted or recycled over 94 million tons of MSW, an average of 1.6 pounds per person per day. In 2018, the recycling and composting rate (32 percent) was approximately double what it was in 1990, and the recycling, composting, combustion with energy recovery and landfilling of MSW saved over 193 million metric tons of carbon dioxide equivalent ($MMtCO_2e$) – comparable to the emissions that could be reduced from taking almost 42 million cars off the road in 2018.[92]

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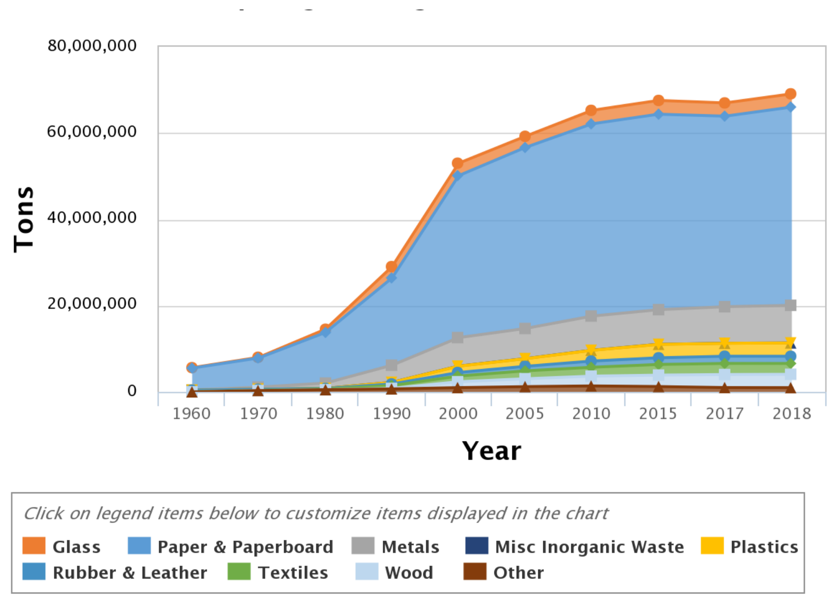
[91] U.S. Environmental Protection Agency (2022), Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020.

[92] https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials#NationalPicture.

Figure 2-24: Recycling Tonnages, 1960-2018



Source: U.S. Environmental Protection Agency (EPA) Facts and Figures about Materials, Waste and Recycling[93]

BUILDING STOCK AND URBAN STRUCTURE

Energy use for buildings accounted for about 28 percent (approximately 21 quadrillion BTU) of total U.S. end-use energy consumption in 2021.[94] Building energy consumption and GHG emissions are influenced by building type (commercial, residential, multi-unit, single-unit, and construction type), size, climate zone, building shell, and the appliances and the heating, ventilation, and cooling systems (HVAC) installed.

U.S. building sector energy use has remained relatively constant since 2000 and is expected to increase only slightly through 2050. While residential housing stocks are expected to increase by over 20 percent and commercial building stocks by over 30 percent over the next three decades, standards and incentives are expected to lead to further energy efficiency improvements. Electrification of HVAC, water heating, and other appliances is expected to contribute to additional efficiency and transition a growing number of buildings from on-site combustion to electric power. Distributed solar generation is also becoming more prevalent

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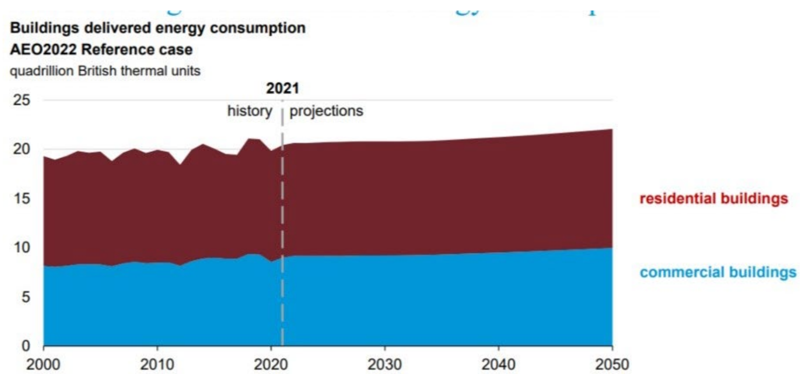
[93] https://www.epa.gov/crwu/climate-resilience-evaluation-and-awareness-tool-creat-risk-assessment-application-water.

[94] https://www.eia.gov/tools/faqs/faq.php?id=86&t=1#:~:text=In%202021%2C%20the%20combined%20end,British%20thermal%20units%20(Btu).&text=This%20was%20equal%20to%20about,use%20energy%20consumption%20in%202021.

on residential and commercial buildings.[95] Figure 2-25 depicts projected changes in projected energy consumption in the buildings sector, noting that the AEO2022 reference case does not reflect the projected effects of the IRA.

Figure 2-25: Total U.S. Buildings Sector Delivered Energy Consumption



Source: U.S. EIA [96]

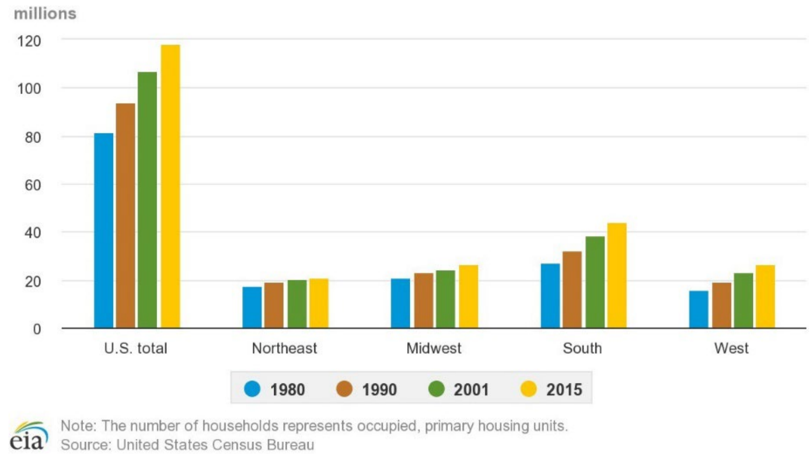
RESIDENTIAL BUILDINGS

While the average U.S. household today uses more air conditioning, appliances, and consumer electronics than ever before, annual site energy use per home has declined due to a variety of factors, including improvements in building insulation and materials; improved efficiencies of heating and cooling equipment, water heaters, refrigerators, lighting, and other appliances; and population migration to regions with lower heating needs. HVAC accounts for about half of home energy use, though it varies by climate zone.

Residential sector energy consumption has remained relatively flat since the mid-1990s, as this declining average energy consumption per household has offset an increasing number of homes overall (see Figures 2-26 and 2-27).[97]

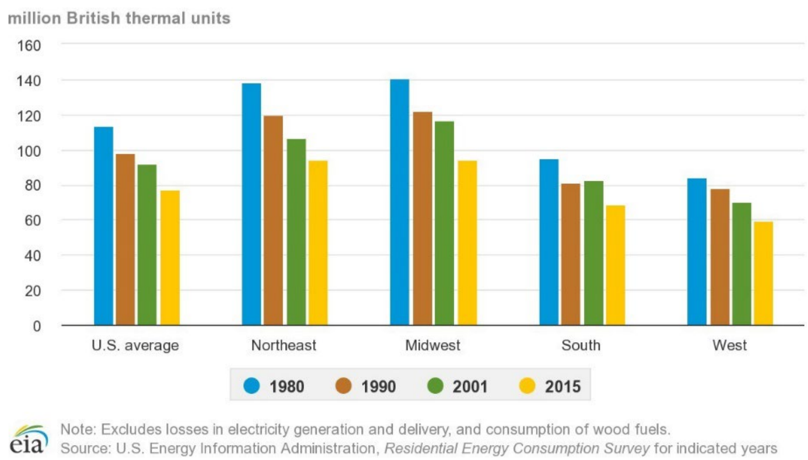
[95] U.S. Department of State, 2021 https://unfccc.int/documents/308100.
[96] EIA, https://www.eia.gov/outlooks/aeo/pdf/AEO2022_ChartLibrary_Buildings.pdf.
[97] https://www.eia.gov/energyexplained/use-of-energy/homes.php.

Figure 2-26: New Privately-Owned Housing Units Started



Source: U.S. EIA[98]

Figure 2-27: Energy Consumption per household, U.S. Average and by Census Region in Selected Years



Source: U.S. EIA[99]

In 2020, residential energy use in the U.S. declined an estimated 4 percent from 2019 levels due to relatively warm winter months and reduced demand for heating, which typically accounts for about 40 percent of energy use in homes. This was despite more time spent at home due to the emergence of Covid-19, with about 30 percent of households reporting at least one person working from home at least one day a week.[100]

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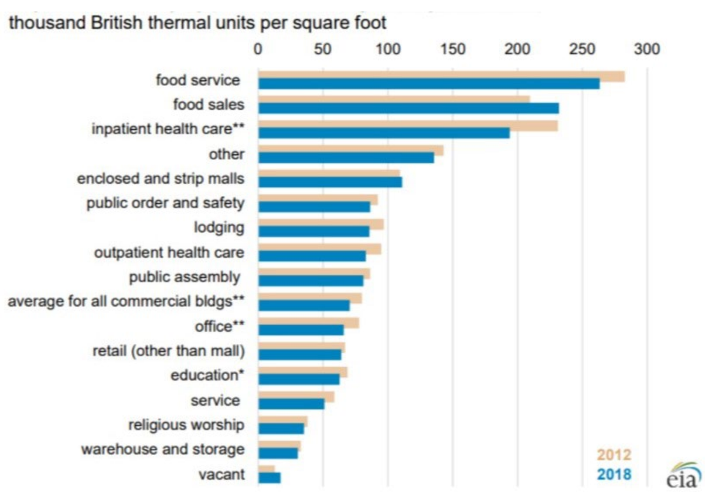
[98] https://www.eia.gov/consumption/residential/webinar_slides/highlights_from_the_2015_RECS.pdf.
[99] *Ibid*.
[100] https://www.eia.gov/consumption/residential/status/pdf/RECS%202020%20Webinar.pdf.

COMMERCIAL BUILDINGS

Commercial buildings include a variety of building types – offices, hospitals, schools, police stations, places of worship, warehouses, hotels, and shopping malls. From 1979 to 2018, the total number of commercial buildings in the U.S. is estimated to have increased approximately 55 percent (up 6 percent since 2012) to 5.9 million, and total commercial floorspace approximately 90 percent (up 11 percent since 2012) to 97 billion square feet.[101]

While commercial floorspace is projected to continue to grow significantly over the next 30 years, total energy use is expected to increase at a much slower space. Wider adoption of commercial building sensors and controls over time – and other factors, including energy efficiency gains and warmer weather – are expected to contribute to declines in commercial energy consumption to meet heating, ventilation, and lighting needs. Commercial buildings are also expected to increasingly electrify HVAC and other appliances, increasing efficiency and replacing on-site fuel combustion.[102] Between 2012 and 2018, commercial building energy consumption per square foot of floorspace fell 12 percent, and buildings used primarily for inpatient health care, offices, and education demonstrated statistically significant decreases in total energy intensity.[103]

Figure 2-28: Major Fuel Intensity by Principal Building Activity, 2012-2018[104]



Source: U.S. Energy Information Administration, *Commercial Buildings Energy Consumption Survey*
* Change is statistically significant at the 10% significance level.
** Change is statistically significant at the 5% significance level.

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[101] https://www.eia.gov/consumption/commercial/pdf/CBECS%202018%20Preliminary%20Results%20Flipbook.pdf.

[102] https://www.eia.gov/tODAyinenergy/detail.php?id=47736.

[103] https://www.eia.gov/consumption/commercial/data/2018/pdf/CBECS%202018%20C&E%20Flipbook.pdf.

[104] EIA, Commercial Buildings Energy Consumption Survey.

AGRICULTURE

Agriculture has long been a key industry in the United States. U.S. farmers and ranchers produce a vast array of food and fiber crops, feed grains, oil seeds, fruits and vegetables, and other agricultural commodities for both domestic consumption and export. Investments in advanced production techniques, efficiencies, and cultivars and livestock varieties over the previous decades have made U.S. agriculture highly productive. While the area under harvest today is roughly the same area as was harvested in 1910, U.S. agriculture now feeds a population three times larger and still exports additional product.[105] In 2021, U.S. agricultural exports reached a record $177 billion, an 18 percent increase from 2020 and up 14.6 percent over the previous record set in 2014.[106] The U.S. agricultural sector is a major source of employment, with average annual jobs on a gradual upward trend since 2010, rising from 1.07 million in 2010 to 1.16 million in 2020, a gain of 9 percent.[107]

In 2021, there were approximately 2.01 million farms and ranches in the United States. Together they covered approximately 362 million hectares (895 million acres). The size of these operations varies greatly, with approximately 82 percent of farms showing sales of less than $100,000 in 2021, and approximately 4 percent with sales of $1 million or more. The average farm size is 180 hectares (445 acres). In recent years there has been a small but notable decline in the overall number of farms, but a small upward trend in average farm size.[108]

Emissions from agriculture, which accounted for approximately 11 percent of total U.S. GHG emissions in 2020, come from a number of sources, including cultivation, organic soils, nitrogen fertilizer use, enteric fermentation, manure, and rice production.[109] Agricultural soil management activities, such as fertilizer application and other cropping practices, were the largest source of U.S. nitrous oxide (N_2O) emissions in 2019, accounting for 75 percent of emissions of this gas. However, soils also have the potential to sequester and store large quantities of carbon, reducing atmospheric CO_2 concentrations. Additional opportunities to reduce agricultural emissions include improving the efficiency of fertilizer use and reducing methane emissions from livestock and rice production.

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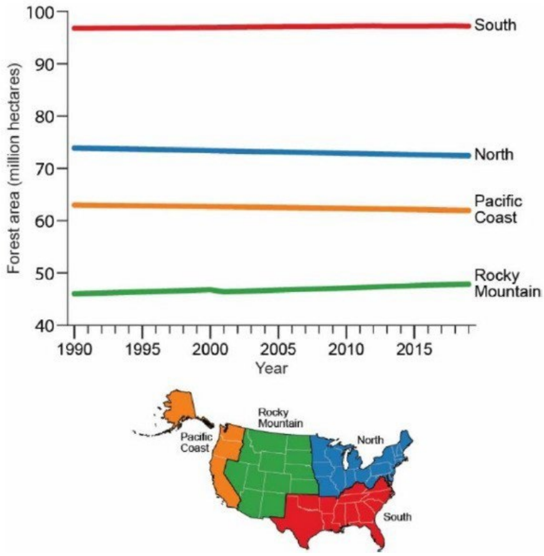
[105] https://www.bls.gov/ooh/farming-fishing-and-forestry/agricultural-workers.htm.
[106] https://www.fas.usda.gov/2021-country-overview#:~:text=U.S.%20agricultural%20exports%20to%20the,8%20of%20them%20setting%20records.
[107] https://www.ers.usda.gov/topics/farm-economy/farm-labor/#size.
[108] https://www.nass.usda.gov/Publications/Todays_Reports/reports/fnlo0222.pdf.
[109] Sources of Greenhouse Gas Emissions, US EPA.

LAND USE, LAND USE CHANGE, AND FORESTS

Forests play a key role in the economy, ecology, and culture of the United States, whose approximately 310 million hectares (766 million acres) of forest[110] comprise the fourth largest forest area of any country in the world. This area has remained fairly stable since the beginning of the 20th century, even as the population of the country tripled. In recent decades, the area of forest land has even increased slightly. The dynamics vary from region to region. In the eastern part of the country, active farmland is decreasing and returning to a forested state. In 2020, total net sequestration from land use, land use change, and forests was 812 million tonnes (MMT) of carbon dioxide equivalent (CO_2e), which offset approximately 14 percent of total United States GHG emissions (EPA 2022).[111] Sequestration was primarily the result of carbon uptake by standing United States forests, forest management, increased tree cover in urban areas, storage in harvested wood products, and the management of agricultural soils. This volume was down from 900 MMT in 1990 but represented an increase from 2015.

[110] Oswalt, Sonja N.; Smith, W. Brad; Miles, Patrick D.; Pugh, Scott A., coords. 2019. Forest Resources of the United States, 2017: a technical document supporting the Forest Service 2020 RPA. Assessment. Gen. Tech. Rep. WO-97. Washington, DC: U.S. Department of Agriculture, Forest Service, Washington Office. 223 p. https://doi.org/10.2737/ WO-GTR-97; based on USDA Forest Service Forest Inventory & Analysis https://www.fs.usda.gov/research/publications/gtr/gtr_wo97.pdf.
[111] https://www.epa.gov/system/files/documents/2022-04/us-ghg-inventory-2022-chapter-6-land-use-land-use-change-and-forestry.pdf.

Figure 2-29: Changes in Forest Area by Region for Forest Land Remaining Forest Land in the Contiguous United States and Alaska 1990-2020



Source: 1990-2020 U.S. Inventory[112]

Private ownership accounts for 60 percent of forest land nationally.[113] Forest ownership patterns vary greatly from region to region though, with public lands predominating in the West. Forests provide a range of economic benefits to the U.S. economy. The U.S. supplies 10 percent of the world's timber; and 96 percent of U.S. consumption of industrial wood comes from domestic sources.[114] The forest products industry accounts for approximately five percent of U.S. manufacturing GDP.[115] Visitor spending in U.S. forests generates more than $13 billion in revenue every year.[116] The value of the ecosystem services provided by these forests is vast. For example, 53 percent of the water in the contiguous United States originates on forest land.[117]

Forest land remaining forest land (including vegetation, soils, and harvested wood) account for the vast majority of total CO_2 removals each year. Other lands converted to forest land and settlements remaining settlements also contributed to substantial net sequestration. Croplands remaining croplands, wetlands remaining wetlands, other lands converted to

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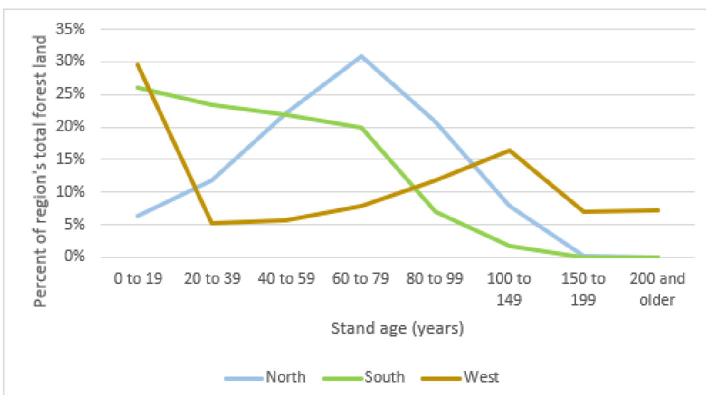
[112] https://www.epa.gov/system/files/documents/2022-04/us-ghg-inventory-2022-chapter-6-land-use-land-use-change-and-forestry.pdf.
[113] https://www.fs.fed.us/nrs/pubs/gtr/gtr_nrs199.pdf.
[114] https://www.fs.fed.us/about-agency/newsroom/by-the-numbers.
[115] https://www.energy.gov/eere/amo/forest-products-industry-profile.
[116] https://www.fs.fed.us/about-agency/newsroom/by-the-numbers.
[117] https://www.fs.fed.us/about-agency/newsroom/by-the-numbers.

wetlands, and settlements remaining settlements. All contributed to the total net removals. Estimates of land use, land use change, and forestry (LULUCF) emissions and removals, with the exception of CO_2 fluxes from wood products and urban trees, are calculated annually based on activity data collected through forest and land-use surveys conducted at multiple-year intervals ranging from 1 to 10 years. The latest *Inventory of U.S. Greenhouse Gas Emissions and Sinks*[118] describes the full methodology.

While forest cover in the United States has increased in recent decades, the age of our forests is also increasing. As more mature trees sequester relatively less carbon over time, this may affect overall rate of sequestration in the long term. Natural disturbances such as wildfires, drought, pest outbreaks, and windthrow may also increase over time, further affecting the rate of net sequestration. These disturbances may lead to increased tree mortality, which releases stored carbon over a period of years. However, regrowth after a disturbance also increases carbon sequestration, especially in the early years after a disturbance. The net impact on emissions over time depends on the specific event, and on subsequent policy responses. Forest management practices are in place to help ameliorate potential increases in future natural disturbances to the degree possible.

Figure 2-30: Distribution of Forest Land by Region and Stand Age (2012)



Source: U.S. Forest Service [119]

Forests are not the only ecosystem of note in the United States. Grassland, or prairie, ecosystems comprise approximately 363.5 million hectares (898.2 million acres). Many of

118 https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks.

119 Oswalt, Sonja N.; Smith, W. Brad; Miles, Patrick D.; Pugh, Scott A., coords. 2019. Forest Resources of the United States, 2017: a technical document supporting the Forest Service 2020 RPA. Assessment. Gen. Tech. Rep. WO-97. Washington, DC: U.S. Department of Agriculture, Forest Service, Washington Office. 223 p. https://doi.org/10.2737/WO-GTR-97.

these grasslands are used for livestock grazing or have been converted to cropland or settlements, but others remain in their natural state and serve as habitat for numerous native and migratory species while also preserving soil resources and storing carbon in soils and perennial biomass.

Coastal and inland wetlands cover approximately 43.3[120] million hectares (107 million acres) of the surface area of the United States. In the past, inland wetlands were occasionally drained for conversion to cropland; today limited conversion of wetlands to settlements may occur along the coasts.[121]

Wetlands mitigate climate change by removing GHGs like carbon dioxide (CO_2) from the atmosphere and storing them in plants and in the soil, and they play a fundamental role in important economic sectors. In 2018, for example, U.S. commercial and recreational fisheries supported 1.7 million jobs and contributed $238 billion in sales.[122] Wetlands also increase the resilience of coastal communities and businesses to extreme weather events through food and storm protection – estimated to save $23 billion each year[123] - and provide valuable ecological services such as natural water purification.

[120] Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019. p. 481.
[121] https://www.fws.gov/wetlands/documents/Wetlands-Status-and-Trends-Reports-Fact-Sheet.pdf.
[122] https://www.fisheries.noaa.gov/national/sustainable-fisheries/fisheries-economics-united-states.
[123] https://www.fisheries.noaa.gov/national/habitat-conservation/coastal-wetland-habitat#:~:text=Coastal%20wetlands%20support%20important%20benefits,for%20commercial%20and%20recreational%20fisheries.

Chapter 3.
GREENHOUSE GAS INVENTORY SUMMARY

Chapter 3. GREENHOUSE GAS INVENTORY SUMMARY

INTRODUCTION

The United States is committed to providing regular, transparent reporting on current and historical greenhouse gas (GHG) emissions. Estimates of emissions and removals are reported annually, via the *Inventory of U.S. Greenhouse Gas Emissions and Sinks*[124]. As a Party to the U.N. Framework Convention on Climate Change (UNFCCC), consistent with Article 4 of the Convention and decisions at the First, Second, Fifth, and Nineteenth Conference of Parties,[125] the United States is committed to submitting a national inventory of anthropogenic sources and sinks of GHGs to the UNFCCC by April 15 of each year. The United States views the *Inventory*, in conjunction with accompanying Common Reporting Format (CRF) reporting tables, as an opportunity to fulfill this annual commitment under the UNFCCC.

This chapter summarizes the latest information on U.S. anthropogenic GHG emission trends from 1990 through 2020, consistent with information submitted to the UNFCCC secretariat in April 2022. To ensure that the U.S. emissions inventory is comparable with those of other UNFCCC Parties, the Inventory emissions and removals estimates presented in the submitted report and this chapter are organized by source and sink categories and calculated using methodologies consistent with those recommended in the *2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories*[126] and UNFCCC guidelines for annual inventory reporting.[127] Additionally, the U.S. emissions inventory has continued to incorporate new methodologies and data from the *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*[128] and the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas*

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[124] EPA (2022). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020. U.S. Environmental Protection Agency, Washington, D.C. EPA. EPA Publication No. EPA 430-R-22-003.
[125] UNFCCC (2014) Report of the Conference of the Parties on its Nineteenth Session, Held in Warsaw from 11 to 23 November 2013. (FCCC/CP/2013/10/Add.3). January 31, 2014. Available online at: http://unfccc.int/ resource/docs/2013/cop19/eng/10a03.pdf.
[126] IPCC (2006) 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change. [H.S. Eggleston, L. Buendia, K. Miwa, T. Ngara, and K. Tanabe (eds.)]. Hayama, Kanagawa, Japan.
[127] UNFCCC (2014).
[128] IPCC (2013) Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. [Stocker, T.F., D.

Inventories[129]. As with each inventory submission, the "Recalculations and Improvements" chapter of the April 2022 *Inventory* submission includes a description on improvements and recalculations relative to the previous *Inventory*, consistent with the principle of continuous improvement. For this latest release, the U.S. Environmental Protection Agency (EPA) has made several important improvements. For example, EPA has added estimates for two important sources of methane: emissions from post-meter uses of natural gas, which includes leak emissions from residential and commercial appliances, industrial facilities and power plants, and natural gas fueled vehicles; and emissions from flooded lands such as hydroelectric and agricultural reservoirs. Additionally, EPA worked with researchers to include estimates of methane emissions from large anomalous leak events, such as well blow-outs.

BACKGROUND INFORMATION

GHGs trap heat and make the planet warmer. The most important GHGs directly emitted as a result of human activities include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and several fluorinated gases: hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3). Although the direct GHGs CO_2, CH_4, and N_2O occur naturally in the atmosphere, human activities have changed their atmospheric concentrations. From the pre-industrial era (i.e., ending about 1750) to 2020, concentrations of CO_2, CH_4, and N_2O have increased globally by 47, 157, and 23 percent, rGHG emissions and removals associated with human activities across the United States.

RECENT TRENDS IN U.S. GREENHOUSE GAS EMISSIONS AND SINKS

In 2020, total gross U.S. GHG emissions were 5,981.4 million metric tonnes of carbon dioxide equivalent (MMT CO_2e). Total U.S. emissions have decreased by 7.3 percent from 1990 to 2020, down from a high of 15.7 percent above 1990 levels in 2007. Total gross emissions decreased from 2019 to 2020 by 9 percent (590.4 MMT CO_2e). Net emissions (i.e., including sinks) were 5,222.4 MMT CO_2e. Overall, net emissions decreased 10.6 percent from 2019 to 2020 and decreased 21.4 percent from 2005 levels, as shown in Table 3-1. Similarly, total gross emissions decreased 9 percent since 2019 and 19.5 percent since 2005. The sharp

Qin, G.-K., Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.

[129] IPCC (2019) 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. e [Buendia, E., Guendehou S., Limmeechokachai B., Pipatti R., Rojas Y., Sturgiss R., Tanabe K., Wirth T., (eds.)]. Cambridge University Press. In Press.

decline in emissions from 2019 to 2020 is largely due to the impacts of the coronavirus (COVID-19) pandemic on travel and economic activity. However, the decline also reflects the combined impacts of many long-term trends in many factors, including population, economic growth, energy market trends, technological changes including energy efficiency, and carbon intensity of energy fuel choices. Between 2019 and 2020, the decrease in total GHG emissions was driven largely by a 10.5 percent decrease in CO_2 emissions from fossil fuel combustion, including a 13.3 percent decrease in transportation sector emissions from less travel due to the COVID-19 pandemic and a 10.4 percent decrease in emissions in the electric power sector[130]. The decrease in electric power sector emissions was due to a decrease in electricity demand of about 2.5 percent and also reflects the continued shift from coal to less carbon intensive natural gas and renewables.

Figures 3-1 and 3-2 illustrate the overall trends in both total U.S. GHG emissions by gas and annual changes in net emissions since 1990. Table 3-1 provides a detailed summary of U.S. GHG emissions and sinks for 1990 through 2020. Overall, from 1990 to 2020, total gross emissions of CO_2 decreased by 406.8 MMT CO_2e (-8 percent), total emissions of methane (CH_4) decreased by 130.4 MMT CO_2e (-16.4 percent), and total emissions of nitrous oxide (N_2O) decreased by 24.4 MMT CO_2e (-5.4 percent). During the same period, aggregate weighted emissions of HFCs, PFCs, SF_6, and NF_3 rose by 89.5 MMT CO_2e (89.9 percent). Despite being emitted in smaller quantities relative to the other principal GHGs, emissions of HFCs, PFCs, SF_6, and NF_3 are significant because many of them have both extremely high global warming potentials (GWPs) and, in the cases of PFCs, SF_6, and NF_3, long atmospheric lifetimes.[131] Conversely, U.S. GHG emissions were partly offset by 812.2 MMT CO_2e of net carbon (C) sequestration in managed forests, trees in urban areas, agricultural soils, landfilled yard trimmings, and coastal wetlands, representing 13.6 percent of total emissions in 2020. Emissions of CH_4 and N_2O from land use, land use change, and forestry (LULUCF) activities in 2020 were 53.2 MMT CO_2e and represent 0.9 percent of total GHG emissions. Figure 3-1, and Figure 3-2 illustrate the overall trends in total U.S. emissions by gas, annual percent changes, and relative change since 1990 for each year of the time series. The discussion that follows these figures describes each gas's contribution to total U.S. GHG emissions in more detail.

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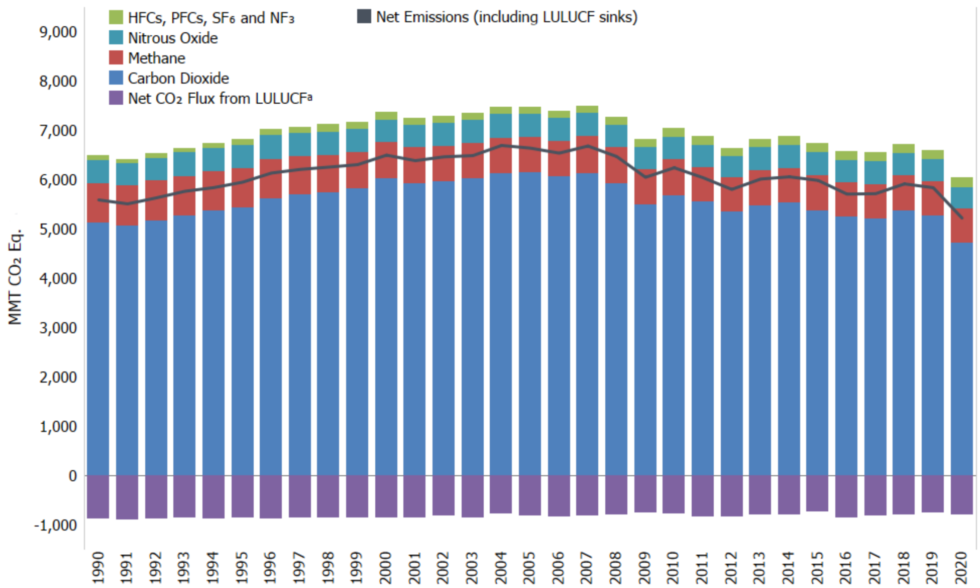
[130] EIA (2022) Electricity Generation. Monthly Energy Review, February 2022. Energy Information Administration, U.S. Department of Energy, Washington, D.C. DOE/EIA-0035(2022/02).

[131] IPCC (1996) Climate Change 1995: The Science of Climate Change. Intergovernmental Panel on Climate Change. [J.T. Houghton, L.G. Meira Filho, B.A. Callander, N. Harris, A. Kattenberg, and K. Maskell (eds.)]. Cambridge University Press. Cambridge, United Kingdom.

Figure 3-1: U.S Greenhouse Gas Emissions by Gas

In 2020, net U.S. emissions from all GHGs declined by a total of 370.4 MMT CO_2e, or 6.6 percent since 1990.



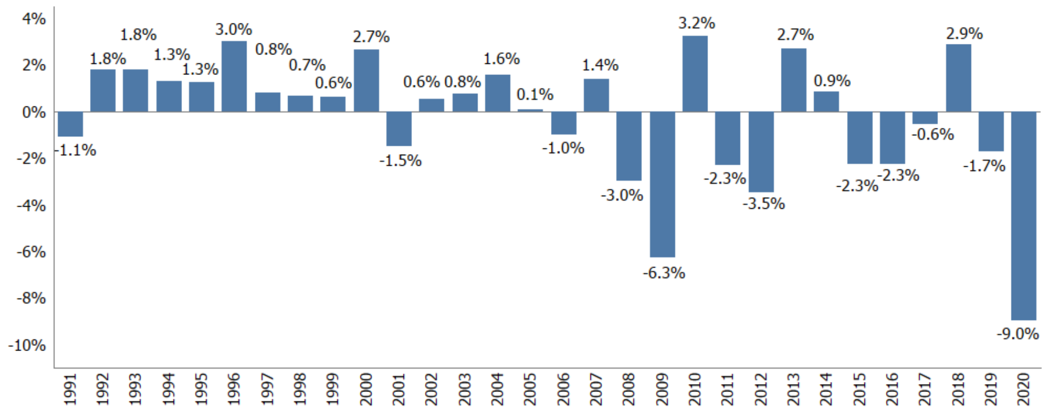
Source: U.S. EPA[132]

Figure 3-2: Annual Percent Change in Gross U.S. Greenhouse Gas Emissions Relative to the Previous Year

Total gross emissions decreased 7.3 percent since 1990 with an average annual rate of decrease of -0.2 percent over that time period. Between 2005 and 2020, total gross U.S. GHG

[132] EPA (2022).

emissions fell by 19.5 percent and average annual rate of decrease over that time period was -1.4 percent.



Source: U.S. EPA[133]

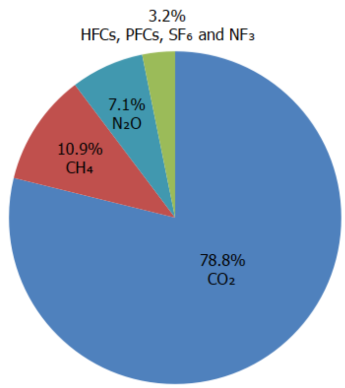
Figure 3-3 illustrates the relative contribution of the direct GHGs to total U.S. emissions in 2020. Table 3-1 provides a detailed summary of U.S. GHG emissions and sinks for 1990 through 2020. The primary GHG emitted by human activities in the United States was CO_2, representing approximately 78.8 percent of total GHG emissions. The largest source of CO_2, and of overall GHG emissions, was fossil fuel combustion, primarily from transportation and power generation. Methane emissions (CH_4) account for approximately 10.9 percent of emissions. The major sources of methane include enteric fermentation associated with domestic livestock, natural gas systems, and decomposition of wastes in landfills. Nitrous oxide emissions accounts for 7.1 percent of 2020 emissions, and major sources include agricultural soil management, wastewater treatment, stationary sources of fuel combustion, and manure management[134]. Ozone depleting substance substitute emissions, and emissions of HFC-23 during the production of HCFC-22, were the primary contributors to aggregate HFC emissions. Perfluorocarbon (PFC) emissions were primarily attributable to electronics manufacturing and primary aluminum production. Electrical transmission and distribution systems accounted for most sulfur emissions. The electronics industry is the only source of nitrogen trifluoride (NF_3) emissions. Collectively, fluorinated emissions account for just over 3 percent of 2020 emissions.

[133] EPA (2022).

[134] NOAA/ESRL (2022b) Trends in Atmospheric Methane. Available online at: https://www.esrl.noaa.gov/gmd/ccgg/trends_ch4/. 05 January 2022.

Figure 3-3: 2020 U.S. Greenhouse Gas Emissions by Gas (Percentages based on MMT CO_2e)

The primary GHGs emitted by human activities in the United States was CO_2, representing approximately 78.8 percent of total GHG emissions.



Source: U.S. EPA[135]

Table 3-1: Recent Trends in U.S. Greenhouse Gas Emission and Sinks (MMT CO_2e)

In 2020, net U.S. GHG emissions were 5,222.4 MMT CO_2e, representing a 6.6 percent decrease since 1990 and a 21.4 percent decrease since 2005.

Gas/Source	1990	2005	2016	2017	2018	2019	2020
CO_2	**5122.5**	**6137.6**	**5251.8**	**5211.0**	**5376.7**	**5259.1**	**4715.7**
Fossil Fuel Combustion	4731.2	5752.0	4909.6	4853.3	4989.3	4852.3	4342.7
Transportation	1468.9	1858.6	1757.6	1780.0	1812.8	1813.8	1572.0
Electric Power Sector	1820.0	2400.1	1808.9	1732.0	1752.9	1606.1	1439.0
Industrial	853.7	851.5	792.7	790.4	814.1	816.1	766.3
Residential	338.6	358.9	292.8	293.4	338.2	341.4	315.8
Commercial	228.3	227.1	231.5	232.0	245.8	250.7	226.8
U.S. Territories	21.7	55.9	26.0	25.5	25.5	24.3	22.7
Non-Energy Use of Fuels	112.2	128.9	99.5	112.6	128.9	126.8	121.0

135 EPA (2022).

Gas/Source	1990	2005	2016	2017	2018	2019	2020
Cement Production	33.5	46.2	39.4	40.3	39.0	40.9	40.7
Iron and Steel Production & Metallurgical Coke Production	104.7	70.1	43.6	40.6	42.6	43.1	37.7
Natural Gas Systems	31.9	24.9	29.8	31.1	32.4	38.7	35.4
Petroleum Systems	9.6	12.0	21.9	25.0	37.3	46.7	30.2
Petrochemical Production	21.6	27.4	28.1	28.9	29.3	30.7	30.0
Incineration of Waste	12.9	13.3	14.4	13.2	13.3	12.9	13.1
Ammonia Production	13.0	9.2	10.2	11.1	12.2	12.3	12.7
Lime Production	11.7	14.6	12.6	12.9	13.1	12.1	11.3
Other Process Uses of Carbonates	6.2	7.5	10.8	9.9	7.4	9.8	9.8
Urea Consumption for Non-Agricultural Purposes	3.8	3.7	5.3	5.2	6.0	6.0	6.0
Urea Fertilization	2.4	3.5	4.7	4.9	5.0	5.1	5.3
Carbon Dioxide Consumption	1.5	1.4	4.6	4.6	4.1	4.9	5.0
Liming	4.7	4.3	3.1	3.1	2.2	2.4	2.4
Coal Mining	4.6	4.2	2.8	3.1	3.1	3.0	2.2
Glass Production	2.3	2.4	2.1	2.0	2.0	1.9	1.9
Aluminum Production	6.8	4.1	1.3	1.2	1.5	1.9	1.7
Soda Ash Production	1.4	1.7	1.7	1.8	1.7	1.8	1.5
Ferroalloy Production	2.2	1.4	1.8	2.0	2.1	1.6	1.4
Titanium Dioxide Production	1.2	1.8	1.7	1.7	1.5	1.5	1.3

Gas/Source	1990	2005	2016	2017	2018	2019	2020
Zinc Production	0.6	1.0	0.8	0.9	1.0	1.0	1.0
Phosphoric Acid Production	1.5	1.3	1.0	1.0	0.9	0.9	0.9
Lead Production	0.5	0.6	0.5	0.5	0.5	0.5	0.5
Carbide Production and Consumption	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Abandoned Oil and Gas Wells	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Magnesium Production and Processing	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Wood Biomass, Ethanol, and Biodiesel Consumption[a]	*219.4*	*230.7*	*316.9*	*312.7*	*319.8*	*317.2*	*291.6*
International Bunker Fuels[b]	*103.6*	*113.3*	*116.7*	*120.2*	*122.2*	*116.1*	*69.6*
CH_4[c]	**780.8**	**697.5**	**657.6**	**663.8**	**671.1**	**668.8**	**650.4**
Enteric Fermentation	163.5	168.0	171.3	174.9	175.7	176.1	175.2
Natural Gas Systems	195.5	177.5	165.2	166.6	171.8	172.1	164.9
Landfills	176.6	131.5	107.9	109.2	111.7	113.6	109.3
Manure Management	34.8	49.0	57.1	57.5	59.4	58.7	59.6
Coal Mining	96.5	64.1	53.8	54.8	52.7	47.4	41.2
Petroleum Systems	47.8	41.4	40.4	40.5	38.6	40.4	40.2
Wastewater Treatment	20.3	20.1	18.7	18.5	18.3	18.1	18.3
Rice Cultivation	16.0	18.0	15.8	14.9	15.6	15.1	15.7
Stationary Combustion	8.6	7.8	7.9	7.7	8.6	8.8	7.9

Gas/Source	1990	2005	2016	2017	2018	2019	2020
Abandoned Oil and Gas Wells	6.5	6.8	6.9	6.9	6.9	7.0	6.9
Abandoned Underground Coal Mines	7.2	6.6	6.7	6.4	6.2	5.9	5.8
Composting	0.4	1.9	2.3	2.5	2.3	2.3	2.3
Mobile Combustion	6.5	4.0	2.6	2.6	2.5	2.5	2.2
Field Burning of Agricultural Residues	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Petrochemical Production	0.2	0.1	0.2	0.3	0.3	0.3	0.3
Anaerobic Digestion at Biogas Facilities	0.0	0.0	0.2	0.2	0.2	0.2	0.2
Carbide Production and Consumption	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ferroalloy Production	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Iron and Steel Production & Metallurgical Coke Production	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Incineration of Waste	0.0	0.0	0.0	0.0	0.0	0.0	0.0
International Bunker Fuels[b]	*0.2*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
N_2O[c]	**450.5**	**453.3**	**449.2**	**444.6**	**457.7**	**456.8**	**426.1**
Agricultural Soil Management	316.0	313.8	330.8	328.3	338.9	345.3	316.2
Wastewater Treatment	16.6	20.3	22.8	23.2	23.5	23.4	23.5

Gas/Source	1990	2005	2016	2017	2018	2019	2020
Stationary Combustion	25.1	34.4	30.0	28.4	28.2	24.9	23.2
Manure Management	13.9	16.3	18.4	19.0	19.3	19.5	19.7
Mobile Combustion	44.6	41.4	21.1	20.1	19.2	20.0	17.4
Nitric Acid Production	12.1	11.3	10.1	9.3	9.6	10.0	9.3
Adipic Acid Production	15.2	7.1	7.1	7.5	10.5	5.3	8.3
N_2O from Product Uses	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Composting	0.3	1.7	2.0	2.2	2.0	2.0	2.0
Caprolactam, Glyoxal, and Glyoxylic Acid Production	1.7	2.1	1.7	1.5	1.4	1.4	1.2
Incineration of Waste	0.5	0.4	0.4	0.4	0.4	0.4	0.4
Electronics Industry	0.0	0.1	0.2	0.3	0.3	0.2	0.3
Field Burning of Agricultural Residues	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Petroleum Systems	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Natural Gas Systems	0.0	0.0	0.0	0.0	0.0	0.0	0.0
International Bunker Fuels[b]	*0.9*	*1.0*	*1.0*	*1.1*	*1.1*	*1.0*	*0.6*
HFCs	**46.5**	**127.4**	**168.3**	**171.1**	**171.0**	**175.9**	**178.8**
Substitution of Ozone Depleting Substances[d]	0.2	107.2	165.1	165.5	167.3	171.8	176.2
HCFC-22 Production	46.1	20.0	2.8	5.2	3.3	3.7	2.1
Electronics Industry	0.2	0.2	0.3	0.4	0.4	0.4	0.4

Gas/Source	1990	2005	2016	2017	2018	2019	2020
Magnesium Production and Processing	0.0	0.0	0.1	0.1	0.1	0.1	0.1
PFCs	24.3	6.7	4.4	4.2	4.8	4.6	4.4
Electronics Industry	2.8	3.3	3.0	3.0	3.1	2.8	2.7
Aluminum Production	21.5	3.4	1.4	1.1	1.6	1.8	1.7
Substitution of Ozone Depleting Substances[d]	0.0	0.0	0.0	0.0	0.1	0.1	0.1
Electrical Transmission and Distribution	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SF_6	**28.8**	**11.8**	**6.0**	**5.9**	**5.7**	**5.9**	**5.4**
Electrical Transmission and Distribution	23.2	8.3	4.1	4.2	3.8	4.2	3.8
Magnesium Production and Processing	5.2	2.7	1.1	1.0	1.0	0.9	0.9
Electronics Industry	0.5	0.7	0.8	0.7	0.8	0.8	0.7
NF_3	**0.0**	**0.5**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**
Electronics Industry	0.0	0.5	0.6	0.6	0.6	0.6	0.6
Total Gross Emissions (Sources)	**6,453.5**	**7,434.8**	**6,537.9**	**6,501.0**	**6,687.5**	**6,571.7**	**5,981.4**
LULUCF Emissions[c]	**31.4**	**41.3**	**35.4**	**45.5**	**39.8**	**30.3**	**53.2**
LULUCF CH_4	27.2	30.9	28.3	34.0	30.7	25.5	38.1
LULUCF N_2O	4.2	10.5	7.1	11.5	9.1	4.8	15.2
LULUCF Carbon Stock Change[e]	**-892.0**	**-831.1**	**-862.0**	**-826.7**	**-809.0**	**-760.8**	**-812.2**
LULUCF Sector Net Total[f]	**-860.6**	**-789.8**	**-826.6**	**-781.2**	**-769.3**	**-730.5**	**-758.9**

Gas/Source	1990		2005		2016	2017	2018	2019	2020
Net Emissions (Sources and Sinks)	**5,592.8**		**6,645.0**		**5,711.2**	**5,719.8**	**5,918.2**	**5,841.2**	**5,222.4**

Notes:

Total (gross) emissions presented without LULUCF. Net emissions presented with LULUCF. Totals may not sum due to independent rounding. Parentheses indicate negative values or sequestration.

+ Does not exceed 0.05 MMT CO_2e. NO (Not Occurring)

a. Emissions from Wood Biomass, Ethanol, and Biodiesel Consumption are not included specifically in summing Energy sector totals. Net carbon fluxes from changes in biogenic carbon reservoirs are accounted for in the estimates for LULUCF.
b. Emissions from International Bunker Fuels are not included in totals.
c. LULUCF emissions of CH_4 and N_2O are reported separately from gross emissions totals. LULUCF emissions include the CH_4 and N_2O emissions reported for Peatlands Remaining Peatlands, Forest Fires, Drained Organic Soils, Grassland Fires, and Coastal Wetlands Remaining Coastal Wetlands; CH_4 emissions from Land Converted to Coastal Wetlands, Flooded Land Remaining Flooded Land, and Land Converted to Flooded Land; and N_2O emissions from Forest Soils and Settlement Soils. Refer to Table 3-5 for a breakout of emissions and removals for LULUCF by gas and source category.
d. Small amounts of PFC emissions also result from this source.
e. LULUCF Carbon Stock Change is the net C stock change from the following categories: Forest Land Remaining Forest Land, Land Converted to Forest Land, Cropland Remaining Cropland, Land Converted to Cropland, Grassland Remaining Grassland, Land Converted to Grassland, Wetlands Remaining Wetlands, Land Converted to Wetlands, Settlements Remaining Settlements, and Land Converted to Settlements. Refer to Table 3-5 for a breakout of emissions and removals for LULUCF by gas and source category.
f. The LULUCF Sector Net Total is the net sum of all LULUCF CH_4 and N_2O emissions to the atmosphere plus net carbon stock changes.

CARBON DIOXIDE EMISSIONS

The global carbon cycle is made up of large carbon flows and reservoirs. Billions of tonnes of carbon in the form of CO_2 are absorbed by oceans and living biomass (i.e., sinks) and are emitted to the atmosphere annually through natural processes (i.e., sources). When in equilibrium, global carbon fluxes among these various reservoirs are roughly balanced.

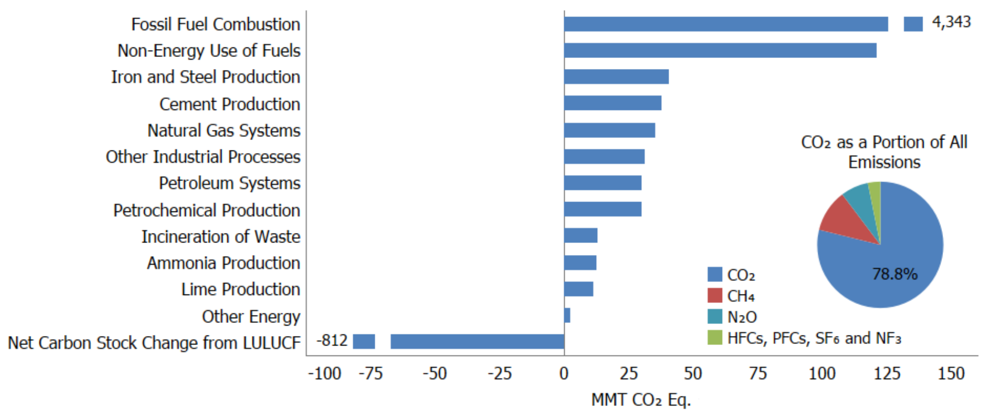
Since the Industrial Revolution (i.e., about 1750), global atmospheric concentrations of CO_2 have risen approximately 47 percent,[136] principally due to the combustion of fossil fuels for

[136] IPCC (2021); NOAA/ESRL (2022a) Trends in Atmospheric Carbon Dioxide. Available online at: http://www.esrl.noaa.gov/gmd/ccgg/trends/. 05 January 2022.

energy. Globally, an estimated 31,500 MMT of CO_2 were added to the atmosphere through the combustion of fossil fuels in 2019, of which the United States accounted for approximately 15.4 percent. Within the United States, fossil fuel combustion accounted for 92.1 percent of CO_2 emissions in 2020. Transportation was the largest emitter of CO_2 in 2020, followed by electric power generation. As illustrated in the Figure 3-4, changes in land use and forestry practices can also lead to net CO_2 emissions (e.g., through conversion of forest land to agricultural or urban use) or to a net sink for CO_2 (e.g., through net additions to forest biomass). See more on these emissions and removals in Table 3-5.

Figure 3-4 2020 Sources of CO_2 Emissions

In 2020, CO_2 accounted for 78.8 percent of U.S. GHG emissions, with fossil fuel combustion accounting for 92.1 percent of CO_2 emissions.



Source: U.S.EPA[137]

As the largest source of U.S. GHG emissions, CO_2 from fossil fuel combustion has accounted for approximately 75.3 percent of GWP-weighted total U.S. gross emissions across the time series. Between 1990 and 2020, CO_2 emissions from fossil fuel combustion decreased from 4,731.2 MMT CO_2e to 4,342.7 MMT CO_2e, an 8.2 percent total decrease. In 2020, CO_2 emissions from fossil fuel combustion were 24.5 per cent (1,409.4 MMT CO_2e) below 2005 levels. From 2019 to 2020, these emissions decreased by 509.7 MMT CO_2e (10.5 percent).

Box 3-1: Global Warming Potentials

UNFCCC reporting guidelines for national inventories require the use of 100-year GWP values from the *IPCC Fourth Assessment Report* (AR4) to ensure that national GHG

[137] EPA (2022).

inventories reported by all nations are comparable (IPCC 2007). All estimates provided throughout the national GHG inventory submission are in both CO_2 equivalents and unweighted units. A comparison of emission values using the 100-year AR4 GWP values versus the 100-year GWP values from *IPCC Fifth Assessment Report* (AR5) (IPCC 2013), and the *IPCC Sixth Assessment Report* (AR6) (IPCC 2021) values can be found in Annex 6 of the national GHG inventory submitted in April 2022. The 100-year GWP values used in this report are listed below in Table 3-2. Parties will be required to shift to use AR5 100-year GWP values when they submit their first reports using updated reporting guidelines under the Paris Agreement at the latest by December 31, 2024, as provided in decision 18/CMA.1.

Note: see Table A-241, pp. A-495 of Annex 6 of the national GHG inventory submitted in April 2022 for a comparison of gross total emissions estimates using AR5 GWP values without climate-carbon feedback relative to AR4 GWP values.[138]

Table 3-2: Global Warming Potentials (100-Year Time Horizon) Used in this Report

Gas	GWP
CO_2	1
CH_4[a]	25
N_2O	298
HFC-23	14,800
HFC-32	675
HFC-41	92
HFC-125	3,500
HFC-134a	1,430
HFC-143a	4,470
HFC-152a	124
HFC-227ea	3,220
HFC-236fa	9,810
CF_4	7,390
$C2F_6$	12,200
C_3F_8	8,830
$c\text{-}C_4F_8$	10,300
SF_6	22,800
NF_3	17,200
Other Fluorinated	See Annex 6 to the national Inventory report

[138] https://www.epa.gov/system/files/documents/2022-04/us-ghg-inventory-2022-annex-6-additional-information.pdf.

Gas	GWP
Gases	

[a] 100-year time horizon.

Source: IPCC, EPA[139]

Note: The GWP of CH_4 includes the direct effects and those indirect effects due to the production of tropospheric ozone and stratospheric water vapor. The indirect effect due to production of CO_2 is not included. See Annex 6 of the national *Inventory* report for additional information.

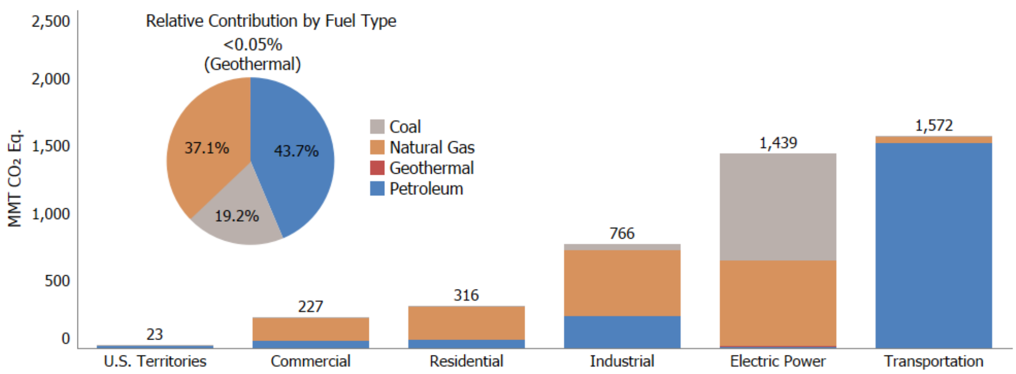
Historically, changes in emissions from fossil fuel combustion have been the driving factor affecting U.S. emissions trends. Changes in CO_2 emissions from fossil fuel combustion are influenced by many long-term and short-term factors. Important drivers include: (1) changes in demand for energy; and (2) a general decline in recent years in the carbon intensity of fuels combusted for energy by non-transport sectors of the economy. Long-term factors affecting energy demand include population and economic trends, technological changes including energy efficiency, shifting energy fuel choices, and various policies at the national, state, and local level. In the short term, the overall consumption and mix of fossil fuels in the United States fluctuates primarily in response to changes in general economic conditions, overall energy prices, the relative price of different fuels, weather, and the availability of non-fossil alternatives. Between 2019 and 2020, reduced economic activity and decreased travel due to the COVID-19 pandemic had significant impacts on energy use and fossil fuel combustion emissions.

The five fuel-consuming economic sectors are transportation, electric power, industrial, residential, and commercial. Carbon dioxide emissions are produced by the electric power sector as fossil fuel is consumed to provide electricity to one of the other four "end use" sectors see Figure 3-5. Note that this Figure reports emissions from U.S. Territories as their own end-use sector due to incomplete data for their individual end-use sectors. Fossil fuel combustion for electric power also includes emissions of less than 0.5 MMT CO_2e from geothermal-based generation. Figure 3-5 further describes direct and indirect CO_2 emissions from fossil fuel combustion (electricity use), separated by end-use sector.

[139] IPCC (2007), EPA (2022).

Figure 3-5: 2020 CO_2 Emissions from Fossil Fuel Combustion by Sector and Fuel Type

In 2020, U.S. transportation sector emissions were primarily from petroleum consumption, while electricity generation emissions were primarily from natural gas and coal consumption.



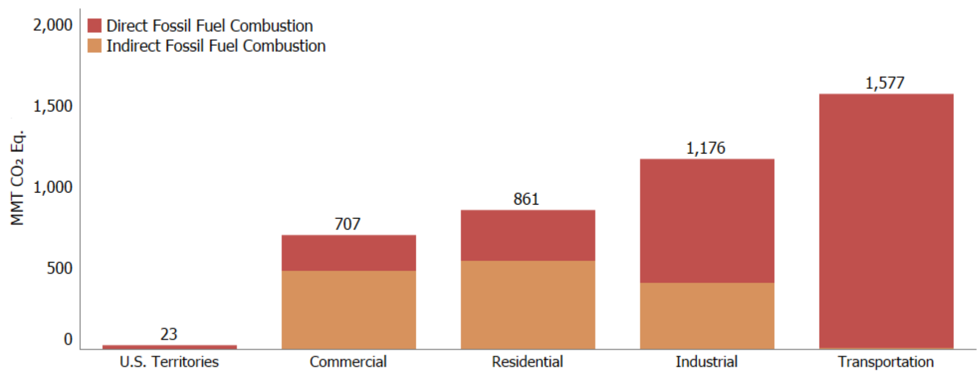
Source: U.S. EPA[140]

Figure 3-6: 2020 End-Use Sector Emissions of CO_2 from Fossil Fuel Combustion

In 2020, direct fossil fuel combustion accounted for the vast majority of fossil fuel-related CO_2 emissions from the transportation sector (mostly petroleum combustion) and industrial sectors (mostly natural gas combustion).[141] Electricity use indirectly accounted for most of the fossil fuel-related CO2 emissions from the commercial and residential sectors

[140] EPA (2022).

[141] FHWA (1996 through 2021) Highway Statistics. Federal Highway Administration, U.S. Department of Transportation, Washington, D.C. Report FHWA-PL-96-024-annual. Available online at: http://www.fhwa.dot.gov/policy/ohpi/hss/hsspubs.htm.



Source: U.S. EPA[142]

Table 3-3: CO_2 Emissions from Fossil Fuel Combustion by End-Use Sector (MMT CO_2e)

The figures below reflect the distribution of electricity generation emissions to each of the four end-use sectors on the basis of each sector's share of aggregate electricity consumption. Between 2005 and 2020, CO_2 emissions from fossil fuel combustion declined by 1,409.4 MMT CO_2e, or 24.5 percent.

End-Use Sector	1990	2005	2016	2017	2018	2019	2020
Transportation	**1472.0**	**1863.3**	**1761.8**	**1784.3**	**1817.4**	**1818.5**	**1576.7**
Combustion	1468.9	1858.6	1757.6	1780.0	1812.8	1813.8	1572.0
Electricity	3.0	4.7	4.2	4.3	4.7	4.7	4.7
Industrial	**1540.1**	**1587.8**	**1310.3**	**1294.8**	**1315.3**	**1281.4**	**1175.8**
Combustion	853.7	851.5	792.7	790.4	814.1	816.1	766.3
Electricity	686.4	736.3	517.6	504.4	501.2	465.3	409.5
Residential	**931.3**	**1214.9**	**946.2**	**910.5**	**980.4**	**925.0**	**860.6**
Combustion	338.6	358.9	292.8	293.4	338.2	341.4	315.8
Electricity	592.7	856.0	653.5	617.1	642.2	583.6	544.8
Commercial	**766.0**	**1030.1**	**865.2**	**838.2**	**850.7**	**803.2**	**706.8**
Combustion	228.3	227.1	231.5	232.0	245.8	250.7	226.8
Electricity	537.7	803.0	633.6	606.2	604.9	552.5	480.0
U.S. Territories [a]	**21.7**	**55.9**	**26.0**	**25.5**	**25.5**	**24.3**	**22.7**
Total	**4731.2**	**5752.0**	**4909.6**	**4853.3**	**4989.3**	**4852.3**	**4342.7**

142 EPA (2022).

End-Use Sector	1990		2005		2016	2017	2018	2019	2020
Electric Power	1820.0		2400.1		1808.9	1732.0	1752.9	1606.1	1439.0

Notes: Combustion-related emissions from electric power are allocated based on aggregate national electricity use by each end-use sector and represent indirect fossil fuel combustion for each end-use sector. Totals may not sum due to independent rounding.

a. Fuel consumption by U.S. Territories (i.e., American Samoa, Guam, Puerto Rico, U.S. Virgin Islands, Wake Island, and other U.S. Pacific Islands) is included in this report.

TRANSPORTATION END-USE SECTOR

Transportation activities accounted for 36.2 percent of U.S. CO_2 emissions from fossil fuel combustion in 2020. The largest sources of transportation CO_2 emissions in 2020 were passenger cars (38.5 percent); freight trucks (26.3 percent); light-duty trucks, which include sport utility vehicles, pickup trucks, and minivans (18.9 percent); commercial aircraft (5.8 percent); pipelines (3.6 percent); other aircraft (2.4 percent); rail (2 percent); and ships and boats (1.8 percent). Annex 3.2 of the national Inventory report presents the total emissions from all transportation and mobile sources, including CO_2, CH_4, N_2O, and HFCs.

In terms of the overall trend, from 1990 to 2020, total transportation CO_2 emissions increased 7 percent, while noting that from 2019 to 2020, transportation CO_2 emissions decreased 13.3 percent, primarily as a result of the COVID-19 pandemic and associated restrictions that led to less travel. The increase in transportation emissions from 1990 to 2019 was due, in large part, to increased demand for travel. The number of vehicle miles travelled (VMT) by light-duty motor vehicles (passenger cars and light-duty trucks) increased 47.5 percent from 1990 to 2019,[143] as a result of a confluence of factors including population growth, economic growth, urban sprawl, and periods of low fuel prices. From 2019 to 2020, the number of VMT by light-duty motor vehicles decreased by 12.2 percent, primarily the result of less travel caused by the COVID-19 pandemic. As noted in Chapter 2, while an increased demand for travel has led to increasing CO_2 emissions since 1990, improvements in average new vehicle fuel economy since 2005 have slowed the rate of increase of CO_2 emissions. Almost all of the energy consumed by the transportation sector is petroleum-based, including motor gasoline, diesel fuel, jet fuel, and residual oil.

INDUSTRIAL END-USE SECTOR

Industrial emissions accounted for 27.1 percent of CO_2 emissions from fossil fuel combustion in 2020. These industrial emissions resulted both directly from the combustion of fossil fuels

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[143] FHWA (2021).

and indirectly from the generation of electricity that is used by industry. Approximately 65.2 percent of these emissions resulted from direct fossil fuel combustion to produce steam and/or heat for industrial processes. The remaining emissions resulted from the use of electricity for motors, electric furnaces, ovens, lighting, and other applications. Total direct and indirect emissions from the industrial sector have declined by 22 percent since 1990. This decline is due to structural changes in the U.S. economy (i.e., shifts from a manufacturing-based to a service-based economy), fuel switching, and efficiency improvements. From 2019 to 2020, total energy use in the industrial sector decreased by 4.4 percent partially as a result of reductions in economic and manufacturing activity due to the COVID-19 pandemic.

RESIDENTIAL AND COMMERCIAL END-USE SECTORS

The residential and commercial end-use sectors accounted for 19.8 and 16.3 percent, respectively, of CO_2 emissions from fossil fuel combustion in 2020. The residential and commercial sectors relied heavily on electricity for meeting energy demands, with 63.3 and 67.9 percent, respectively, of their emissions attributable to electricity use for lighting, heating, cooling, and operating appliances. The remaining emissions were due to the use of natural gas and petroleum for heating and cooking. Total direct and indirect emissions from the residential sector have decreased by 7.6 percent since 1990. Total direct and indirect emissions from the commercial sector have increased by 7.7 percent since 1990.

ELECTRIC POWER

The United States relies on electricity to meet a significant portion of its energy demands. Electricity generators used 3.21 percent of U.S. energy from fossil fuels and emitted 33.1 percent of the CO_2 from fossil fuel combustion in 2020. The type of energy source used to generate electricity is the main factor influencing emissions. For example, some electricity is generated through non-fossil fuel options such as nuclear, hydroelectric, wind, solar, or geothermal energy. The mix of fossil fuels used also impacts emissions. The electric power sector is the largest consumer of coal in the United States. The coal used by electricity generators accounted for 91.4 percent of all coal consumed for energy in the United States in 2019.[144] However, the amount of coal and the percentage of total electricity generation from coal has been decreasing over time. Coal-fired electric generation (in kilowatt-hours

[144] EIA (2022) Electricity Generation. Monthly Energy Review, February 2022. Energy Information Administration, U.S. Department of Energy, Washington, D.C. DOE/EIA-0035(2022/02).

[kWh]) decreased from 54.2 percent of generation in 1990 to 19.9 percent in 2020.[145] This corresponded with an increase in natural gas generation and renewable energy generation, largely from wind and solar energy. Natural gas generation in kilowatt hours (kWh) represented 10.7 percent of electric power generation in 1990 and increased over the subsequent thirty-year period to represent 39.5 percent of electric power generation in 2020. Wind and solar generation (in kWh) represented 0.1 percent of electric power generation in 1990 and increased over the subsequent thirty-year period to represent 11.1 percent of electric power generation in 2020.

Overall U.S. demand for electricity has been relatively flat since 2005, due in part to a shift toward energy efficient products and more stringent energy efficiency standards for household equipment and building energy code adoption.[146] Across the time series, changes in electricity generation and the carbon intensity of fuels used for electric power had a significant impact on CO_2 emissions. CO_2 emissions from the electric power sector have decreased by approximately 20.9 percent since 1990; the carbon intensity of the electric power sector, in terms of CO_2e per quadrillion British thermal units (QBtu) input, has also significantly decreased (-19.2 percent) during that same timeframe. This decoupling of the level of electric power generation and the resulting CO_2 emissions is shown in Figure 3-7.

Figure 3-7: 2020 Electric Power Generation and Emissions

Changes in electricity demand and the carbon intensity of fuels used for electric power generation have a significant impact on CO_2 emissions. Carbon dioxide emissions from the electric power sector have decreased by approximately 20.9 percent since 1990, and the carbon intensity of the electric power sector, in terms of CO_2e per QBtu input, has significantly decreased by 19.2 percent during that same timeframe.

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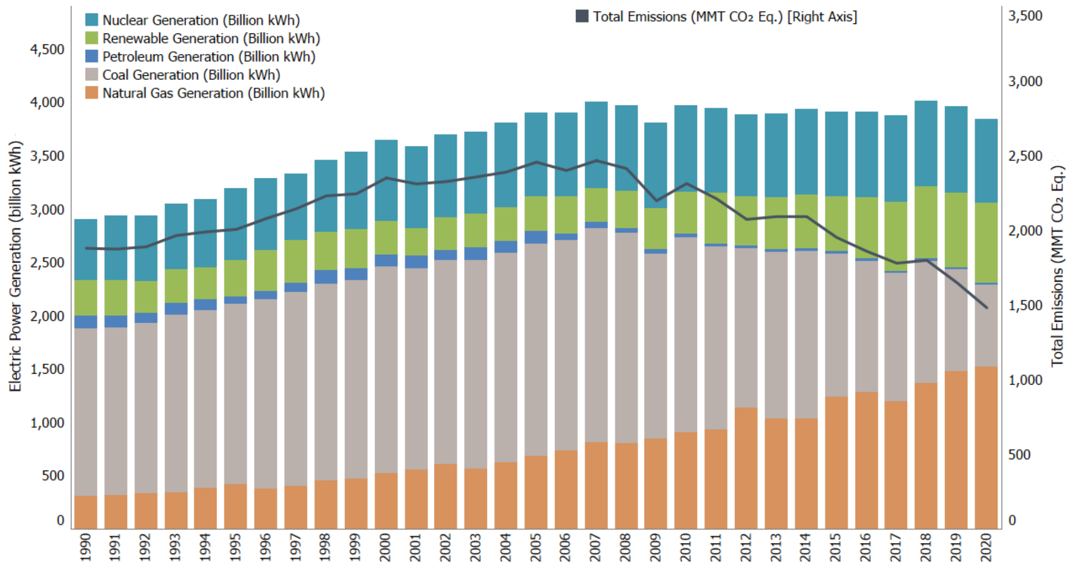
[145] EPA (2021b) "1970 - 2020 Average annual emissions, all criteria pollutants in MS Excel." National Emissions Inventory (NEI) Air Pollutant Emissions Trends Data. Office of Air Quality Planning and Standards, December 2021. Available online at: https://www.epa.gov/air-emissions-inventories/air-pollutant-emissions-trends-data.

[146] EIA (2017) Residential End Uses: Historical Efficiency Data and Incremental Installed Costs for Efficiency Upgrades, Energy Information Administration, U.S. Department of Energy. Washington, D.C. Available online at https://www.eia.gov/analysis/studies/residential/pdf/res_ee_fuel_switch.pdf.



Source: U.S. EPA[147]

OTHER CO_2 TRENDS

Other significant CO_2 trends over this time series include the following:

- Carbon dioxide emissions from natural gas and petroleum systems increased by 24.0 MMT CO_2e (57.9 percent) from 1990 to 2020. This increase is due primarily to increases in the production segment, where flaring emissions from associated gas flaring, tanks, and miscellaneous production flaring have increased over time.
- Carbon dioxide emissions from iron and steel production and metallurgical coke production have decreased by 67.0 MMT CO_2e (64.0 percent) from 1990 through 2020. This decrease is primarily due to restructuring of the industry, technological improvements, and increased scrap steel utilization.
- Total C stock change (i.e., net CO_2 removals) in the LULUCF sector decreased by 9.0 percent between 1990 and 2020. This decrease was primarily due to a decrease in the rate of net C accumulation in forest C stocks and Cropland Remaining Cropland, as well as an increase in emissions from Land Converted to Settlements.

METHANE EMISSIONS

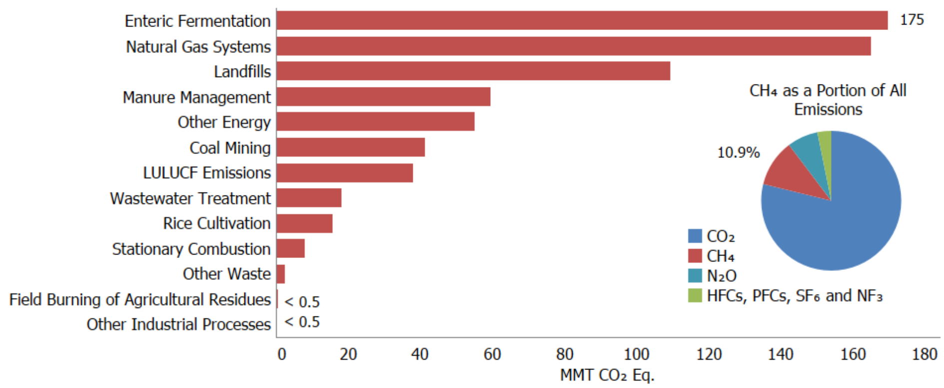
Methane (CH_4) is significantly more potent than CO_2 at trapping heat in the atmosphere–by a factor of 25 over a 100-year time frame, based on the *IPCC Fourth Assessment Report*

[147] EPA (2022).

estimate.[148] Over the last 250 years, the concentration of CH_4 in the atmosphere increased by 168.4 percent.[149] Within the United States, the main anthropogenic sources of CH_4 include enteric fermentation from domestic livestock, natural gas systems, landfills, domestic livestock manure management, coal mining, and other energy production related activities (i.e., petroleum systems) (see Figure 3-8).

Figure 3-8: 2020 Sources of CH_4 Emissions

In 2020, CH_4 accounted for 10.9 percent of U.S. GHG emissions on a 100-year GWP-weighted basis. Enteric Fermentation is the largest source of CH_4 emissions contributing 175.2 MMT CO_2e, accounting for approximately 27 percent of total CH_4 emissions. Natural Gas Systems followed close behind, contributing 164.9 MMT CO_2e or 25 percent.



Source: U.S. EPA[150]

Note: Methane emissions from Abandoned Oil and Gas Wells, Abandoned Coal Mines, Incineration of Waste, and Mobile Combustion are included in Other Energy. Methane emissions from anaerobic digestion at biogas facilities and composting are included in Other Waste. Methane emissions from Carbide Production and Consumption, Ferroalloy Production, Iron and Steel Production, and Petrochemical Production are included in Other Industrial Processes. LULUCF emissions include the CH_4 reported for Peatlands Remaining Peatlands, Forest Fires, Drained Organic Soils, Grassland Fires, and Coastal Wetlands Remaining Coastal Wetlands, Land Converted to Coastal Wetlands, Flooded Land Remaining Flooded Land, and Land Converted to Flooded Land. Refer to Table 3-5 for a breakout of LULUCF emissions by gas.

Significant trends for the largest sources of U.S. CH_4 emissions include the following:

- Enteric fermentation was the largest anthropogenic source of CH_4 emissions in the United States in 2020, accounting for 175.2 MMT CO_2e (26.9 percent of total CH_4

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[148] IPCC (2007).
[149] IPCC (2021); NOAA/ESRL (2022b).
[150] EPA (2022).

emissions) and representing an increase of 11.7 MMT CO_2e (7.2 percent) since 1990. This increase in emissions from 1990 to 2020 generally follows the increase in cattle populations.

- Natural gas systems were the second largest anthropogenic source category of CH_4 emissions in the United States in 2020, accounting for 164.9 MMT CO_2e of CH_4 into the atmosphere. Those emissions have decreased by 30.6 MMT CO_2e (15.7 percent) since 1990 largely due to decreases in emissions from distribution, transmission, and storage.
- Landfills were the third largest anthropogenic source of CH_4 emissions in the United States (109.3 MMT CO_2e), accounting for 16.8 percent of total CH_4 emissions in 2020 and representing a decrease of 67.2 MMT CO_2e (38.1 percent) since 1990, with small year- to-year increases. This downward trend in emissions coincided with both increased landfill gas collection and control systems and a reduction of decomposable materials (i.e., paper and paperboard, food scraps, and yard trimmings) discarded in municipal solid waste (MSW) landfills over the time series.[11]

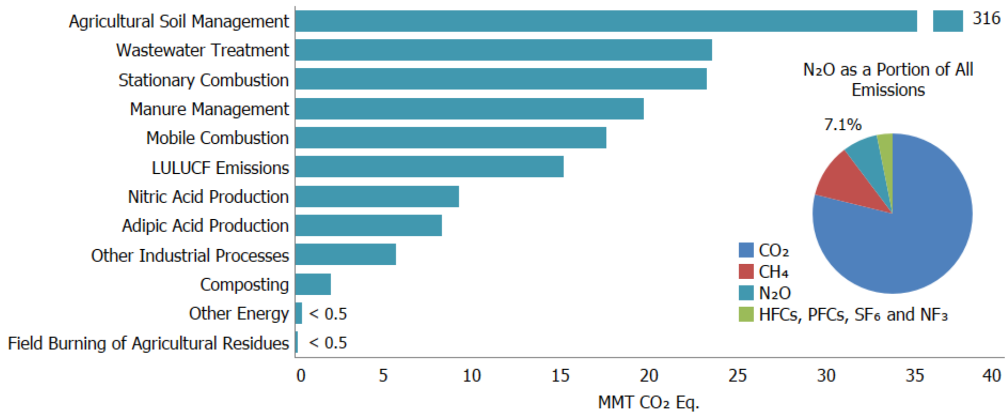
NITROUS OXIDE EMISSIONS

Nitrous oxide (N_2O) is produced by biological processes that occur in soil and water and by a variety of anthropogenic activities in the agricultural, energy, industrial, and waste management fields. While total N_2O emissions are much lower than CO_2 emissions, N_2O is nearly 300 times more powerful than CO_2 at trapping heat in the atmosphere over a 100-year time frame.[151] Since 1750, the global atmospheric concentration of N_2O has risen by approximately 23 percent.[152] The main anthropogenic activities producing N_2O in the United States are agricultural soil management, wastewater treatment, stationary fuel combustion, manure management, fuel combustion in motor vehicles, and nitric acid production (see Figure 3-9).

[151] NOAA/ESRL (2022c) Nitrous Oxide (N2O) hemispheric and global monthly means from the NOAA/ESRL Chromatograph for Atmospheric Trace Species data from baseline observatories (Barrow, Alaska; Summit, Greenland; Niwot Ridge, Colorado; Mauna Loa, Hawaii; American Samoa; South Pole). Available online at: https://www.esrl.noaa.gov/gmd/ccgg/trends_n2o/. 05 January 2022.
[152] IPPC (2021); NOAA/ESRL (2022c) Nitrous Oxide (N2O) hemispheric and global monthly means from the NOAA/ESRL Chromatograph for Atmospheric Trace Species data from baseline observatories (Barrow, Alaska; Summit, Greenland; Niwot Ridge, Colorado; Mauna Loa, Hawaii; American Samoa; South Pole). Available online at: https://www.esrl.noaa.gov/gmd/ccgg/trends_n2o/. 05 January 2022.

Figure 3-9: 2020 Sources of N_2O Emissions

In 2020, N_2O accounted for 7.1 percent of U.S. GHG emissions on a 100-year GWP-weighted basis. Agricultural Soil Management was the largest source, accounting for 316.2 MMT CO_2e (74.2 percent) of N_2O emissions.



Source: U.S. EPA[153]

Note: Nitrous oxide emissions from Petroleum Systems, Natural Gas Systems, and Incineration of Waste are included in Other Energy. Nitrous oxide emissions from Caprolactam, Glyoxal, and Glyoxylic Acid Production, Electronics Industry, and Product Uses are included in Other Industrial Processes. LULUCF emissions include N_2O emissions reported for Peatlands Remaining Peatlands, Forest Fires, Drained Organic Soils, Grassland Fires, Coastal Wetlands Remaining Coastal Wetlands, Forest Soils, and Settlement Soils. Refer to Table 3-5 for a breakout of LULUCF emissions by gas.

Significant trends for the largest sources of U.S. emissions of N_2O include the following:

- Agricultural soils were the largest anthropogenic source of N_2O emissions in 2020, accounting for 316.2 MMT CO_2e (74.2 percent of N_2O emissions) and 5.3 percent of total GHG emissions in the United States. These emissions increased by 0.2 MMT CO_2e (0.1 percent) from 1990 to 2020 but have fluctuated during that period due to annual variations in weather patterns, fertilizer use, and crop production.
- Wastewater treatment, both domestic and industrial, was the second largest anthropogenic source of N_2O emissions in 2020, accounting for 23.5 MMT CO_2e (5.5 percent of N_2O emissions) and 0.4 percent of total GHG emissions in the United States in 2020. Emissions from wastewater treatment increased by 6.9 MMT CO_2e (41.8 percent) since 1990 as a result of growing U.S. population and protein consumption. Nitrous oxide emissions from industrial wastewater treatment sources fluctuated throughout the time

[153] EPA (2022).

series with production changes associated with the treatment of wastewater from the pulp and paper manufacturing, meat and poultry processing, fruit and vegetable processing, starch-based ethanol production, petroleum refining, and brewery industries.

- Nitrous oxide emissions from manure management accounted for 19.7 MMT CO_2e (4.6 percent of N_2O emissions) and 0.3 percent of total GHG emissions in the United States in 2020. These emissions increased by 5.7 MMT CO_2e (41.2 percent) from 1990 to 2020. While the industry trend has been a shift toward liquid systems, driving down the emissions per unit of nitrogen excreted (dry manure handling systems have greater aerobic conditions that promote N_2O emissions), increases in specific animal populations have driven an increase in overall manure management N_2O emissions over the time series.
- Nitrous oxide emissions from mobile combustion decreased by 27.2 MMT CO_2e (61.0 percent) from 1990 to 2020, primarily as a result of national vehicle emissions standards and emission control technologies for on-road vehicles.

HFC, PFC, SF_6, AND NF_3 EMISSIONS

HFCs, PFCs, SF_6, and NF_3 are potent GHGs. In addition to having very high global warming potentials, SF_6 and PFCs have extremely long atmospheric lifetimes, resulting in their essentially irreversible accumulation in the atmosphere once emitted. Sulfur hexafluoride is the most potent greenhouse gas the IPCC has evaluated.[154]

Hydrofluorocarbons (HFCs) are synthetic chemicals that are used as alternatives to ozone depleting substances (ODS), which are being phased out under the Montreal Protocol on Substances that Deplete the Ozone Layer, and the Clean Air Act Amendments of 1990. The most common HFCs are, however, powerful GHGs. Currently, they have a small aggregate radiative forcing impact, but it is anticipated that without further controls their contribution to overall radiative forcing will increase.[155] Under the 2016 Kigali Amendment to the Montreal Protocol, there is now an international effort to phase down HFCs. The United States ratified the Kigali Amendment on October 31, 2022. The United States enacted the American Innovation and Manufacturing (AIM) Act on December 27, 2020, which gives EPA authority to phase down HFC production and consumption in line with the Kigali Amendment phase-down schedule through an allowance allocation program, promulgate certain regulations for purposes of maximizing reclamation and minimizing releases of HFCs and

[154] IPCC (2021).

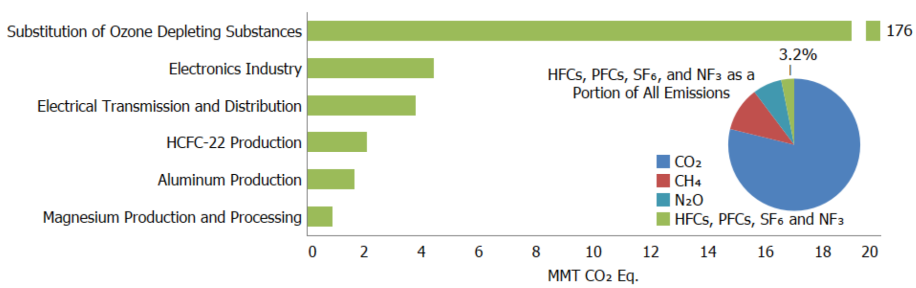
[155] https://www.epa.gov/climate-hfcs-reduction/aim-act.

their substitutes from equipment, and facilitate transitions to next-generation technologies through sector-based restrictions on HFCs.

Perfluorocarbons (PFCs) are emitted from the production of electronics and aluminum and also (in smaller quantities) from their use as alternatives to ODS. Sulfur hexafluoride (SF_6) is emitted from the production of electronics and magnesium, as well as from the manufacturing and use of electrical transmission and distribution equipment. NF_3 is also emitted from electronics production. One HFC, HFC-23, is emitted during production of hydrochlorofluorocarbon-22 (HCFC-22) and electronics (see Figure 3-10).

Figure 3-10: 2020 Sources of HFCs, PFCs, SF6, and NF_3 Emissions

In 2020, HFCs, PFCs, SF6, and NF_3 accounted for 3.2 percent of U.S. GHG emissions on a GWP-weighted basis. Emissions from the substitution of ozone-depleting substances (e.g., chlorofluorocarbons) have been consistently increasing, from 0.2 MMT CO_2e in 1990 to 176 MMT CO_2e in 2020.



Source: U.S. EPA[156]

Some significant trends for the largest sources of U.S. HFC, PFC, SF_6, and NF_3 emissions include the following:

- Hydrofluorocarbon and perfluorocarbon emissions resulting from their use as substitutes for ODS (e.g., chlorofluorocarbons [CFCs]) are the largest share of fluorinated emissions (93.2 percent) and have been consistently increasing, from small amounts in 1990 to 176 MMT CO_2e in 2020. This increase was in large part the result of efforts to phase out CFCs and other ODS in the United States.
- PFC, HFC, SF_6, and NF_3 emissions from the electronics industry have increased by 24.7 percent from 1990 to 2020, reflecting the competing influences of industrial growth and the adoption of emission reduction technologies. Within that time span, emissions

[156] EPA (2022).

peaked at 9.0 MMT CO_2e in 1999, the initial year of EPA's PFC Reduction/Climate Partnership for the Semiconductor Industry but have since declined to 4.4 MMT CO_2e in 2020 (a 50.9 percent decrease relative to 1999).

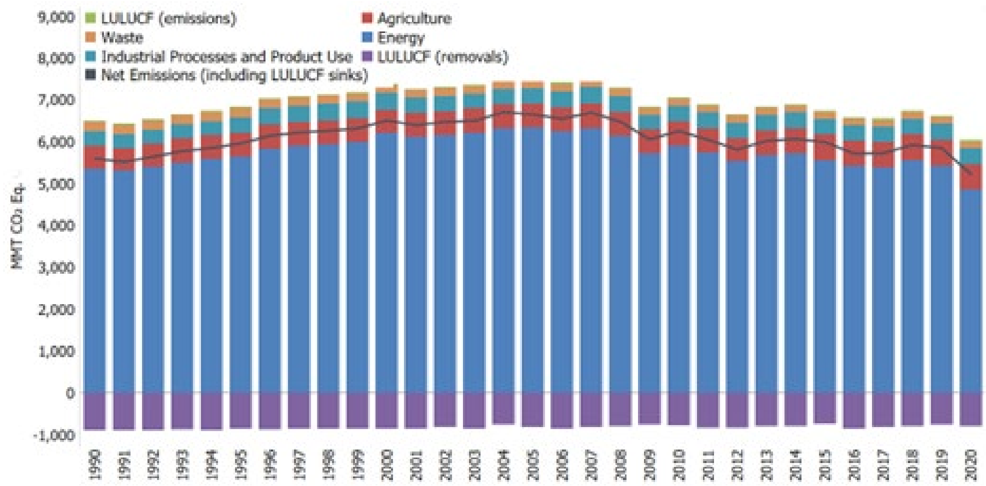
- Sulfur hexafluoride emissions from electric power transmission and distribution systems decreased by 83.6 percent (19.4 MMT CO_2e) from 1990 to 2020. There are two factors contributing to this decrease: (1) a sharp increase in the price of SF_6 during the 1990s; and (2) a growing awareness of the environmental impact of SF_6 emissions through programs such as EPA's SF_6 Emission Reduction Partnership for Electric Power Systems.
- Emissions from HCFC-22 production were 2.1MMT CO_2e in 2020, a 95.4 percent decrease from 1990 emissions. The decrease from 1990 emissions was caused primarily by a reduction in the HFC-23 emission rate (kilogram (kg) HFC-23 emitted/kg HCFC-22 produced). The emission rate was lowered by optimizing the production process and capturing much of the remaining HFC-23 for use or destruction.
- PFC emissions from aluminum production decreased by 92.2 percent (19.8 MMT CO_2e) from 1990 to 2020, due to both industry emission reduction efforts and lower domestic aluminum production.

OVERVIEW OF IPCC SECTOR EMISSIONS AND TRENDS

Figure 3-11 and Table 3-4 show aggregate emissions and sinks, using the sectors defined by the IPCC methodological guidance and UNFCCC reporting guidelines to promote comparability across countries. Over the thirty-one-year period of 1990 to 2020, total emissions from the Energy and Waste sectors decreased by 486.5 MMT CO_2e (9.1 percent) and 58.6 MMT CO_2e (27.4 percent), respectively. Emissions from the Industrial Processes and Product Use, and Agriculture sectors grew by 30.2 MMT CO_2e (8.7 percent) and 42.8 MMT CO_2e (7.8 percent), respectively. Over the same period, net carbon (C) sequestration in the LULUCF sector decreased by 79.8 MMT CO_2 (9 percent decrease in total net C sequestration), while emissions from the LULUCF sector (i.e., CH_4 and N_2O) increased by 21.8 MMT CO_2e (69.6 percent).

Figure 3-11: U.S. Greenhouse Gas Emissions and Sinks by IPCC Sector

Along with Table 3-4, this figure aggregates emissions and sinks by sectors, as defined by the Intergovernmental Panel on Climate Change, and presents net emissions including sinks.



Source: U.S. EPA

Table 3-4: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks by IPCC Sector (MMT CO_2e)

From 1990 to 2020, total emissions in the Energy and Waste sectors decreased while emissions in the Industrial Processes and Product Use and Agriculture sectors increased. Net sequestration in the Land Use, Land-Use Change and Forestry Sector decreased by 79.80 MMT CO_2 (9 percent).

IPCC Sector/Category	1990	2005	2016	2017	2018	2019	2020
Energy	5,341.1	6,319.8	5,413.1	5,372.7	5,539.5	5,409.8	4,854.7
Industrial Processes and Product Use	346.2	365.9	369.0	369.4	373.4	379.5	376.4
Agriculture	551.9	573.6	601.9	603.2	616.7	622.9	594.7
Waste	214.2	175.6	153.9	155.7	157.9	159.6	155.6
Total Gross Emissions[a] (Sources)	**6,453.5**	**7,434.8**	**6,537.9**	**6,501.0**	**6,687.5**	**6,571.7**	**5,981.4**
LULUCF Sector Net Total[b]	**(860.6)**	**(789.8)**	**(826.6)**	**(781.2)**	**(769.3)**	**(730.5)**	**(758.9)**
Net Emissions (Sources and Sinks)[c]	**5,592.8**	**6,645.0**	**5,711.2**	**5,719.8**	**5,918.2**	**5,841.2**	**5,222.4**

Notes: Total emissions presented without LULUCF sector. Net emissions presented with LULUCF. Totals may not sum due to independent rounding. Parentheses indicate negative values or sequestration.

a Total emissions without LULUCF.

b The LULUCF Sector Net Total is the sum of all LULUCF CH4 and N2O emissions to the atmosphere plus net carbon stock changes in units of MMT CO_2e.

c Net emissions with LULUCF.

ENERGY

The Energy sector contains emissions of all GHGs resulting from stationary and mobile energy activities including fuel combustion and fugitive fuel emissions, and the use of fossil fuels for non-energy purposes. As noted above, energy-related activities, primarily fossil fuel combustion, accounted for the vast majority of U.S. CO_2 emissions for the period of 1990 through 2020. Energy- related activities are also responsible for CH_4 and N_2O emissions (41.4 percent and 9.6 percent of total U.S. emissions of each gas, respectively). Overall, emission sources in the Energy sector account for a combined 81.2 percent of total U.S. GHG emissions in 2020.

INDUSTRIAL PROCESSES AND PRODUCT USE

The Industrial Processes and Product Use (IPPU) sector includes GHG emissions generated and emitted as the byproducts of non-energy-related industrial processes, which involve the chemical or physical transformation of raw materials and can release waste gases such as CO_2, CH_4, N_2O, and fluorinated gases (e.g., HFC-23). These processes include iron and steel production and metallurgical coke production, cement production, petrochemical production, ammonia production, lime production, other process uses of carbonates (e.g., flue gas desulfurization and soda ash consumption not associated with glass manufacturing), nitric acid production, adipic acid production, urea consumption for non-agricultural purposes, aluminum production, HCFC-22 production, glass production, soda ash production, ferroalloy production, titanium dioxide production, caprolactam production, zinc production, phosphoric acid production, lead production, and silicon carbide production and consumption. Most of these industries also emit CO_2 from fossil fuel combustion which, in line with IPCC sectoral definitions, is included in the Energy Sector.

This sector also includes the release of HFCs, PFCs, SF_6, and NF_3 and other fluorinated compounds used in industrial manufacturing processes and by end-consumers (e.g., residential and mobile air conditioning). These industries include electronics industry, electric power transmission and distribution, and magnesium metal production and processing. In addition, N_2O is used in and emitted by the electronics industry and by anesthetic and aerosol applications, and CO_2 is consumed and emitted through various end-use applications. In 2020, emissions resulting from use of ODS substitutes (e.g., chlorofluorocarbons (CFCs) by end-consumers was the largest source of IPPU emissions and accounted for 176 MMT CO_2e (46.8 percent) of total IPPU emissions.

IPPU activities are responsible for 3.5, 0.1, and 5.5 percent of total U.S. CO_2, CH_4, and N_2O emissions respectively, as well as for all U.S. emissions of fluorinated gases such as HFCs, PFCs, SF_6 and NF_3. Overall, emission sources in the IPPU sector accounted for 6.3 percent of U.S. GHG gas emissions in 2020.

AGRICULTURE

The Agriculture sector includes anthropogenic emissions from agricultural activities (except fuel combustion, which per IPCC guidance is addressed in the Energy sector, and some agricultural CO_2, CH_4, and N_2O fluxes, which per IPCC guidance are addressed in the Land Use, Land-Use Change, and Forestry sector). Agricultural activities contribute directly to emissions of GHGs through a variety of processes, including the following source categories: agricultural soil management, enteric fermentation in domestic livestock, livestock manure management, rice cultivation, urea fertilization, liming, and field burning of agricultural residues.

In 2020, agricultural activities were responsible for emissions of 549.7 MMT CO_2e, or 9.9 percent of total U.S. GHG emissions. Methane, N_2O, and CO_2 are GHGs emitted by agricultural activities. Methane emissions from enteric fermentation and manure management represented approximately 26.9 percent and 9.2 percent of total CH_4 emissions from anthropogenic activities, respectively, in 2020. Agricultural soil management activities, such as application of synthetic and organic fertilizers, deposition of livestock manure, and retention of residues from N-fixing legumes and non-legume crops and forages, were the largest contributors to U.S. N_2O emissions in 2020, accounting for 74.2 percent of total N_2O emissions. Carbon dioxide emissions from the application of crushed limestone and dolomite (i.e., soil liming) and urea fertilization represented 0.2 percent of total CO_2 emissions from anthropogenic activities.

LAND USE, LAND-USE CHANGE, AND FORESTRY

The LULUCF sector contains emissions and removals of CO_2 and emissions of CH_4 and N_2O from managed lands in the United States. Consistent with the *2006 IPCC Guidelines*, emissions and removals from managed lands are considered to be anthropogenic, while emissions and removals from unmanaged lands are considered to be natural. The share of managed land in the United States is approximately 95 percent of total land included in the national Inventory. More information on the definition of managed land used is provided in Chapter 6 of the national Inventory.

Overall, the Inventory results show that U.S. managed land is a net sink for CO_2 (i.e., provides net carbon sequestration). The primary drivers of fluxes on managed lands include forest management practices, tree planting in urban areas, the management of agricultural soils, and land use change. The main drivers for forest carbon sequestration include forest growth and increasing forest area (i.e., afforestation), as well as a net accumulation of carbon stocks in harvested wood pools. The net sequestration in *Settlements Remaining Settlements,* which occurs predominantly from urban forests (i.e., Settlement Trees) and landfilled yard trimmings and food scraps, is a result of net tree growth and increased urban forest area, as well as long-term accumulation of yard trimmings and food scraps carbon in landfills.

The LULUCF sector in 2020 resulted in a net increase in carbon stocks (i.e., net CO_2 removals) of 812.2 MMT CO_2e (Table 3-5). This represents an offset of 13.6 percent of total (i.e., gross) U.S. GHG emissions in 2020.[157] Emissions of CH_4 and N_2O from LULUCF activities in 2020 were 53.2 MMT CO_2e, representing 0.9 percent of total GHG emissions. Between 1990 and 2020, total carbon sequestration in the LULUCF sector decreased by 9 percent, primarily due to a decrease in the rate of net carbon accumulation in forests and *Cropland Remaining Cropland,* as well as an increase in CO_2 emissions from *Land Converted to Settlements*. The overall net flux from LULUCF (i.e., net sum of all CH_4 and N_2O emissions to the atmosphere plus net carbon stock changes in units of MMT CO_2e) resulted in a removal of 758.9 MMT CO_2e in 2020.

Flooded lands were the largest source of CH_4 emissions from the LULUCF sector in 2020, totaling 19.9 MMT CO_2e. Forest fires were the second largest source and resulted in CH_4 emissions of 13.6 MMT CO_2e, followed by Coastal Wetlands Remaining Coastal Wetlands with CH_4 emissions of 3.8 MMT CO_2e.

Forest fires were also the largest source of N_2O emissions from the LULUCF sector in 2020, totaling 11.7 MMT CO_2e. Nitrous oxide emissions from fertilizer application to settlement soils in 2020 totaled 2.5 MMT CO_2e. Carbon dioxide removals from C stock changes are presented in Table 3-5 along with CH_4 and N_2O emissions for LULUCF source categories.

Table 3-5: U.S. Greenhouse Gas Emissions and Removals (Net Flux) from Land Use, Land-Use Change, and Forestry (MMT CO_2e)

Land-Use Category	1990		2005		2016	2017	2018	2019	2020
Forest Land Remaining Forest Land[a]	(769.7)		(674.0)		(717.3)	(670.1)	(664.6)	(631.8)	(642.2)
Land Converted to Forest Land[b]	(98.6)		(99.1)		(99.5)	(99.5)	(99.5)	(99.5)	(99.5)
Cropland Remaining	(23.2)		(29.0)		(22.7)	(22.3)	(16.6)	(14.5)	(23.3)

[157] EPA (2021a) Acid Rain Program Dataset 1996-2020. Office of Air and Radiation, Office of Atmospheric Programs, U.S. Environmental Protection Agency, Washington, D.C.

Cropland									
Land Converted to Cropland[c]	51.8		52.0		54.1	54.3	54.0	53.9	54.4
Grassland Remaining Grassland[d]	7.1		9.4		8.6	9.9	10.3	13.1	5.1
Land Converted to Grassland[c]	(3.1)		(37.0)		(22.6)	(22.7)	(22.4)	(21.5)	(24.1)
Wetlands Remaining Wetlands[e]	14.7		17.2		15.8	15.9	15.9	15.9	15.8
Land Converted to Wetlands[e]	7.1		1.2		0.6	0.6	0.6	0.6	0.6
Settlements Remaining Settlements[f]	(107.6)		(113.5)		(121.5)	(125.3)	(124.9)	(124.5)	(123.7)
Land Converted to Settlements[c]	60.8		82.8		77.8	77.9	78.0	77.9	77.9
LULUCF Carbon Stock Change/CO_2[g]	**(892.0)**		**(831.2)**		**(862.0)**	**(826.7)**	**(809.0)**	**(760.8)**	**(812.2)**
LULUCF CH_4 and N_2O Emissions[h]	**31.4**		**41.3**		**35.4**	**45.5**	**39.8**	**30.3**	**53.2**
CH_4	27.2		30.9		28.3	34.0	30.7	25.5	38.1
N_2O	4.2		10.5		7.1	11.5	9.1	4.8	15.2
LULUCF Sector Net Total[i]	**(860.6)**		**(789.8)**		**(826.6)**	**(781.2)**	**(769.3)**	**(730.5)**	**(758.9)**

Notes: Totals may not sum due to independent rounding. Parentheses indicate net sequestration.

[a] Includes the net changes to carbon stocks stored in all forest ecosystem pools and harvested wood products, emissions from fires on both *Forest Land Remaining Forest Land* and *Land Converted to Forest Land,* emissions from N fertilizer additions on both *Forest Land Remaining Forest Land* and *Land Converted to Forest Land*, and CH_4 and N_2O emissions from drained organic soils on both *Forest Land Remaining Forest Land* and *Land Converted to Forest Land.*

[b] Includes the net changes to carbon stocks stored in all forest ecosystem pools.

[c] Includes changes in mineral and organic soil carbon stocks for all land use conversions to cropland, grassland, and settlements, respectively. Also includes aboveground/belowground biomass, dead wood, and litter carbon stock changes for conversion of forest land to cropland, grassland, and settlements, respectively.

[d] Estimates include CH_4 and N_2O emissions from fires on both Grassland Remaining Grassland and *Land Converted to Grassland.*

[e] Estimates include CH_4 emissions from Flooded Land Remaining Flooded Land and Land Converted to Flooded Land.

[f] Estimates include N_2O emissions from N fertilizer additions on both *Settlements Remaining Settlements* and Land Converted to Settlements because it is not possible to separate the activity data at this time.

[g] LULUCF Carbon Stock Change includes any C stock gains and losses from all land use and land use conversion categories.

[h] LULUCF emissions include the CH_4 and N_2O emissions reported for Peatlands Remaining Peatlands, Forest Fires, Drained Organic Soils, Grassland Fires, and *Coastal Wetlands Remaining Coastal Wetlands*; CH_4 emissions from *Land Converted to Coastal Wetlands*, Flooded Land Remaining Flooded Land, and Land Converted to Flooded Land; and N_2O emissions from Forest Soils and Settlement Soils.

[i] The LULUCF Sector Net Total is the net sum of all LULUCF CH_4 and N_2O emissions to the atmosphere plus net carbon stock changes in units of MMT CO_2e.

WASTE

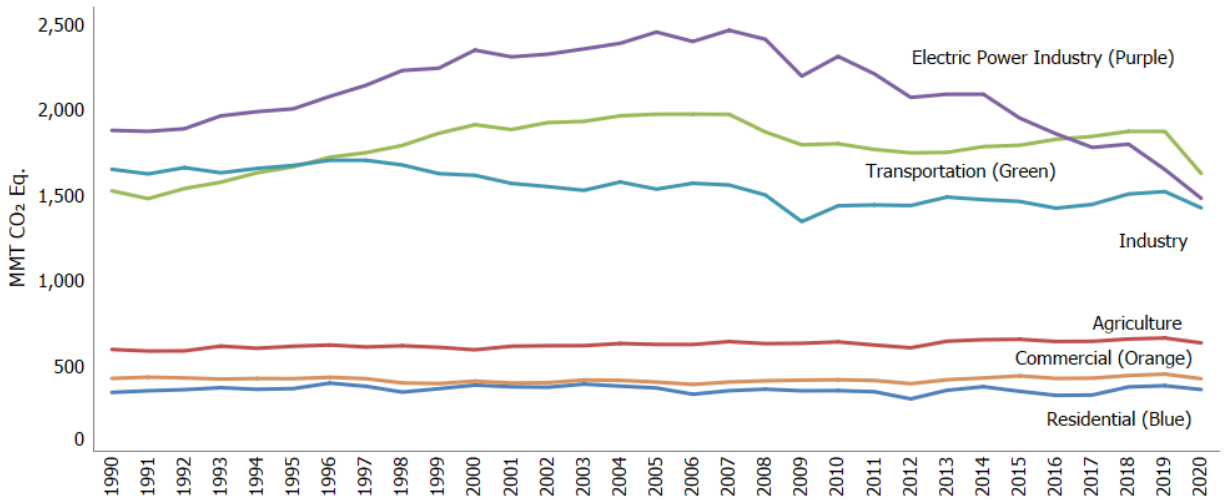
The Waste sector includes emissions from waste management activities (except incineration of waste, which is addressed in the Energy sector). Landfills were the largest source of anthropogenic GHG emissions from waste management activities, generating 109.3 MMT CO_2e and accounting for 70.3 percent of total GHG emissions from waste management activities and 16.8 percent of total U.S. CH_4 emissions. Additionally, wastewater treatment generated emissions of 41.8 MMT CO_2e and accounted for 26.9 percent of total Waste sector GHG emissions, 2.8 percent of U.S. CH_4 emissions, and 5.5 percent of U.S. N_2O emissions in 2020. Emissions of CH_4 and N_2O from composting are also accounted for in this sector, generating emissions of 2.3 MMT CO_2e and 2.0 MMT CO_2e, respectively. Anaerobic digestion at biogas facilities generated CH_4 emissions of 0.2 MMT CO_2e, accounting for 0.1 percent of emissions from the waste sector. Overall, emission sources accounted for in the Waste sector generated 155.6 MMT CO_2e, or 2.6 percent of total U.S. GHG emissions in 2020.

EMISSIONS BY ECONOMIC SECTOR

Throughout the Inventory of U.S. Greenhouse Gas Emissions and Sinks report, emission estimates are grouped into five sectors defined by the IPCC: Energy; IPPU; Agriculture; LULUCF; and Waste. It is also useful to characterize emissions according to commonly used economic sector categories: residential, commercial, industry, transportation, electric power, and agriculture. Emissions from U.S. Territories are reported as their own end-use sector due to a lack of specific consumption data for the individual end-use sectors within U.S. Territories. For more information on trends in the LULUCF sector, see discussion above on LULUCF sector emission and removal trends.

Figure 3-12: 2020 U.S. Greenhouse Gas Emissions Allocated to Economic Sectors

In 2020, transportation accounted for the largest portion (27.2 percent) of U.S. GHG emissions, electricity generation activities accounted for 24.8 percent, and industry accounted for 23.8 percent. In contrast to transportation and industry, emissions from electricity generation emissions have generally declined over the past decade.



Source: U.S.EPA[158]

Note: Emissions and removals from Land Use, Land-Use Change, and Forestry are excluded from figure above. Excludes U.S. Territories.

Table 3-6: U.S. Greenhouse Gas Emissions Allocated to Economic Sectors (MMT CO_2e)

U.S. GHG emissions from major economic sectors decreased for the Electric Power. The long-term decline in these emissions has been due to structural changes in the U.S. economy, fuel switching, and energy efficiency improvements.

Economic Sectors	1990	2005	2016	2017	2018	2019	2020
Transportation	1,526.4	1,975.5	1,828.0	1,845.2	1,874.7	1,874.3	1,627.6
Electric Power Industry	1,880.5	2,456.7	1,860.5	1,780.6	1,799.8	1,651.0	1,482.2
Industry	1,652.4	1,536.2	1,424.4	1,446.7	1,507.6	1,521.7	1,426.2
Agriculture	596.8	626.3	643.4	644.4	657.9	663.9	635.1

[158] EPA (2022).

Commercial	427.1	405.4	426.9	428.5	444.2	452.1	425.3
Residential	345.1	371.0	327.8	329.9	377.4	384.2	362.0
U.S. Territories	25.1	63.7	26.8	25.8	25.8	24.6	23.0
Total Gross Emissions (Sources)	**6,453.5**	**7,434.8**	**6,537.9**	**6,501.0**	**6,687.5**	**6,571.7**	**5,981.4**
LULUCF Sector Net Total[a]	**(860.6)**	**(789.8)**	**(826.6)**	**(781.2)**	**(769.3)**	**(730.5)**	**(758.9)**
Net Emissions (Sources and Sinks)	**5,592.8**	**6,645.0**	**5,711.2**	**5,719.8**	**5,918.2**	**5,841.2**	**5,222.4**

Notes: Total emissions presented without LULUCF. Total net emissions presented with LULUCF. Totals may not sum due to independent rounding. Parentheses indicate negative values or sequestration.

[a] The LULUCF Sector Net Total is the net sum of all LULUCF CH_4 and N_2O emissions to the atmosphere plus net carbon stock changes.

Using this categorization, emissions from transportation activities, in aggregate, accounted for the largest portion (27.2 percent) of total U.S. GHG emissions in 2020. Electric power accounted for the second largest portion (24.8 percent) of U.S. GHG emissions in 2020, while emissions from industry accounted for the third largest portion (23.8 percent). Emissions from industry have in general declined over the past decade due to a number of factors, including structural changes in the U.S. economy (i.e., shifts from a manufacturing-based to a service-based economy), fuel switching, and energy efficiency improvements.

The remaining 24.2 percent of U.S. GHG emissions were contributed by, in order of magnitude, the agriculture, commercial, and residential sectors, plus emissions from U.S. Territories. Activities related to agriculture accounted for 10.6 percent of U.S. emissions; unlike other economic sectors, agricultural sector emissions, as previously noted, were dominated by N_2O emissions from agricultural soil management and CH_4 emissions from enteric fermentation. An increasing amount of carbon is stored in agricultural soils each year, but per reporting guidelines this CO_2 sequestration is assigned to the LULUCF sector rather than the agriculture economic sector and is reflected in the LULUCF sector Net Total. The commercial and residential sectors accounted for 7.1 percent and 6.1 percent of emissions, respectively, and U.S. Territories accounted for 0.4 percent of emissions; emissions from these sectors primarily consisted of CO_2 emissions from fossil fuel combustion. As described above, carbon dioxide was also emitted and sequestered by a variety of activities related to forest management practices, tree planting in urban areas, the management of agricultural soils, landfilling of yard trimmings, and changes in carbon stocks in coastal wetlands.

Electricity is ultimately used in the economic sectors described above. Table 3-7 presents GHG emissions from economic sectors with emissions related to electric power distributed into end-use categories (i.e., emissions from electric power are allocated to the economic sectors in which the electricity is used). To distribute electricity emissions among end-use sectors, emissions from the source categories assigned to electric power were allocated to the residential, commercial, industry, transportation, and agriculture economic sectors according to retail sales of electricity for each end-use sector.[159] These source categories include CO_2 from fossil fuel combustion and the use of limestone and dolomite for flue gas desulfurization, CO_2 and N_2O from incineration of waste, CH_4 and N_2O from stationary sources, and SF_6 from electrical transmission and distribution systems.

When emissions from electricity use are distributed among these end-use sectors, industrial activities and transportation account for the largest shares of U.S. GHG emissions (30.3 percent and 27.3 percent, respectively) in 2020. The commercial and residential sectors contributed the next largest shares of total U.S. GHG emissions in 2020 (15.4 and 15.4 percent, respectively). Emissions from the commercial and residential sectors increase substantially when emissions from electricity use are included, due to their relatively large share of electricity use for energy (e.g., lighting, cooling, appliances).

Table 3-7: U.S. Greenhouse Gas Emissions by Economic Sector with Electricity-Related Emissions Distributed (MMT CO_2e)

In 2020, after distributing emissions from electricity generation to end-use sectors, industry accounted for 30.37 percent of total U.S. GHG emissions, and the transportation sector accounted for 27.3 percent.

Economic Sectors	1990		2005		2016	2017	2018	2019	2020
Industry	2,326.5		2,251.6		1,917.5	1,926.4	1,983.1	1,964.7	1,813.7
Transportation	1,529.6		1,980.3		1,832.4	1,849.6	1,879.5	1,879.1	1,632.4
Residential	957.6		1,247.2		999.9	964.3	1,036.7	984.1	923.1
Commercial	982.7		1,227.4		1,078.6	1,051.7	1,065.3	1,020.1	919.7
Agriculture	631.9		664.6		682.6	683.2	697.1	699.1	669.5
U.S. Territories	25.1		63.7		26.8	25.8	25.8	24.6	23.0
Total Gross Emissions (Sources)	**6,453.5**		**7,434.8**		**6,537.9**	**6,501.0**	**6,687.5**	**6,571.7**	**5,981.4**

[159] EIA (2022); U.S.D.A./NASS (2020).

LULUCF Sector Net Total[a]	**(860.6)**		**(789.8)**		**(826.6)**	**(781.2)**	**(769.3)**	**(730.5)**	**(758.9)**
Net Emissions (Sources and Sinks)	**5,592.8**		**6,645.0**		**5,711.2**	**5,719.8**	**5,918.2**	**5,841.2**	**5,222.4**

Notes: Emissions from electric power are allocated based on aggregate electricity use in each end-use sector. Totals may not sum due to independent rounding. Parentheses indicate negative values or sequestration.

a. The LULUCF Sector Net Total is the net sum of all LULUCF CH4 and N2O emissions to the atmosphere plus net carbon stock changes.

Box 3-2: Trends in U.S. Greenhouse Gas Emissions and Other Key Indices

Total GHG emissions can be compared to other economic and social indices to highlight changes over time. These comparisons include: (1) emissions per unit of aggregate energy use, because energy-related activities are the largest sources of emissions; (2) emissions per unit of fossil fuel consumption, because almost all energy-related emissions involve the combustion of fossil fuels; (3) emissions per unit of total gross domestic product as a measure of national economic activity; and (4) emissions per capita.

Table 3-8 provides data on various statistics related to U.S. GHG emissions normalized to 1990 as a baseline year. These values represent the relative change in each statistic since 1990. GHG emissions in the United States have decreased at an average annual rate of 0.2 percent since 1990, although changes from year to year have been significantly larger. This growth rate is slightly slower than that for total energy use and fossil fuel consumption, overall gross domestic product (GDP), and national population (see Figure 3-13). The direction of these trends started to change after 2005, when GHG emissions, total energy use and fossil fuel consumption began to peak. GHG emissions in the United States have decreased at an average annual rate of 1.4 percent since 2005. Fossil fuel consumption has also decreased at a slower rate than emissions since 2005, while total energy use, GDP, and national population continued to increase.

Source: U.S EPA[160]

[160] EIA (2022).

Table 3-8: Recent Trends in U.S. Greenhouse Gas Emissions and Other Key Indices

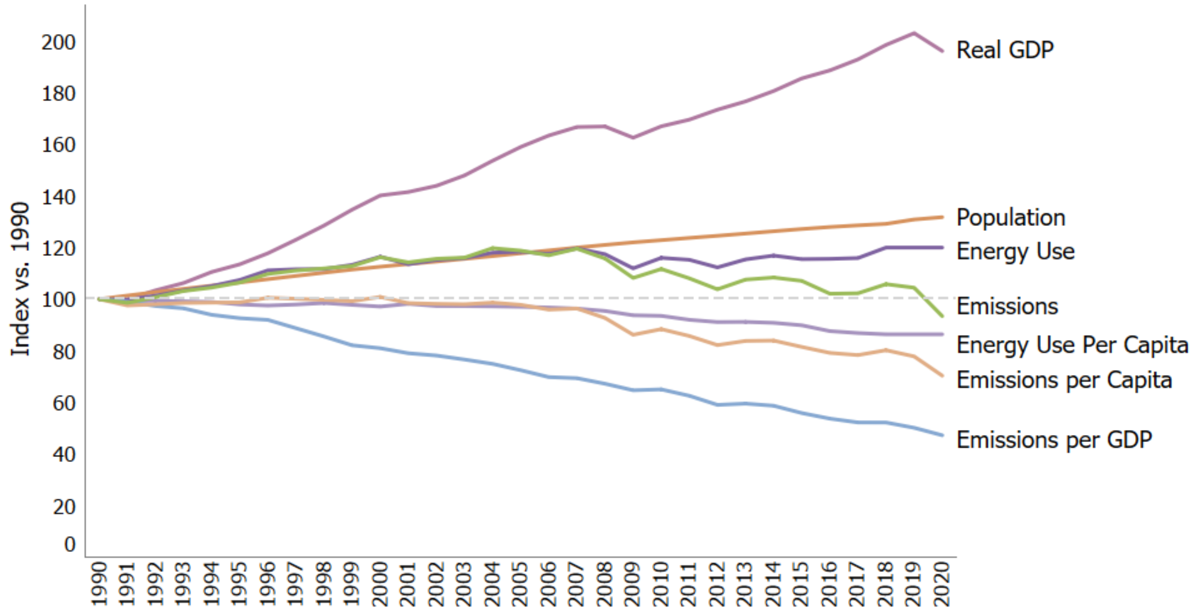
(Index 1990 = 100)

Variable	1990		2005		2016	2017	2018	2019	2020	Avg. Annual Growth Rate Since 1990[a]	Avg. Annual Growth Rate Since 2005[a]
Greenhouse Gas Emissions[b]	100		115		101	101	104	102	93	-0.2%	-1.4%
Energy Use[c]	100		119		116	116	120	119	109	0.3%	-0.5%
GDP[d]	100		159		189	193	199	203	196	2.3%	1.4%
Population[e]	100		118		128	129	129	131	132	0.9%	0.8%

a Average annual growth rate.
b GWP-weighted values.
c Energy content-weighted values.[161]
d GDP in chained 2009 dollars.[162]
e U.S. Census Bureau.[163]

[161] EIA (2022).
[162] BEA (2022) 2021 Comprehensive Revision of the National Income and Product Accounts: Current-dollar and "real" GDP, 1929–2021. Bureau of Economic Analysis (BEA), U.S. Department of Commerce, Washington, D.C. Available online at: http://www.bea.gov/national/index.htm#gdp.
[163] U.S. Census Bureau (2021) U.S. Census Bureau International Database (IDB). Available online at: https:// www.census.gov/programs-surveys/international-programs.html\.

Figure 3-13: U.S. Greenhouse Gas Emissions Per Capita and Per Dollar of Gross Domestic Product (GDP)



Source: U.S. EPA,[164] U.S. BEA, U.S. Census Bureau[165]

PRECURSOR GREENHOUSE GAS EMISSIONS

The reporting requirements of the UNFCCC request that information be provided on precursor greenhouse gases, which include carbon monoxide (CO), nitrogen oxides (NO_x), non-CH_4 volatile organic compounds (NMVOCs), and sulfur dioxide (SO_2). These gases are not direct greenhouse gases, but can indirectly impact Earth's radiative balance, by altering the concentrations of other greenhouse gases (e.g., tropospheric ozone) and atmospheric aerosol (e.g., particulate sulfate). Carbon monoxide is produced when carbon-containing fuels are combusted incompletely in energy, transportation, and industrial processes, and is also emitted from practices such as agricultural burning and waste disposal and treatment. Anthropogenic sources of NO_x (i.e., NO and NO_2) are primarily fossil fuel combustion (for energy, transportation, industrial process) and agricultural burning. Anthropogenic sources of NMVOCs, which include hundreds of organic compounds that participate in atmospheric chemical reactions (i.e., propane, butane, xylene, toluene, ethane, and many others)—are emitted primarily from transportation, industrial processes, oil and natural gas production, waste practices, agricultural burning, and non-industrial consumption of organic solvents. In

[164] EPA (2022)

[165] BEA (2022); U.S. Census Bureau (2021).

the United States, SO_2 is primarily emitted from coal combustion for electric power generation and the metals industry. Other indirect impacts include the formation of sulfate and nitrate aerosol from emissions of NOx and SO_2, both of which have a net negative impact on radiative forcing.

One important indirect climate change effect of NMVOCs and NOx is their role as precursors for tropospheric ozone formation. They can also alter atmospheric lifetimes of other greenhouse gases. Additional compound such as NO_x, NMVOCs, and CO also have indirect effects on Earth's radiative balance and climate change. For example, chemical reactions involving these compounds will directly impact the atmospheric concentrations of CH_4, CO_2, and ozone (O_3).

Since 1970, the United States has published triennial estimates of emissions of CO, NOx, NMVOCs, and SO_2 (EPA 2021b),[166] which are regulated under the Clean Air Act. Precursor emission estimates for this report for 1990 through 2020 were obtained from data published on EPA's National Emissions Inventory (NEI) Air Pollutants Emissions Trends Data website.[167] For Table 3-9, NEI-reported emissions of CO, NOx, SO_2, and NMVOCs are recategorized from NEI Tier 1/Tier 2 source categories to those more closely aligned with IPCC sectors as described in Annex 6 of the national Inventory report. Table 3-9 shows that fuel combustion accounts for the majority of emissions of these indirect greenhouse gases. Industrial processes— such as the manufacture of chemical and allied products, metals processing, and industrial uses of solvents—are also significant sources of CO, NOx, and NMVOCs. As Table 3-9 shows, emissions of each of these precursor greenhouse gas has decreased significantly since 1990 as a result of the implementation of Clean Air Act programs, as well as technological improvements.

[166] EPA (2021b).
[167] *Ibid*.

Table 3-9 Emissions of NOx, CO, NMVOCs, and SO_2 (kt)

Gas/Activity	1990	2005	2016	2017	2018	2019	2020
NO_x	**21,764**	**17,333**	**8,792**	**8,483**	**8,008**	**7,425**	**7,128**
Energy	21,106	16,602	8,268	7,883	7,456	6,962	6,471
IPPU	592	572	402	397	397	397	397
LULUCF	52	142	107	188	139	50	244
Agriculture	13	15	14	14	14	14	14
Waste	+	2	1	1	1	1	1
CO	**132,759**	**74,553**	**39,981**	**43,688**	**39,531**	**34,170**	**43,799**
Energy	125,640	64,985	34,461	33,401	32,392	31,384	30,376
LULUCF	2,673	7,642	4,099	8,936	5,789	1,436	12,074
IPPU	4,129	1,557	1,075	1,007	1,007	1,007	1,007
Agriculture	315	363	340	339	338	337	336
Waste	1	7	6	5	5	5	5
NMVOCs	**20,923**	**13,309**	**9,855**	**9,483**	**9,310**	**9,136**	**8,963**
Energy	12,612	7,345	6,022	5,664	5,491	5,318	5,145
IPPU	7,638	5,849	3,776	3,767	3,767	3,767	3,767
Waste	673	114	57	52	52	52	52
Agriculture	NA	NA	NA	NA	NA	NA	NA
LULUCF	NA	NA	NA	NA	NA	NA	NA
SO_2	**20,935**	**13,196**	**2,906**	**2,303**	**2,211**	**1,943**	**1,780**
Energy	19,628	12,364	2,439	1,794	1,701	1,433	1,270
IPPU	1,307	831	466	509	509	509	509
Waste	+	1	1	1	1	1	1
Agriculture	NA	NA	NA	NA	NA	NA	NA
LULUCF	NA	NA	NA	NA	NA	NA	NA

Note: Totals may not sum due to independent rounding.
+ Does not exceed 0.5 kt.
NA (Not Available)

Source: (EPA 2021b) EPA 2021[168] except for estimates from Forest Fires, Grassland Fires, and Field Burning of Agricultural Residues. Emission categories from EPA (2021b) are aggregated into IPCC sector.

INSTITUTIONAL ARRANGEMENTS

Federal and state government authorities, research and academic institutions, industry associations, and private consultants are involved in supplying data to, preparing portions and/or reviewing the national GHG inventory. The U.S. Department of Agriculture's Forest Service and Agricultural Research Service, National Oceanic and Atmospheric Administration (NOAA), Federal Aviation Administration (FAA), and Department of Defense (DOD) contribute to the collection of data and also support compilation of the estimates and supporting analysis. Other U.S. agencies provide official data for use in the Inventory. For example, the U.S. Department of Energy's Energy Information Administration provides national fuel

[168] *Ibid.*

consumption data, and DOD provides data on military fuel consumption and use of bunker fuels. The institutional arrangements for preparing the Inventory are explained in more detail in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990–2020*, in Section 1.2 on National Inventory Arrangements.[169] The institutional arrangements for development of the Inventory have not changed significantly[170] since the *Seventh National Communication, and 3rd and 4th Biennial Report of the United States of America.*[171] The U.S. Environmental Protection Agency (EPA), in cooperation with other U.S. government agencies, prepares the annual greenhouse gas inventory. Within EPA, the Office of Atmospheric Programs (OAP) is the lead office responsible for the emission calculations provided in the Inventory, as well as the completion of the National Inventory Report and the preparation of the Common Reporting Format tables. EPA's Office of Transportation and Air Quality is also involved in calculating transportation and mobile combustion emissions, and EPA's Office of Research and Development compiles emissions and removals from management of flooded lands for the inventory. While the U.S. Department of State is the UNFCCC focal point, EPA's OAP serves as the Inventory focal point for review, covering technical questions and comments on the U.S. Inventory.

[169] EPA (2022).

[170] The main change is the addition of arrangements to compile estimates of greenhouse gas emissions and removals from management of flooded lands.

[171] U.S. DOS (2021) A Review of Sustained Climate Action through 2020: Available online at: https://unfccc.int/sites/default/files/resource/United percent20States percent207th percent20NC percent203rd percent204th percent20BR percent20final.pdf.

U.S. CLIMATE AMBITION REPORT

Chapter 4.

POLICIES AND MEASURES

Chapter 4. POLICIES AND MEASURES

INTRODUCTION

As described in the previous U.S. National Communication, *A Review of Sustained Climate Action Through 2020*, a range of U.S. policies have helped continually reduce greenhouse gas emissions over the past decade, even as the economy grew.[172] In 2021 and 2022, the United States built on this foundation with a historic wave of new executive and legislative actions at the federal level, as well as continued progress across states, territories, Tribal Nations, local governments, the private sector, and civil society.

In January 2021, President Biden issued an Executive Order on Tackling the Climate Crisis at Home and Abroad, placing climate considerations at the forefront of U.S. foreign policy and mobilizing the full capacity of the federal government to reduce domestic emissions while creating good-paying jobs, delivering environmental justice, and protecting public health.[173] This Executive Order created new structures and initiatives to achieve these goals equitably, including:

- The country's first-ever **National Climate Task Force**, bringing together federal agency leaders to deploy a whole-of-government approach to combat the climate crisis and achieve net-zero U.S. emissions no later than 2050.[174]
- The **Justice40 Initiative**, to deliver 40 percent of the overall benefits of federal climate, clean energy, and related investments to disadvantaged communities.[175]
- The **Interagency Working Group on Coal and Power Plant Communities and Economic Revitalization**, to ensure that communities that have powered the country for generations benefit from job creation, pollution cleanup, and other opportunities provided by the growing clean energy economy.[176]

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[172] The White House. https://www.whitehouse.gov/wp-content/uploads/2021/10/ClimateNationalCommunication.pdf.
[173] The White House. https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/27/executive-order-on-tackling-the-climate-crisis-at-home-and-abroad/.
[174] The White House. https://www.whitehouse.gov/climate/.
[175] The White House. https://www.whitehouse.gov/environmentaljustice/justice40/.
[176] Interagency Working Group on Coal and Power Plant Communities and Economic Revitalization. https://energycommunities.gov/.

In April 2021, President Biden announced the new target of reducing U.S. greenhouse gas emissions 50-52 percent below 2005 levels in 2030.[177] In setting this target, the Biden-Harris Administration emphasized that climate change poses an existential threat—and that addressing the climate crisis provides opportunities to create millions of good-paying jobs, reduce energy costs and protect families from fossil fuel price spikes, and deliver clean air and clean water to communities.

Over the last two years, the Administration has taken new executive actions to reduce greenhouse gas emissions across sectors, including steps to:

- **Fast-track clean energy projects**, by jumpstarting the American offshore wind industry,[178] launching a Permitting Action Plan,[179] advancing renewables on public lands,[180] accelerating buildout of transmission lines,[181] and supporting community solar[182] and other distributed energy resources.[183]
- **Accelerate electric transportation**, by setting a national goal of 50 percent zero-emission vehicle sales in 2030,[184] finalizing the strongest-ever greenhouse gas

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[177] The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2021/04/22/fact-sheet-president-biden-sets-2030-greenhouse-gas-pollution-reduction-target-aimed-at-creating-good-paying-union-jobs-and-securing-u-s-leadership-on-clean-energy-technologies/.
[178] The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2021/03/29/fact-sheet-biden-administration-jumpstarts-offshore-wind-energy-projects-to-create-jobs/.
[179] The White House. https://www.whitehouse.gov/wp-content/uploads/2022/05/Biden-Harris-Permitting-Action-Plan.pdf.
[180] The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2022/01/12/fact-sheet-biden-harris-administration-races-to-deploy-clean-energy-that-creates-jobs-and-lowers-costs/.
[181] The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2022/11/18/fact-sheet-the-biden-harris-administration-advances-transmission-buildout-to-deliver-affordable-clean-electricity/.
[182] U.S. Department of Energy. https://www.energy.gov/communitysolar/listings/news.
[183] The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2022/04/20/fact-sheet-biden-harris-administration-creates-cost-saving-clean-energy-opportunities-to-combat-climate-crisis/.
[184] The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2021/08/05/fact-sheet-president-biden-announces-steps-to-drive-american-leadership-forward-on-clean-cars-and-trucks/.

(GHG) emissions standards for passenger vehicles,[185] and strengthening battery supply chains.[186]

- **Tackle super-pollutants** through the U.S. Methane Emissions Reduction Action Plan covering the oil and gas industry, agriculture, buildings and more,[187] and via ratifying the Kigali Amendment to the *Montreal Protocol on Substances that Deplete the Ozone Layer*[188] and an aligned national phasedown of hydrofluorocarbons.[189]
- **Support industrial decarbonization**, by advancing the first-ever carbon-based trade instrument[190] and Buy Clean actions to incentivize low-carbon production of key materials like steel and advancing research, development, demonstration, and deployment of technologies like clean hydrogen.[191]
- **Cut emissions and energy costs in buildings,** by strengthening federal efficiency standards for appliances and equipment[192] and launching partnerships with state and local governments[193] and the private sector[194] to advance retrofits, electrification, and more.

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185 U.S. Environmental Protection Agency. https://www.epa.gov/newsreleases/epa-finalizes-greenhouse-gas-standards-passenger-vehicles-paving-way-zero-emissions.
186 The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2022/10/19/fact-sheet-biden-harris-administration-driving-u-s-battery-manufacturing-and-good-paying-jobs/.
187 The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2022/01/31/fact-sheet-biden-administration-tackles-super-polluting-methane-emissions/.
188 The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2022/09/21/statement-by-president-joe-biden-on-senate-ratification-of-the-kigali-amendment-to-the-montreal-protocol/.
189 The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2021/09/23/fact-sheet-biden-administration-combats-super-pollutants-and-bolsters-domestic-manufacturing-with-new-programs-and-historic-commitments/.
190 The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2021/10/31/fact-sheet-the-united-states-and-european-union-to-negotiate-worlds-first-carbon-based-sectoral-arrangement-on-steel-and-aluminum-trade/.
191 The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2022/02/15/fact-sheet-biden-harris-administration-advances-cleaner-industrial-sector-to-reduce-emissions-and-reinvigorate-american-manufacturing/.
192 U.S. Department of Energy. https://www.energy.gov/articles/doe-releases-energy-saving-rules-federal-buildings-and-proposes-new-standards-consumer.
193 National Building Performance Standards Coalition. https://nationalbpscoalition.org/
194 U.S. Department of Energy – Better Climate Challenge. https://betterbuildingssolutioncenter.energy.gov/climate-challenge.

- **Enhance carbon sequestration,** by launching the America the Beautiful initiative to conserve 30 percent of U.S. lands and waters by 2030,[195] issuing an Executive Order to strengthen forests and other nature-based solutions,[196] and supporting climate-smart agriculture.[197]
- **Drive innovation,** by identifying 37 technologies with the power to change the game on achieving net-zero emissions by no later than 2050 and prioritizing five for immediate federal support.[198]
- **Lead by example through the Federal Sustainability Plan** to reduce emissions across the federal government's 300,000 buildings, 600,000 vehicles, and $650 billion in annual purchasing power.[199]

President Biden has also signed into law two transformative pieces of legislation that will work in tandem with continued executive actions to achieve the nation's climate goals.

- The **Bipartisan Infrastructure Law** (BIL) makes foundational investments in the U.S. clean energy economy, with historic levels of support for: upgrading the power grid to transmit more clean energy and withstand extreme weather; building a nationwide network of electric vehicle chargers; improving public transit and passenger rail; deploying zero-emission school and transit buses; weatherizing low-income homes; cleaning up legacy pollution; and supporting demonstration projects and research hubs for next-generation clean technologies. Key investments by sector are highlighted throughout this chapter, and the BIL Guidebook provides detailed program-by-program information.[200]
- The **Inflation Reduction Act** (IRA) is estimated to have more than ten times the climate impact of any other single piece of U.S. legislation. It provides approximately $370 billion for emissions reduction, environmental justice, and climate resilience. This law will more than double U.S. deployment of solar, wind, and battery storage

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[195] The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2021/12/20/fact-sheet-biden-harris-administration-celebrates-expansion-of-locally-led-conservation-efforts-in-first-year-of-america-the-beautiful-initiative/.
[196] The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2022/04/22/fact-sheet-president-biden-signs-executive-order-to-strengthen-americas-forests-boost-wildfire-resilience-and-combat-global-deforestation/.
[197] U.S. Department of Agriculture. https://www.usda.gov/climate-solutions
[198] The White House. https://www.whitehouse.gov/wp-content/uploads/2022/11/U.S.-Innovation-to-Meet-2050-Climate-Goals.pdf.
[199] Office of the Federal Chief Sustainability Officer. https://www.sustainability.gov/federalsustainabilityplan/.
[200] The White House. https://www.whitehouse.gov/build/.

by 2030, with new and extended tax incentives for clean energy. A variety of rebates and tax incentives will help families save money on energy costs, including support for making home energy efficiency upgrades, installing new electric appliances or rooftop solar panels, and purchasing new or used electric vehicles. This law also provides grants, loans, and other programs to support cleaner industrial facilities, ports, and heavy-duty vehicles; community-led climate and environmental justice projects; and climate-smart agriculture and forestry. Key investments by sector are highlighted throughout this chapter, and the IRA Guidebook provides detailed program-by-program information.[201]

With these policies in place, the United States is now on track to reduce economy-wide greenhouse gas emissions to 40 percent below 2005 levels in 2030. Through additional federal actions and efforts across other levels of government, civil society, and the private sector through 2030, the United States is in a strong position to achieve the 50-52 percent reduction goal.

This chapter highlights policies and measures that are already in place across each relevant economic sector, with a focus on efforts launched or expanded in the last two years. An accompanying table in Annex 2 provides more details on key policies and measures, including several longstanding federal efforts that were reported in previous National Communications. This reporting is not a comprehensive account of every policy and measure that supports U.S. climate goals, but rather a selection of significant actions underway.

POLICY MAKING PROCESS

FEDERAL GOVERNMENT

The U.S. federal government utilizes various types of policies and measures to promote the mitigation of greenhouse gas emissions, including laws, investments, regulations, voluntary programs, and partnerships with nonfederal governments and the private sector. The federal government has jurisdiction over important mechanisms to mitigate greenhouse gas emissions, including the regulation of pollution from power plants and vehicles, the advancement of fuel economy in vehicles and energy efficiency of appliances, the advancement of building energy codes, the regulation of interstate and international trade,

[201] The White House. https://www.whitehouse.gov/cleanenergy/inflation-reduction-act-guidebook/

and the ability to invest in technology research, innovation, and deployment—including within federally-owned and occupied properties.

The United States operates a whole-of-government approach through numerous interagency processes to ensure the efficient coordination of programs and funding. Many federal processes require a consideration of the impact of proposed federal actions on greenhouse gas emissions, as well as the costs and benefits of actions to mitigate those impacts. Additionally, progress made with policies and measures intended to mitigate greenhouse gas emissions is monitored and evaluated over time. Because of the multi-branch system of government in the United States, described in Chapter 2, many federal policies and measures can continue through multiple changes in leadership within the executive and legislative branches.

In Annex 2, a table provides details on key federal policies and measures that contribute to U.S. emissions reduction—a subset of the wide-ranging efforts underway across the agencies of the National Climate Task Force.

NON-FEDERAL GOVERNMENTS

In addition to federal actions, non-federal governments—state, local, Tribal, and territorial—are advancing a range of policies and measures to reduce greenhouse gas emissions. These bottom-up efforts are particularly critical in areas where the federal government has limited authority.
For example:

- **State public utility commissions** are accelerating the clean energy transition through their oversight of electric and gas utilities, by streamlining adoption of smart grid technologies and distributed energy resources, directing resources to building upgrades and electric vehicle charging infrastructure, using performance-based ratemaking to incentivize end-use energy efficiency and emissions reductions, advancing modern rate designs, and expanding access of low- and moderate-income households to community solar and other programs that reduce energy bills.[202]

[202] National Association of Regulatory Utility Commissioners. https://maxxwww.naruc.org/forms/committee/CommitteeFormPublic/viewExecCommittee?id=764000C03D7.

- **State legislatures and governors** are setting in-state targets to move faster on clean electricity[203] and zero-emission vehicle sales,[204] and state and local governments are using building codes to advance energy efficiency and electrification.[205]
- **Metropolitan planning organizations and state, regional, and local transportation agencies** are integrating climate goals into their planning, in order to decrease transportation fuel emissions, improve transit services, and promote more livable and sustainable communities.[206]
- **Tribal Nations** are developing and implementing climate action plans to advance clean energy, nature-based solutions, resilience efforts, and more.[207]
- **Local land use officials** are pursuing smart growth strategies, by using planning and zoning tools to support sustainable and affordable housing,[208] clean energy deployment,[209] and transit-oriented development.[210]

Several coalitions are working to increase ambition for non-federal climate action. For example, the U.S. Climate Alliance includes governors representing over half the U.S. population that have committed to the collective goal of reducing greenhouse gas emissions 50-52 percent below 2005 levels by 2030 while advancing environmental justice and creating high-quality jobs.[211] The *America is All In* coalition mobilizes thousands of government and non-government members in support of climate action, including cities, counties, Tribal Nations, businesses and investors, faith groups, health care organizations, and educational

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[203] National Conference of State Legislatures. https://www.ncsl.org/research/energy/renewable-portfolio-standards.aspx.
[204] Center for Climate and Energy Solutions. https://www.c2es.org/document/us-state-clean-vehicle-policies-and-incentives/.
[205] U.S. Department of Energy. https://www.energycodes.gov/.
[206] Federal Highway Administration. https://www.fhwa.dot.gov/environment/sustainability/; U.S. Department of Transportation.https://www.transportation.gov/sustainability/climate/case-studies-mpo-activities.
[207] National Congress of American Indians. https://www.ncai.org/ptg/climate.
[208] U.S. Department of Housing and Urban Development. https://www.hud.gov/program_offices/comm_planning/conplan/greenhomes.
[209] National Renewable Energy Laboratory. https://www.nrel.gov/news/program/2022/nrel-releases-comprehensive-databases-of-local-ordinances-for-siting-wind-solar-energy-projects.html.
[210] U.S. Department of Transportation. https://www.transportation.gov/buildamerica/TOD.
[211] U.S. Climate Alliance. http://www.usclimatealliance.org/publications/2022/9/19/2022-annual-report.

and cultural institutions.[212] The Climate Mayors network brings together hundreds of cities working to achieve local emissions reduction targets.[213]

To further highlight non-federal actions, the presentation below of key policies and measures in each sector includes specific examples from state, local, Tribal, and territorial governments.

NATIONAL TARGETS

As detailed in its *Fifth National Communication*, and as part of its commitment under the Copenhagen Accord, in 2010 the United States set a target of achieving economy-wide greenhouse gas emissions reductions in the range of 17 percent below 2005 levels in 2020. The United States achieved and exceeded this target, with net greenhouse gas emissions in 2020 that were 21 percent below 2005 levels. More information on achievement of this target is presented in Chapter 3 of the annexed Biennial Report.

In April 2021 the United States communicated its Nationally Determined Contribution (NDC) under the Paris Agreement: to achieve an economy-wide target of reducing its net greenhouse gas emissions by 50-52 percent below 2005 levels in 2030. This 2030 NDC represents increased ambition compared to the NDC communicated in 2015, which set a target of reducing net greenhouse gas emissions by 26-28 percent below 2005 levels in 2025. More information on the NDC is presented in Chapter 2 of the annexed Biennial Report.

The United States has also set a goal of achieving net-zero greenhouse gas emissions by no later than 2050, and the *2021 Long-Term Strategy* lays out pathways to achieve this goal through actions spanning every sector of the economy.[214]

KEY POLICIES AND MEASURES

The United States continues to advance many effective and complementary policies and measures across sectors to meet its targets. Discussed here are a subset of policies and measures that provide a significant contribution to greenhouse gas mitigation—or have the potential to over time. While this section mentions some policies and measures that have continued since the last National Communication, the focus is on new or expanded policies and measures.

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[212] America Is All In. https://www.americaisallin.com/whos-in.
[213] Climate Mayors. https://climatemayors.org/join-us/.
[214] The White House. https://www.whitehouse.gov/wp-content/uploads/2021/10/US-Long-Term-Strategy.pdf.

ENERGY: SUPPLY

The federal government deploys a number of policies to accelerate clean and renewable sources of energy, including a major focus on near-term deployment as well as supporting research, development, demonstration, and deployment.

The Biden-Harris Administration has set a goal to reach 100 percent carbon pollution-free electricity by 2035, which will eliminate emissions from power plants and help decarbonize other sectors as more end uses across transportation, buildings, and industry run on clean electricity. By 2025, the United States aims to permit at least 25 gigawatts of solar, onshore wind, and geothermal on public lands, and to enable community solar systems to power the equivalent of five million households and create $1 billion in energy bill savings.[215] The Administration has also created an Energy Earthshots™ Initiative to drive breakthroughs and reduce the costs of clean energy technologies including clean hydrogen, long-duration storage, enhanced geothermal systems, and floating offshore wind.[216]

Recently enacted legislation will supercharge these efforts. The Inflation Reduction Act (IRA) provides a historic suite of tax incentives to provide long-term certainty for clean energy investment, with additional benefits for meeting high labor standards and bonus credits for investing in low-income communities and communities that have historically depended on the energy sector for jobs and economic activity.[217] These policies will drive continued growth in deployment of wind, solar, and energy storage, as well as other clean technologies. Additionally, both the IRA and the BIL invest in innovation and deployment of technologies including nuclear, carbon capture and storage, clean hydrogen, direct air capture, geothermal, and more.[218] These laws also support the buildout of long-distance transmission lines to deliver clean power across the country, and the Administration's Building a Better Grid Initiative is working to mobilize these resources.[219]

Against this backdrop of new executive goals and legislative support, ongoing federal agency efforts include the following subset of key programs:

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[215] U.S. Department of Energy. https://www.energy.gov/articles/doe-sets-2025-community-solar-target-power-5-million-homes.
[216] U.S. Department of Energy. https://www.energy.gov/policy/energy-earthshots-initiative.
[217] U.S. Department of the Treasury. https://home.treasury.gov/system/files/136/Fact-Sheet-IRA-Equitable-Clean-Energy-Economy.pdf.
[218] U.S. Department of Energy. https://www.energy.gov/sites/default/files/2022-08/8.18 percent20InflationReductionAct_Factsheet_Final.pdf.
[219] U.S. Department of Energy. https://www.energy.gov/gdo/building-better-grid-initiative.

- **Leading on Federal Lands:** The U.S. Department of the Interior (DOI) works with communities, state regulators, industry, and other federal agencies to remediate legacy energy sites and build a clean energy future. DOI provides opportunities for and encourages use of federal public lands for the development of wind, solar, and geothermal energy, and has approved over 120 clean energy projects on public land with combined generating capacity of over 12 gigawatts.[220] In January 2022, five federal agencies—the Departments of the Interior, Agriculture (USDA), Defense (DOD), Energy (DOE), and the Environmental Protection Agency (EPA)—issued a Memorandum of Understanding to streamline reviews for these projects.[221]
- **Launching an American Offshore Wind Industry:** In 2021, DOI, DOE, and the Department of Commerce announced a shared goal of deploying 30 gigawatts of offshore wind in the United States by 2030, while protecting biodiversity and promoting ocean co-use.[222] Since then, the Biden-Harris Administration has held record-breaking lease sales and approved and celebrated the groundbreaking of the nation's first two commercial-scale offshore wind projects in federal waters. DOI has announced plans to hold up to seven new offshore wind lease sales by 2025, and to complete the review of at least 16 plans to construct and operate commercial, offshore wind energy facilities by 2025, which would alone represent more than 22 gigawatts of clean energy for the nation.[223]
- **Financing Clean Energy:** DOE's Loan Programs Office (LPO) provides loans and loan guarantees to finance the commercial deployment of large-scale energy projects. Since 2009, LPO has issued more than $35 billion, including guaranteed loans to the first five utility-scale photovoltaic solar projects in the United States and one of the largest utility-scale wind farms in the world. The IRA appropriates additional funding to support issuing new loans, providing an additional $40 billion of loan authority for Innovative Clean Energy projects (via an appropriation of $3.6 billion to support the

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[220] U.S. Department of the Interior. https://www.doi.gov/pressreleases/interior-department-outlines-roadmap-continued-renewable-energy-progress-public-lands.

[221] The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2022/01/12/fact-sheet-biden-harris-administration-races-to-deploy-clean-energy-that-creates-jobs-and-lowers-costs/.

[222] The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2021/03/29/fact-sheet-biden-administration-jumpstarts-offshore-wind-energy-projects-to-create-jobs/.

[223] The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2022/01/12/fact-sheet-biden-harris-administration-races-to-deploy-clean-energy-that-creates-jobs-and-lowers-costs/.

cost of those loans) and increasing the aggregate amount of loans available at any time under the Tribal Energy Loan Guarantee Program from $2 billion to $20 billion. It also creates a new Energy Infrastructure Reinvestment Program, with $250 billion in total loan authority to support projects that retool, repower, repurpose, or replace energy infrastructure that has ceased operations, or enable operating energy infrastructure to avoid, reduce, utilize, or sequester greenhouse gases.[224]

- **Supporting Clean Energy for Farmers and Rural Small Businesses:** The USDA Rural Energy for America Program (REAP) provides grants and loan guarantees to agricultural producers and rural small businesses to install renewable energy systems and make energy efficiency improvements to reduce energy use and costs. Examples of renewable energy systems that have been funded through REAP include photovoltaic arrays, geothermal heating, ventilation, and air conditioning (HVAC) systems, and anaerobic digestors. Between 2007 and 2017—per the latest Census of Agriculture produced by USDA—the number of farms using a renewable energy-producing system has more than quadrupled to 130,000 farms, or 6.5 percent of all farms, in part aided by REAP funding.[225] The IRA provides $2 billion in additional funding to this program, which supports projects in all 50 states and Puerto Rico.
- **Advancing Clean Energy Across Rural Utilities:** Under the Rural Electrification Act, USDA's Rural Utilities Service (RUS) Electric Loan Program makes low-interest loans available to electric utilities for distribution, transmission, generation, smart grid, security, and energy efficiency infrastructure investments serving rural communities. The program's portfolio of rural renewable power generation is growing rapidly. In 2016, borrowers in this program supported an estimated 155 megawatts of renewable energy generation capacity, and as of 2020 this value is estimated to be more than 476 megawatts. These renewable systems include solar, wind, biomass, and hydroelectric projects that are providing power to rural consumers. The Inflation Reduction Act supercharges this program with $9.7 billion, as well as an additional $1 billion in clean energy financial assistance for rural electric cooperatives and municipal utilities.
- **Growing the American Market for Clean Energy:** EPA's Green Power Partnership (GPP) encourages U.S. organizations to voluntarily purchase green power to protect

[224] U.S. Department of Energy. https://www.energy.gov/lpo/inflation-reduction-act-2022.
[225] Census of Agriculture, U.S. Department of Agriculture.
https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_1_US/usv1.pdf.

human health and the environment. The GPP provides organizations with credible minimum green power usage benchmarks, market and supply options information, procurement assistance and guidance, and public recognition for green power leadership and use. At the end of 2020, the program included over 700 partners who have committed to purchasing about 70 billion kilowatt-hours of green power—40 percent of the voluntary green power market. In addition, the program recognizes over 100 Green Power Communities–towns, villages, cities, counties, and Tribal governments that collectively buy green power in amounts that meet or exceed EPA's GPP community purchase requirements.[226]

NON-FEDERAL SPOTLIGHT:

- **State Renewable Portfolio Standards and Clean Energy Standards:** More than thirty states and territories and the District of Columbia have adopted legally binding renewable portfolio standards (RPS) or clean energy standards (CES) requiring that a specific percentage of electricity sold in the state must come from renewable or carbon-free sources. These binding standards cover about two-thirds of total electricity retail sales in the United States. The designs of these programs vary across states, including components on performance-based standards, targets and timetables, geographic and resource eligibility, and alternative compliance payments. In 2021, the states of Delaware, Illinois, North Carolina, and Oregon all increased their RPS or CES targets, and Nebraska became the twentieth state with a goal to achieve 100 percent clean electricity by 2050 or sooner.[227]
- **State, Local, and Utility Incentives for Clean Power:** Financial mechanisms and incentives for clean energy exist in most states, with hundreds of programs offered by state and local governments across the nation, as well as utilities and nonprofit organizations.[228] Additionally, many utilities regulated by state commissions have adopted programs with performance-based incentives, including feed-in tariffs, standard offer payments, and payments in exchange for renewable energy certificates. Twenty of the largest investor-owned utilities have committed to reducing emissions by 100 percent (net or absolute) or reaching 100 percent clean electricity by 2050, and some as early as 2035.[229]

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[226] U.S. Environmental Protection Agency. https://www.epa.gov/greenpower
[227] U.S. Energy Information Administration. https://www.eia.gov/todayinenergy/detail.php?id=51118
[228] Database of State Incentives for Renewables & Efficiency. https://programs.dsireusa.org/system/program
[229] Natural Resources Defense Council. https://www.nrdc.org/resources/race-100-clean

- **Regional Greenhouse Gas Initiative:** The Regional Greenhouse Gas Initiative (RGGI) is a cooperative, market-based effort among several Northeast and Mid-Atlantic states to cap and reduce CO_2 emissions in the power sector. The nine RGGI states that participated from 2009-2020 achieved a reduction in power sector CO_2 of over 50 percent, even as the regional economy grew. Ninety percent of emission allowances are distributed through quarterly auctions, generating proceeds for reinvestment in energy efficiency, clean and renewable energy, electrification, greenhouse gas abatement, and direct bill assistance.[230]

ENERGY: RESIDENTIAL AND COMMERCIAL END USE

The United States pursues multiple approaches to reduce the emissions intensity of energy used by residential and commercial buildings, including through building and appliance energy efficiency codes and standards; state-mandated and voluntary energy efficiency and conservation programs; investments in rural energy efficiency; investments in efficient public housing and housing for low-income households; and innovation in grid-interactive technology for high-performance buildings of the future.

President Biden promised to help weatherize two million homes during his election campaign, and thanks to the home efficiency incentives he signed into law with the Inflation Reduction Act as well as the Weatherization Assistance Program he expanded ten-fold with the BIL, the United States is on track to meet that goal.[231]

The Biden-Harris Administration has also launched several new initiatives to advance these efforts across other levels of government and the private sector. More than 100 companies and organizations have joined the Better Climate Challenge to reduce portfolio-wide greenhouse gas emissions (scope 1 & 2) by at least 50 percent within 10 years, supported by DOE's technical assistance and convening of peer exchanges that support pathways to decarbonization.[232] The Building Performance Standards Coalition includes more than 30 state and local governments working to reduce building emissions, create good-paying jobs

[230] The Regional Greenhouse Gas Initiative. https://www.rggi.org/sites/default/files/Uploads/Proceeds/RGGI_Proceeds_Report_2020.pdf
[231] The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2022/11/02/fact-sheet-biden-harris-administration-announces-new-actions-to-lower-energy-costs-for-families/
[232] U.S. Department of Energy. https://betterbuildingssolutioncenter.energy.gov/climate-challenge

in energy efficiency and electrification, and lower energy bills.[233] Through the White House/HHS Health Care Sector Climate Pledge and similar commitments made by federal health systems, over 1000 hospitals, along with other organizations across the sector, have committed to emissions reductions goals in line with the Biden-Harris Administration's targets.[234]

Recent legislation will help reduce building emissions in the near-term and for decades to come. The IRA provides tax incentives for more energy-efficient homes and commercial buildings,[235] rebate programs for home efficiency and electrification,[236] and funding for affordable housing retrofits.[237] The BIL expands funding for the Weatherization Assistance Program, Energy Efficiency and Conservation Block Grant Program, State Energy Program, Capitalization for Efficiency Revolving Loan Funds, and Efficiency and Renewable Energy Grants for public schools.[238]

Ongoing building sector initiatives across federal agencies include the following subset of key programs:

- **Strengthening Energy Efficiency Standards for Appliances and Equipment:** DOE establishes and regularly updates energy efficiency standards and test procedures for more than 60 categories of appliances, equipment, and lighting, as well as for manufactured homes. In 2022 alone, DOE is taking 100 actions to strengthen standards that will save families $100 on average each year on their energy bills.[239]

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[233] The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2022/01/21/fact-sheet-biden-harris-administration-launches-coalition-of-states-and-local-governments-to-strengthen-building-performance-standards/
[234] The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2022/06/30/fact-sheet-health-sector-leaders-join-biden-administrations-pledge-to-reduce-greenhouse-gas-emissions-50-by-2030; U.S. Department of Health and Human Services. https://www.hhs.gov/about/news/2022/11/10/hhs-shares-health-sector-emissions-reduction-climate-resilience-announcements-at-cop27.html
[235] U.S. Department of the Treasury. https://home.treasury.gov/system/files/136/Fact-Sheet-IRA-Equitable-Clean-Energy-Economy.pdf
[236] U.S. Department of Energy. https://www.energy.gov/articles/biden-harris-administration-announces-state-and-tribe-allocations-home-energy-rebate
[237] U.S. Department of Housing and Urban Development. https://www.hud.gov/press/press_releases_media_advisories/HUD_No_22_185
[238] U.S. Department of Energy. https://www.energy.gov/bil/bipartisan-infrastructure-law-programs-department-energy
[239] The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2022/12/19/fact-sheet-biden-harris-administration-takes-more-than-100-actions-in-2022-to-strengthen-energy-efficiency-standards-and-save-families-money/

By 2030, cumulative operating cost savings from all standards in effect since 1987 will reach $2 trillion. Products covered by standards represent about 90 percent of home energy use, 60 percent of commercial building use, and 30 percent of industrial energy use.[240]

- **Developing Strong Building Energy Codes:** DOE's Building Energy Codes Program participates in the development and advancement of cost-saving building energy codes. It is the responsibility of the federal government to make determinations on the energy and cost savings of new commercial and residential model energy codes, and to help states review, adopt, and implement these codes through financial and technical assistance. DOE found that the adoption of recent model energy codes could result in $138 billion in energy cost savings and 900 million metric tonnes (MMT) of avoided carbon dioxide (CO_2) emissions between 2010 and 2040.[241] The BIL and IRA provide additional funding for DOE to support state and local adoption of the latest building energy codes.
- **Helping Consumers and Businesses Choose Efficient Solutions:** The EPA ENERGY STAR program provides simple, credible, and unbiased information that consumers and businesses rely on to make well-informed decisions and save money through energy efficiency. ENERGY STAR encompasses efficient options for home and commercial products, new homes, commercial buildings, and industrial plants. Since 1992, ENERGY STAR and its partners have helped American families and businesses save 5 trillion kilowatt-hours of electricity, avoid more than $500 billion in energy costs, and achieve 4 billion metric tons of CO_2-equivalent greenhouse gas reductions. In 2020 alone, savings resulted in emissions reductions of more than 400 million metric tons of CO_2-equivalent greenhouse gases, roughly equivalent to more than five percent of U.S. total greenhouse gas emissions.[242]
- **Supporting Home Efficiency Upgrades:** Launched in 2002, the Home Performance with ENERGY STAR® (HPwES) program is a national collaborative program between DOE and EPA that includes a network of 32 utility and nonprofit sponsors, and 1,300 home performance contractors. Through HPwES, households make energy-saving improvements to single family and low-rise multifamily buildings—such as sealing

[240] U.S. Department of Energy. https://www.energy.gov/eere/buildings/appliance-and-equipment-standards-program
[241] U.S. Department of Energy. Building Energy Codes Program. https://www.energycodes.gov/impact-analysis
[242] U.S. Environmental Protection Agency. ENERGY STAR Program Impacts. https://www.energystar.gov/impacts

and insulating the home envelope, installing energy-efficient heating and cooling systems and ENERGY STAR lighting and appliances—that reduce their energy use and associated CO_2 emissions by an average of 25 percent per home. Measures are installed by trained and qualified contractors, and quality assurance procedures are established by participating sponsors to ensure measures are installed properly and achieve intended outcomes for energy performance and durability.

- **Investing in Weatherization of Low-Income Homes:** DOE's Weatherization Assistance Program (WAP) serves approximately 35,000 low-income families every year to permanently reduce their energy bills by making their homes more energy efficient, healthy, and safe. Through weatherization improvements and upgrades, these households save an average of $372 every year. The BIL expanded funding for WAP ten-fold. For each federal dollar invested, this program generates $2.78 in non-energy benefits—such as job creation and cleaner air. DOE provides program funding to all 50 states, the District of Columbia, Native American tribes, and five U.S. territories—American Samoa, Guam, Northern Mariana Islands, Puerto Rico, and the Virgin Islands—through formula grants.[243]
- **Improving Energy Efficiency in Rural Communities:** The Rural Energy Savings Program at USDA provides zero-interest loan capital to eligible rural utilities and similar energy efficiency providers to relend to their customers for energy efficiency measures and customer-owned renewable energy systems. Loans awarded to the Rappahannock Electric Co-operative in Virginia and Hawaii Green Infrastructure Authority in Hawaii, for example, were used to set up successful on-bill financing programs that offered cost-effective energy efficiency and electrification upgrades to low- and moderate-income homeowners and renters.
- **Reducing Emissions Across Federally-Supported Housing:** The U.S. Department of Housing and Urban Development (HUD) has a portfolio of 4.5 million public and assisted housing units (including 2.2 million market-rate apartments occupied by Housing Choice Voucher households) and plays a key role in the development and preservation of affordable housing. HUD's Climate Action Plan, launched in 2021, includes steps to strengthen green building standards and update minimum new construction standards for HUD-assisted or insured projects and manufactured housing, and to provide training, educational resources, and data products to help

[243] U.S. Department of Energy. https://www.energy.gov/sites/default/files/2022-06/wap-fact-sheet_0622.pdf

grantees and other program beneficiaries pursue energy efficiency and clean energy opportunities.[244]

- **Promoting Voluntary Leadership through Better Buildings:** DOE's Better Buildings Initiative is a market transformation program through which partners collaboratively pursue ambitious energy, waste, water, and greenhouse gas reduction goals. More than 900 program partners represent 13 percent of U.S. commercial building space and 10 of the top 25 U.S. employers, as well as more than 100 state and local governments.[245] DOE's Better Buildings Solution Center provides proven and cost-effective decarbonization, energy, water, and waste efficiency solutions—with more than 3,000 solutions categorized by barrier, building type, sector, technology, and more.[246]
- **Accelerating Innovation for Building Decarbonization:** DOE's new Initiative for Better Energy, Emissions, and Equity (E3 Initiative) advances the research, development, and national deployment of clean heating and cooling systems that include heat pumps, advanced water heaters, low-to-no global warming potential refrigerants, and smarter HVAC diagnostic tools in residential and commercial buildings.[247] For example, the E3 Initiative launched a Residential Cold Climate Heat Pump Challenge, in partnership with manufacturers, to develop a new technology specification for a high-performance cold climate heat pump, demonstrate its performance in the field, and launch pilot programs with utilities to identify and alleviate installation challenges.[248]

NON-FEDERAL SPOTLIGHT:

- **Building Performance Standards:** In 2019, New York City became the first major U.S. city to establish building performance standards for greenhouse gas emissions. Starting in 2024, the new standard will set building emission intensity limits across large commercial and multifamily buildings to reduce their emissions 40 percent

[244] U.S. Department of Housing and Urban Development. https://www.hud.gov/climate/reducing_greenhouse_gas
[245] U.S. Department of Energy. https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/DOE_BBI_2022_Progress_Report.pdf
[246] U.S. Department of Energy. https://betterbuildingssolutioncenter.energy.gov/
[247] U.S. Department of Energy. https://www.energy.gov/eere/buildings/energy-emissions-and-equity-e3-initiative
[248] U.S. Department of Energy. https://www.energy.gov/eere/buildings/residential-cold-climate-heat-pump-challenge

below 2005 levels in 2030.[249] In January 2022, President Biden launched the National Building Performance Standards Coalition, which includes more than thirty state and local governments that have committed to inclusively design and implement equitable building performance standards and complementary programs and policies.[250]

- **Utility Regulation:** More than thirty states have implemented Energy Efficiency Resource Standards that typically set mandatory targets (or in some cases voluntary goals) for utilities to achieve energy savings.[251] Since 2021, states including California,[252] Colorado,[253] Connecticut,[254] Massachusetts,[255] Michigan,[256] Minnesota,[257] Nevada,[258] New York,[259] Oregon,[260] Rhode Island,[261] and Washington[262] have taken new steps to support building decarbonization through their regulation of gas utilities, such as promoting efficiency, electrification, and long-term emissions reduction planning.

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[249] New York City. Sustainable Buildings. https://www1.nyc.gov/site/sustainablebuildings/ll97/local-law-97.page
[250] National Building Performance Standards Coalition. https://nationalbpscoalition.org/
[251] National Conference of State Legislatures. https://www.ncsl.org/research/energy/energy-efficiency-resource-standards-eers.aspx
[252] California Public Utilities Commission. https://www.cpuc.ca.gov/news-and-updates/all-news/cpuc-decision-makes-ca-first-state-in-country-to-eliminate-natural-gas-subsidies
[253] Colorado Public Utilities Commission. https://puc.colorado.gov/cleanheatplans
[254] Connecticut Public Utilities Regulatory Authority. https://www.dpuc.state.ct.us/dockcurr.nsf/4b3c728dd1c0d642852586db0069aa70/b09c5c63c09c2a25852588310054086c/$FILE/210824-042722.pdf
[255] Massachusetts Department of Public Utilities. https://www.mass.gov/news/dpu-approves-massachusetts-nation-leading-three-year-energy-efficiency-plan
[256] Michigan Public Service Commission. https://www.michigan.gov/mpsc/commission/news-releases/2022/10/27/mpsc-approves-updates-to-michigans-irp
[257] Minnesota Public Utilities Commission. https://content.govdelivery.com/accounts/MNPUBUC/bulletins/3167ec0
[258] Public Utilities Commission of Nevada. https://pucweb1.state.nv.us/PDF/AxImages/DOCKETS_2020_THRU_PRESENT/2021-5/12764.pdf
[259] New York Public Service Commission. https://www3.dps.ny.gov/pscweb/WebFileRoom.nsf/ArticlesByCategory/8240969C7564FBD485258840005DBC35/$File/pr22043.pdf?OpenElement
[260] Public Utility Commission of Oregon. https://edocs.puc.state.or.us/efdocs/HAH/um2178hah155046.pdf
[261] Rhode Island Public Utilities Commission. https://ripuc.ri.gov/Docket-22-01-NG
[262] Washington Utilities and Transportation Commission. https://www.utc.wa.gov/ru/casedocket/2021/210553/docsets

- **Heat Pumps:** A heat pump is a highly efficient piece of equipment used for heating and cooling a building using electricity. Several states have already set time-bound deployment targets that already total over 12 million new heat pumps by 2030,[263] and this number is highly likely to grow considerably in the coming years due to new incentives provided by the Inflation Reduction Act for this efficient, electric equipment.

TRANSPORT

The United States pursues multiple approaches to reduce emissions produced by transportation activities including from fossil-fuel powered on-road vehicles, rail equipment, aviation, and marine vessels.

The Biden-Harris Administration has launched major new initiatives to accelerate decarbonization of the transportation sector. In August 2021, President Biden issued an Executive Order on Strengthening American Leadership in Clean Cars and Trucks, setting a national goal that 50 percent of all new passenger cars and light trucks sold in 2030 be zero-emission vehicles—including battery electric, plug-in hybrid electric, or fuel cell electric vehicles.[264] The Administration's American Battery Materials Initiative will help strengthen critical mineral supply chains for electric vehicles and other uses.[265] The Administration also issued the U.S. Aviation Climate Action Plan,[266] outlining a whole-of-government approach to achieving a net-zero U.S. aviation sector by 2050, and launched a Sustainable Aviation Fuel Grand Challenge to reduce costs and boost production of sustainable aviation fuels, with a goal of 3 billion gallons per year by 2030.[267] On the world stage, the Administration continues to support increased climate ambition from the International Civil Aviation Organization and the International Maritime Organization, and recently signed a Global Memorandum of

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[263] The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2022/11/02/fact-sheet-biden-harris-administration-announces-new-actions-to-lower-energy-costs-for-families/

[264] Executive Order 14037 of August 5, 2021, "Strengthening American Leadership in Clean Cars and Trucks." https://www.federalregister.gov/documents/2021/08/10/2021-17121/strengthening-american-leadership-in-clean-cars-and-trucks

[265] The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2022/10/19/fact-sheet-biden-harris-administration-driving-u-s-battery-manufacturing-and-good-paying-jobs/

[266] U.S. Department of Transportation. Federal Aviation Administration. https://www.faa.gov/sustainability/aviation-climate-action-plan

[267] U.S. Department of Energy. https://www.energy.gov/eere/bioenergy/sustainable-aviation-fuel-grand-challenge

Understanding on Zero-Emission Medium and Heavy-Duty Vehicles with an aim of 30 percent of new sales to be zero-emissions by 2030.[268]

Additionally, the BIL provides the nation's largest investments ever in improving public transportation[269] and passenger rail,[270] deploying a national network of electric vehicle chargers,[271] strengthening battery supply chains,[272] and switching transit[273] and school bus[274] fleets to low- and zero-emission models. The Inflation Reduction Act provides tax credits to accelerate adoption of clean cars and heavy-duty vehicles; support battery manufacturing; install charging equipment in low-to-moderate income and rural communities; and facilitate use of clean fuels including biodiesel, renewable diesel, advanced biofuel, and sustainable aviation fuel. It also includes programs to support advanced vehicle technologies, cleaner freight and mail delivery vehicles, and cleaner ports.[275]

To continue making progress toward a clean transportation future, four federal agencies—the Department of Energy, Department of Housing and Urban Development, Department of Transportation, and the Environmental Protection Agency—signed a Memorandum of Understanding to develop a comprehensive blueprint for achieving widespread and equitable decarbonization of the U.S. transportation sector.[276] This blueprint will build on existing efforts and help guide additional public and private sector action to advance low- and zero-emission transportation solutions.

Ongoing transportation sector initiatives across federal agencies include the following subset of key programs:

- **Setting Standards for Low-Emission and Fuel-Efficient Cars, Trucks, and Heavy-Duty Vehicles:** The United States first introduced fuel economy standards for vehicles in 1975. Since 2009, the United States has been implementing a coordinated

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[268] U.S. Department of Energy. https://www.energy.gov/articles/us-secretary-energy-advances-americas-commitment-reaching-net-zero-global-emissions-and
[269] Federal Transit Administration. https://www.transit.dot.gov/BIL
[270] Federal Railroad Administration. https://railroads.dot.gov/BIL
[271] U.S. Department of Energy. https://www.energy.gov/articles/doe-and-dot-launch-joint-effort-build-out-nationwide-electric-vehicle-charging-network
[272] U.S. Department of Energy. https://www.energy.gov/articles/biden-administration-announces-316-billion-bipartisan-infrastructure-law-boost-domestic
[273] Federal Transit Administration. https://www.transit.dot.gov/1800buses
[274] U.S. Environmental Protection Agency. https://www.epa.gov/cleanschoolbus
[275] U.S. Department of Energy. https://www.energy.gov/sites/default/files/2022-08/8.18 percent20InflationReductionAct_Factsheet_Final.pdf
[276] U.S. Department of Energy. https://www.energy.gov/articles/biden-harris-administration-announces-interagency-commitment-lower-transportation

national program across the Department of Transportation (DOT) and EPA to dramatically increase the efficiency of American vehicles and reduce carbon pollution. In December 2021, the EPA finalized its strongest standards ever for greenhouse gas emissions from passenger cars and light trucks, model years (MYs) 2023 through 2026.[277] In April 2022, the U.S. Department of Transportation's National Highway Traffic Safety Administration (NHTSA) issued new Corporate Average Fuel Economy Standards requiring an estimated industry-wide fleet average of approximately 49 mpg for passenger cars and light trucks in model year 2026, the nation's strongest cost savings and fuel efficiency standards to date.[278] Both EPA and NHTSA are also advancing stronger standards for heavy-duty vehicles and the next phase of standards for light-duty vehicles, to speed the transition to zero-emission technologies while continuing to improve energy conservation, saving consumers money on fuel costs, and improving air quality.

- **Investing in Zero-Emission Vehicle Infrastructure and Manufacturing:** To complement these vehicle standards, the United States also invests in critical vehicle infrastructure and manufacturing to accelerate the deployment of zero-emission technology. The Biden-Harris Administration launched an Electric Vehicle Charging Action Plan to deploy resources from the BIL, support communities in their planning, and continue designating Alternative Fuel Corridors along the national highway system.[279] The Advanced Technology Vehicle Manufacturing Loan Program, operated out of the Loan Programs Office at DOE, has loaned $8 billion for projects that have supported production of more than 4 million advanced technology vehicles to date, and the Inflation Reduction Act expands this program's loan authority.[280] The Inflation Reduction Act also provides $2 billion to the Domestic Manufacturing Conversion Grants program to support manufacturing of efficient hybrid, plug-in electric hybrid, plug-in electric drive, and hydrogen fuel cell electric vehicles.
- **Supporting Transit-Oriented Development:** The U.S. Department of Transportation (DOT) provides a range of support for transit-oriented development—

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[277] U.S. Environmental Protection Agency. https://www.epa.gov/newsreleases/epa-finalizes-greenhouse-gas-standards-passenger-vehicles-paving-way-zero-emissions

[278] U.S. Department of Transportation. https://www.transportation.gov/briefing-room/usdot-announces-new-vehicle-fuel-economy-standards-model-year-2024-2026

[279] The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2021/12/13/fact-sheet-the-biden-harris-electric-vehicle-charging-action-plan/

[280] U.S. Department of Energy. https://www.energy.gov/lpo/advanced-technology-vehicles-manufacturing-loan-program

projects that create dense, walkable, and mixed-used spaces near transit to support vibrant, sustainable, and equitable communities. For example, DOT's Federal Transit Administration administers a Pilot Program for Transit-Oriented Development Planning to help communities integrate land use and transportation planning to improve economic development and ridership, foster multimodal connectivity and accessibility, improve transit access for pedestrian and bicycle traffic, engage the private sector, identify infrastructure needs, and engage mixed-use development near transit stations.[281] In 2022 USDOT announced that the Transportation Infrastructure Finance and Innovation Act (TIFIA) program would begin offering low-cost and flexible financing for transit and transit-oriented development (TOD) projects at the maximum level authorized under law.[282]

- **Helping States Reduce Transportation Emissions:** DOT's new Carbon Reduction Program, created by the BIL, provides $6.4 billion in formula funding for states and localities over five years for projects designed to reduce transportation emissions from on-road highway sources. Eligible projects include: on- and off-road trail facilities for pedestrians, bicyclists and other nonmotorized forms of transportation; zero emission vehicles and facilities; projects that support congestion pricing and travel demand strategies; truck stop and port electrification systems to reduce the environmental impacts of freight movement and CO_2 emissions at port facilities; public transportation projects such as the construction of bus rapid transit corridors or dedicated bus lanes; and micro-mobility and electric bike projects, including charging infrastructure.[283]
- **Tackling Emissions in Aviation:** In support of the U.S. Aviation Climate Action Plan highlighted above, the Federal Aviation Administration's (FAA) Continuous Lower Energy, Emissions and Noise (CLEEN) Program accelerates the development of new aircraft and engine technologies that reduce fuel burn, emissions, and noise.[284]

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[281] Federal Transit Administration. https://www.transit.dot.gov/TODPilot
[282] U.S. Department of Transportation. https://www.transportation.gov/briefing-room/us-department-transportation-expands-its-financing-program-help-even-more
[283] Federal Highway Administration. https://highways.dot.gov/newsroom/president-biden-usdot-announce-new-guidance-and-64-billion-help-states-reduce-carbon
[284] Federal Aviation Administration. https://www.faa.gov/about/office_org/headquarters_offices/apl/eee/technology_saf_operations/cleen

Additionally, the FAA's Airport Terminals Program, funded by the BIL, can provide support for projects including energy efficiency improvements.[285]

- **Expanding Infrastructure for Biofuels:** USDA's Higher Blends Infrastructure Incentive Program (HBIIP) helps to increase the sales and use of higher blends of ethanol and biodiesel by expanding the infrastructure for renewable fuels derived from U.S. agricultural products.[286] The program is also intended to encourage a more comprehensive approach to market higher blends by sharing the costs related to building out biofuel-related infrastructure. The expansion of biofuel infrastructure, as facilitated by HBIIP, broadens the availability of renewable fuels like E15, E85, and B20, and helps American families save money at the pump while reducing carbon emissions and harmful tailpipe pollution. Expanded use of higher blends of biofuels also boosts the availability of skilled jobs with good wages in rural communities.

NON-FEDERAL SPOTLIGHT:

- **Low-Emission and Zero-Emission Vehicle Standards:** In March 2022, the EPA reinstated California's authority under the Clean Air Act to implement its own greenhouse gas emission standards and zero emission vehicle (ZEV) sales mandate.[287] Seventeen other states and the District of Columbia have adopted California's low-emission vehicle standards, and fourteen of these states have also adopted California's program to increase ZEV sales share for light- and medium-duty vehicles.[288] Additionally, the Multi-State Medium- and Heavy-Duty Zero-Emission Vehicle initiative brings together seventeen states and the District of Columbia (together representing 43 percent of the U.S. population) that are collaborating to achieve goals of 30 percent ZEV sales by 2030 and 100 percent ZEV sales by 2050 for medium- and heavy-duty vehicles, including large pickup trucks and vans, delivery trucks, box trucks, school and transit buses, and long-haul delivery trucks.[289]

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[285] Federal Aviation Administration. https://www.faa.gov/bil/airport-terminals

[286] U.S. Department of Agriculture. https://www.rd.usda.gov/HBIIP

[287] U.S. Environmental Protection Agency. https://www.epa.gov/newsreleases/epa-restores-californias-authority-enforce-greenhouse-gas-emission-standards-cars-and

[288] Center for Climate and Energy Solutions. https://www.c2es.org/document/us-state-clean-vehicle-policies-and-incentives/

[289] Northeast States for Coordinated Air Use Management. https://www.nescaum.org/documents/multi-state-medium-and-heavy-duty-zero-emission-vehicle-action-plan

- **Low Carbon Fuel Standards:** California implemented the first statewide low-carbon fuel standard in 2011, to reduce carbon intensity of transportation fuels and provide an increasing range of low-carbon and renewable alternatives. California amended the regulation in 2018 with stronger carbon intensity benchmarks aligned with California's 2030 greenhouse gas emission reduction target.[290] Oregon's Clean Fuels Program[291] and Washington's Clean Fuel Standard[292] similarly establish annual standards to steadily decrease lifecycle emissions from transportation fuels.
- **Climate Mayors EV Purchasing Collaborative:** Launched in September 2018, the Mayors EV Purchasing Collaborative brings together cities, counties, transit agencies, port authorities, and colleges and universities committed to leverage their collective buying power and accelerate the conversion of fleets to electric vehicles.[293]

INDUSTRIAL ENERGY END-USE, INDUSTRIAL PROCESSES AND PRODUCT USE

The industrial sector is the backbone of the U.S. economy, producing chemicals, electronics, machinery, steel, metals, textiles, and many other products that are critical to our society. However, the industrial sector currently accounts for nearly one third of U.S. greenhouse gas emissions.

The Biden-Harris Administration has taken major steps forward on reducing emissions from this notoriously "hard-to-decarbonize" sector, with executive actions including: the launch of a federal Buy Clean Initiative for purchasing low-carbon construction materials; new guidance on responsible deployment of carbon capture, utilization, and sequestration (CCUS) technologies; and a commitment to negotiate with the European Union the world's first emissions-based sectoral arrangement on steel and aluminum trade.[294] The White House also included industrial decarbonization among the top five innovation priorities to

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[290] California Air Resources Board. https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard/about
[291] Oregon Department of Environmental Quality. https://www.oregon.gov/deq/ghgp/cfp/Pages/default.aspx
[292] Washington State Department of Ecology. https://ecology.wa.gov/Air-Climate/Climate-change/Reducing-greenhouse-gases/Clean-Fuel-Standard
[293] Climate Mayors. https://climatemayors.org/ev-purchasing-collaborative/
[294] The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2022/02/15/fact-sheet-biden-harris-administration-advances-cleaner-industrial-sector-to-reduce-emissions-and-reinvigorate-american-manufacturing/

reach net-zero emissions by no later than 2050.[295] To guide additional efforts going forward, the Administration's Industrial Decarbonization Roadmap lays out key pathways to reduce industrial emissions and presents a staged research, development, and demonstration agenda for industry and government.[296]

New legislation will accelerate these industrial decarbonization efforts.[297] The Inflation Reduction Act creates a new Advanced Industrial Facilities Deployment Program that will provide financial assistance for facilities across emission-intensive industrial sectors (such as iron and steel, cement, and chemicals) to use electrification, low-carbon fuels, carbon capture, and other advanced-manufacturing processes. The IRA also leverages the purchasing power of the federal government to support demand for low-carbon construction materials through procurement provisions and supports standardizing Environmental Product Declarations to make it easier for the federal government as well as other climate-conscious buyers to select and purchase cleaner materials. The clean hydrogen production tax credit will leverage the hydrogen hub and demonstration investments from the BIL to drive clean hydrogen production and subsequent use in sectors including heavy industry. Similarly, the extension and enhancement of the tax credit for industrial applications of carbon capture and storage (CCS) will leverage BIL investments in CCS demonstrations and CO_2 transportation infrastructure to abate industrial emissions.

Other ongoing industrial sector initiatives across federal agencies include the following subset of key programs:

- **Supporting Low-Carbon Steel, Cement, and More through Federal Procurement:** Under the Federal Buy Clean Initiative, federal agencies are prioritizing the use of lower-carbon construction materials—including steel, concrete, asphalt, and flat glass products—in federal procurement and federally-funded infrastructure projects. This initiative seeks to reduce the embodied emissions associated with the manufacturing of these materials, as well as other lifecycle stages including extraction and transportation.[298]

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[295] The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2022/11/04/fact-sheet-biden-harris-administration-makes-historic-investment-in-americas-national-labs-announces-net-zero-game-changers-initiative/
[296] U.S. Department of Energy. https://www.energy.gov/articles/biden-harris-administration-releases-bold-agenda-reduce-emissions-across-americas
[297] U.S. Department of Energy. https://www.energy.gov/sites/default/files/2022-08/8.18 percent20InflationReductionAct_Factsheet_Final.pdf
[298] Office of the Federal Chief Sustainability Officer. https://www.sustainability.gov/buyclean

- **Advancing Next-Generation Clean Manufacturing:** The Administration is revitalizing American manufacturing to support lower-carbon production of the technologies needed for a net-zero economy. In response to President Biden's Executive Order 14017 on America's Supply Chains, DOE issued the first comprehensive U.S. government plan to build an Energy Sector Industrial Base.[299] President Biden has also authorized use of the Defense Production Act to expand American manufacturing of five critical clean energy technologies.[300] Administration-wide efforts are being supercharged by new investments. The Inflation Reduction Act provides historic support for clean manufacturing, including an expansion of the Advanced Energy Project Credit that can support re-equipping industrial or manufacturing facilities with equipment designed to reduce greenhouse gas emissions by at least 20 percent. It also creates a new Advanced Manufacturing Production Credit to support manufacturing of components along the supply chain for solar modules, wind turbines, battery cells and modules, critical minerals, and more. The BIL funds an Advanced Energy Manufacturing and Recycling Grant Program to help small and medium-sized manufacturers produce or recycle clean energy products or deploy cutting edge emissions reduction equipment.
- **Promoting Voluntary Leadership:** DOE's Better Plants program has worked with over 270 manufacturers and water and wastewater utilities—representing every U.S. state and territory—to accelerate the adoption of more energy-efficient practices, highlight new and innovative technologies, and spur change at an organizational level. Partners set ambitious energy, water, waste, and carbon reduction goals and commit to reducing energy intensity by 25 percent over a 10-year period across all U.S. operations. Through this program, DOE supports 3,600 facilities, representing 14 percent of the U.S. manufacturing footprint, that have reported 2.2 QBtu of energy savings and $10.6 billion of cost savings.[301] Additionally, the BIL provides $550 million for DOE to expand the Industrial Assessment Centers program, which trains engineering students and provides no-cost technical assessments to help small- and

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[299] U.S. Department of Energy. https://www.energy.gov/policy/securing-americas-clean-energy-supply-chain

[300] The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2022/06/06/fact-sheet-president-biden-takes-bold-executive-action-to-spur-domestic-clean-energy-manufacturing/

[301] U.S. Department of Energy. https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/2022 percent20Better percent20Plants percent20Progress percent20Update_0.pdf

medium-sized manufacturers save energy, improve productivity, and reduce waste.[302]

- **Accelerating Innovation on Key Technologies:** As part of the Energy Earthshots™ Initiative, DOE launched the Industrial Heat Shot™ to develop cost-competitive industrial heat decarbonization technologies with at least 85 percent lower greenhouse gas emissions by 2035.[303] DOE is also creating a new Clean Energy Manufacturing Innovation Institute, bringing together industry, academia, and government partners to develop and scale technologies to electrify industrial process heating and reduce emissions across the sector.[304]

NON-FEDERAL SPOTLIGHT:

- **"Buy Clean" Policies:** States including California,[305] Colorado,[306] Minnesota,[307] New York,[308] and Washington[309] are using their procurement power to support lower-carbon construction materials. Additionally, through the Federal Highway Administration's Climate Challenge, more than two dozen state departments of transportation are receiving federal funding to help quantify the impacts of sustainable pavements and to demonstrate ways to reduce greenhouse gas emissions in highway projects using sustainable construction materials.[310]

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302 U.S. Department of Energy. https://www.energy.gov/eere/amo/industrial-assessment-centers-iacs
303 U.S. Department of Energy. https://www.energy.gov/eere/industrial-heat-shot
304 U.S. Department of Energy. https://www.energy.gov/eere/articles/us-department-energy-announces-7th-clean-energy-manufacturing-institute
305 California Department of General Services. https://www.dgs.ca.gov/PD/Resources/Page-Content/Procurement-Division-Resources-List-Folder/Buy-Clean-California-Act
306 Colorado Office of the State Architect. https://osa.colorado.gov/energy-environment/buy-clean-colorado-act
307 BlueGreen Alliance. https://www.bluegreenalliance.org/the-latest/bluegreen-alliance-lauds-inclusion-of-buy-clean-buy-fair-provision-in-minnesota-omnibus-commerce-climate-and-energy-finance-bill/
308 New York State. https://www.governor.ny.gov/executive-order/no-22-leading-example-directing-state-agencies-adopt-sustainability-and
309 BlueGreen Alliance. https://www.bluegreenalliance.org/the-latest/statement-washington-makes-critical-progress-on-buy-clean-and-buy-fair/
310 Federal Highway Administration. https://highways.dot.gov/newsroom/fhwa-steps-efforts-tackle-greenhouse-gas-emissions-highway-construction-71-million-climate

SPOTLIGHT: METHANE

In November 2021, President Biden issued the U.S. Methane Emissions Reduction Action Plan, in support of the Global Methane Pledge goal to reduce global methane emissions 30 percent below 2020 levels by 2030.[311] As detailed in the November 2022 Action Plan update, the Administration is taking more than 50 actions targeted at reducing methane emissions across the major emitting sectors[312]—including efforts highlighted in the Agriculture and Waste sections below. Other key actions include:

- **Setting Standards for Oil and Gas Sources:** The EPA is advancing a rulemaking to sharply reduce methane emissions, other harmful air pollution, and energy waste from both new and existing sources across the oil and gas industry.[313] This rulemaking has a particular focus on equipment that can leak or release methane, and the estimated impact would be to reduce methane emissions from covered sources by 87 percent below 2005 levels in 2030.[314] EPA's proposal would expand the use of new technologies and monitoring approaches, including through a ground-breaking "Super-Emitter Response Program" that would require operators to respond to credible third-party reports of high-volume methane leaks.
- **Plugging Methane Leaks from Orphaned Oil & Gas Wells.** The BIL provides nearly $5 billion for orphaned well site plugging, remediation, and restoration activities led by the Department of the Interior. In addition to emitting methane, orphaned oil and gas wells (those with no solvent owner of record) jeopardize public health and safety by contaminating groundwater and seeping toxic chemicals. Once remediated, these sites can support new economic development opportunities.[315]
- **Preventing Gas Pipeline Leaks:** DOT's Pipeline and Hazardous Materials Safety Administration (PHMSA) is implementing a comprehensive approach to eliminate methane emissions from gas pipeline systems—including production-related

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[311] The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2021/11/02/fact-sheet-president-biden-tackles-methane-emissions-spurs-innovations-and-supports-sustainable-agriculture-to-build-a-clean-energy-economy-and-create-jobs/

[312] The White House. https://www.whitehouse.gov/wp-content/uploads/2022/11/US-Methane-Emissions-Reduction-Action-Plan-Update.pdf

[313] U.S. Environmental Protection Agency. https://www.epa.gov/controlling-air-pollution-oil-and-natural-gas-industry

[314] U.S. Environmental Protection Agency. https://www.epa.gov/newsreleases/biden-harris-administration-strengthens-proposal-cut-methane-pollution-protect

[315] U.S. Department of the Interior. https://www.doi.gov/pressreleases/interior-department-federal-partners-announce-interagency-effort-clean-legacy

gathering lines, trunk line transmission pipelines, and local distribution pipelines. PHMSA is advancing rulemakings to boost safety requirements that will also reduce leaks; requiring pipeline operators to update their inspection and maintenance plans; and implementing a $1 billion Natural Gas Distribution Infrastructure Safety and Modernization grant program to reduce risks from municipality or community owned legacy gas distribution pipelines that are prone to methane leaks.[316]

- **Reclaiming Abandoned Coal Mines:** The BIL provides more than $11 billion for states and Tribes to reclaim abandoned coal mines over 15 years. These reclamation projects will reduce methane emissions, while also closing dangerous mine shafts, restoring water supplies damaged by mining, and creating good-paying jobs for current and former coal industry workers. Following reclamation, these sites can be used for economic redevelopment, including through advanced manufacturing and clean energy deployment.[317]

NON-FEDERAL SPOTLIGHT:

- **State-level Oil and Gas Regulations:** In 2014, Colorado became the first state to adopt regulations limiting methane emissions from the oil and gas sector. Since then, states including California, Massachusetts, New York, and New Mexico have adopted similar regulations.[318]

SPOTLIGHT: HYDROFLUOROCARBONS

Hydrofluorocarbons (HFCs) are potent greenhouse gases used in refrigeration and air conditioning equipment, along with several other applications. The American Innovation and Manufacturing Act ("AIM" Act), national legislation enacted in 2020, directs the EPA to phase down production and consumption of HFCs in the United States by 85 percent by 2036. This phasedown schedule aligns with the Kigali Amendment to the *Montreal Protocol on Substances that Deplete the Ozone Layer*, which the United States has also ratified.

- **Implementing the Phasedown through Rulemaking:** The EPA is promulgating regulations to implement the AIM Act, which authorizes EPA to address HFCs in three

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[316] The White House. https://www.whitehouse.gov/wp-content/uploads/2022/11/US-Methane-Emissions-Reduction-Action-Plan-Update.pdf
[317] U.S. Department of the Interior. https://www.doi.gov/pressreleases/biden-harris-administration-announces-availability-725-million-bipartisan
[318] America is All In, Center for Global Sustainability, and University of Maryland. https://www.americaisallin.com/sites/default/files/2022-09/All-In percent20to percent202030_Methane.pdf

main ways: phasing down HFC production and consumption through an allowance allocation program; promulgating certain regulations for purposes of maximizing reclamation and minimizing releases of HFCs and their substitutes from equipment; and facilitating sector-based transitions to next-generation technologies through sector-based restrictions on HFCs.[319]

- **Preventing Illegal Import and Trade of HFCs:** To help ensure the integrity of the program and a rigorous and timely phasedown, EPA and the Department of Homeland Security co-lead an Interagency Task Force on Illegal HFC Trade, in partnership with the Departments of Justice, State, and Defense. The Task Force works to detect, deter, and disrupt any attempt to illegally import HFCs into the United States, building on experience in preventing illegal imports of ozone-depleting substances and vehicles that fail to comply with Clean Air Act standards.[320]
- **Advancing Development and Use of HFC Alternatives:** Several federal agencies are supporting research and development of additional HFC alternatives, promoting use of recovered HFCs from retired equipment to offset the need for newly manufactured HFCs, and reducing HFC use across federal procurement, as part of a whole-of-government approach to supporting the HFC phasedown.[321]

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[319] U.S. Environmental Protection Agency. https://www.epa.gov/climate-hfcs-reduction
[320] U.S. Environmental Protection Agency. https://www.epa.gov/newsreleases/us-takes-aim-violators-greenhouse-gas-phasedown-and-reporting-programs
[321] The White House. FACT SHEET: Biden Administration Combats Super-Pollutants and Bolsters Domestic Manufacturing with New Programs and Historic Commitments. https://www.whitehouse.gov/briefing-room/statements-releases/2021/09/23/fact-sheet-biden-administration-combats-super-pollutants-and-bolsters-domestic-manufacturing-with-new-programs-and-historic-commitments/

NON-FEDERAL SPOTLIGHT:

- **State-level HFC Restrictions:** States including California,[322] Colorado,[323] Delaware,[324] Maine,[325] Maryland,[326] Massachusetts,[327] New Jersey,[328] New York,[329] Rhode Island,[330] Vermont,[331] Virginia,[332] and Washington[333] have adopted state-level policies to reduce HFC emissions, including limits on HFC use in specific product categories, helping to provide a foundation for the national phasedown now being implemented.

AGRICULTURE

In 2020, greenhouse gas emissions from the agriculture sector accounted for 9.9 percent of gross U.S. emissions, excluding emissions associated with electric power consumed in the sector.[334] As noted in previous National Communications, the United States has undertaken a range of efforts to reduce emissions and enhance sequestration related to the use and management of agricultural lands and livestock.

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[322] California Air Resources Board. https://ww2.arb.ca.gov/our-work/programs/stationary-hydrofluorocarbon-reduction-measures

[323] Colorado Department of Public Health & Environment. https://cdphe.colorado.gov/aqcc-regulations

[324] Delaware Department of Natural Resources and Environmental Control. https://regulations.delaware.gov/register/march2021/final/24 percent20DE percent20Reg percent20876 percent2003-01-21.htm

[325] State of Maine Legislature. https://legislature.maine.gov/LawMakerWeb/summary.asp?ID=280078280

[326] Maryland Department of the Environment. https://news.maryland.gov/mde/2020/11/13/maryland-finalizes-regulations-to-phase-out-hydrofluorocarbons-and-reduce-methane-emissions/

[327] Massachusetts Department of Environmental Protection. https://www.mass.gov/service-details/prohibitions-on-the-use-of-certain-hydrofluorocarbons-310-cmr-776

[328] New Jersey Office of Legislative Services. https://www.njleg.state.nj.us/bill-search/2018/A5583

[329] New York State Department of Environmental Conservation. https://www.dec.ny.gov/regulations/119026.html

[330] Rhode Island Department of State. https://rules.sos.ri.gov/regulations/part/250-120-05-53

[331] Vermont Department of Environmental Conservation. https://dec.vermont.gov/sites/dec/files/aqc/laws-regs/documents/Vermont_HFC_Rule_Adopted_CLEAN.pdf

[332] Virginia Department of Environmental Quality. https://www.deq.virginia.gov/air/greenhouse-gases/hfcs

[333] Washington State Department of Ecology. https://ecology.wa.gov/Regulations-Permits/Laws-rules-rulemaking/Closed-rulemaking/WAC173-443#CR101

[334] U.S. Environmental Protection Agency. https://www.epa.gov/system/files/documents/2022-04/us-ghg-inventory-2022-main-text.pdf

Additionally, the Biden-Harris Administration has launched new initiatives to support U.S. agricultural producers in advancing climate solutions. For example, as directed by President Biden's Executive Order on Tackling the Climate Crisis at Home and Abroad, USDA developed a Climate-Smart Agriculture and Forestry Strategy to deliver measurable emissions reductions and carbon sequestration through conservation actions, source sustainable bioproducts and fuels, and decrease wildfire risk fueled by climate change.[335]

Through the IRA, the United States is making historic investments to support farmers, ranchers, and forest landowners in deploying climate-smart practices that will reduce greenhouse gas emissions, increase storage of carbon in soils and trees, and make their operations more productive.[336]

Key federal programs include:

- **Supporting Markets for Climate-Smart Commodities**: Through the new Partnerships for Climate-Smart Commodities Initiative—launched in February 2022, with the first set of awards announced in September 2022—USDA is providing grants for pilot projects that create market opportunities for U.S. agricultural and forest products produced using climate-smart practices.[337] Funded projects will provide technical and financial assistance to producers who implement climate-smart practices on a voluntary basis on working lands; market climate-smart commodities that result from those practices; and test and evaluate innovative and cost-effective methods for quantification, monitoring, reporting, and verification of greenhouse gas benefits associated with those products and production systems. A "Partnerships for Climate-Smart Commodities Learning Network" will synthesize lessons learned from the projects to facilitate efforts by USDA and others to scale up the development and marketing of climate-friendly products and further incentivize deployment of climate-smart agricultural and forestry practices.
- **Promoting Climate-Smart Practices on Agricultural Lands:** The Natural Resources Conservation Service (NRCS) at the U.S. Department of Agriculture administers a number of technical and financial assistance programs that help agricultural producers implement conservation practices with quantifiable greenhouse gas

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[335] U.S. Department of Agriculture. https://www.usda.gov/sites/default/files/documents/climate-smart-ag-forestry-strategy-90-day-progress-report.pdf
[336] U.S. Department of Agriculture. https://www.nrcs.usda.gov/about/priorities/inflation-reduction-act
[337] U.S. Department of Agriculture. https://www.usda.gov/climate-solutions/climate-smart-commodities

benefits. These climate-smart practices include soil health improvements, nitrogen management, livestock and manure management, agroforestry, and other approaches to build carbon stocks in soils and perennial biomass and reduce emissions. NRCS's two largest financial assistance programs are the Environmental Quality Incentives Program (EQIP) and Conservation Stewardship Program (CSP), which together delivered more than 27 million metric tonnes of CO_2 equivalent ($MMTCO_2e$) in estimated emissions reductions in 2020. The Inflation Reduction Act provides additional support for EQIP and CSP, as well as USDA's Agricultural Conservation Easement Program, Regional Conservation Partnership Program, and Conservation Technical Assistance.

- **Reducing Methane Emissions from Agriculture:** Operating since 1993, AgSTAR is a voluntary effort run by EPA with support from USDA that provides technical and regulatory assistance and planning guidance to livestock managers who wish to pursue anaerobic digestor projects. AgSTAR also works to identify and address barriers to biogas recovery projects and provides information and training to the state and local government agencies that permit these projects and the private-sector organizations that implement them. Digestion systems attributed to the AgSTAR program have resulted in over 20 $MMTCO_2e$ in emissions reductions since 2000.[338] Through its conservation programs, NRCS provides technical and financial assistance to help private agricultural operations manage their livestock and manure, as well as improve rice production in ways that can reduce methane emissions. Through the Rural Energy for America Program (REAP)—which is receiving additional support from the Inflation Reduction Act—USDA's Rural Development agency also provides grants and loan guarantees to rural residents, agricultural producers, and rural businesses for energy efficiency improvements and renewable energy systems that include methane digesters; 49 digesters have been funded under the program since 2014.

NON-FEDERAL SPOTLIGHT:

- **Healthy Soils Initiatives:** Several states have advanced "healthy soils" efforts to promote carbon sequestration, reduce erosion, and boost agricultural productivity and resilience. Examples include California's Healthy Soils Program,[339] the Colorado

[338] U.S. Environmental Protection Agency. AgSTAR Accomplishments. https://www.epa.gov/agstar/agstar-accomplishments
[339] California Department of Food and Agriculture. https://www.cdfa.ca.gov/oefi/healthysoils/

Soil Health Program,[340] Healthy Soils Hawaii,[341] the Maine Healthy Soils Program,[342] Maryland's Healthy Soils Program,[343] the Nebraska Healthy Soils Task Force,[344] New York's Climate Resilient Farming Program,[345] New Mexico's Healthy Soil Program,[346] the Oklahoma Carbon Sequestration Enhancement Act,[347] and the Washington Soil Health Initiative.[348]

LAND USE, LAND-USE CHANGE AND FORESTRY (LULUCF)

Land use, land-use change and forestry (LULUCF) practices contribute greenhouse gas emissions to the atmosphere, but in the U.S. these emissions have historically been outweighed by the carbon absorbed through forests, vegetation, and soils. In 2020, the LULUCF sector was a net sink that removed the equivalent of 13 percent of U.S. greenhouse gas emissions.[349] The United States continues to pursue multiple approaches to reduce gross emissions from the land sector while also growing its capacity to maintain and enhance carbon sequestration.

Major new efforts launched by the Biden-Harris Administration include the America the Beautiful initiative, with the goal of conserving and restoring 30 percent of U.S. lands and waters by 2030 through support of locally-led efforts. As part of this initiative, the Administration is developing the American Conservation and Stewardship Atlas to measure the progress of conservation and restoration efforts across the country.[350] In April 2022, President Biden issued an Executive Order on Strengthening the Nation's Forests, Communities, and Local Economies, directing agencies to safeguard mature and old-growth

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[340] Colorado Department of Agriculture. https://ag.colorado.gov/soil-health
[341] Hawaii Office of Planning and Sustainable Development. https://planning.hawaii.gov/wp-content/uploads/Healthy-Soils-Hawaii-Year-1-OP-Final-Report.pdf
[342] Maine Legislature – Maine Revised Statutes. https://legislature.maine.gov/statutes/12/title12sec352.html
[343] Maryland Department of Agriculture. https://mda.maryland.gov/resource_conservation/Pages/Soil-Health.aspx
[344] Nebraska Department of Agriculture. https://nda.nebraska.gov/healthysoils/index.html
[345] New York State Department of Agriculture and Markets. https://agriculture.ny.gov/soil-and-water/climate-resilient-farming
[346] New Mexico Department of Agriculture. https://nmdeptag.nmsu.edu/healthy-soil-program.html
[347] Oklahoma Conservation Commission. https://conservation.ok.gov/carbon-sequestration-enhancement-act/
[348] Washington State Department of Agriculture. https://agr.wa.gov/departments/land-and-water/natural-resources/soil-health
[349] U.S. Environmental Protection Agency. https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions
[350] U.S. Department of the Interior. https://www.doi.gov/priorities/america-the-beautiful

forests on federal lands, increase support for reforestation partnerships, and advance nature-based climate solutions more broadly.[351] President Biden has also taken historic steps to protect the Tongass National Forest, which stores more carbon than any other U.S. national forest and represents the largest intact tract of coastal temperate rainforest on earth.[352]

Recent legislation further advances carbon sequestration across U.S. landscapes. The BIL provides funding for a variety of ecosystem restoration efforts[353] and for the USDA Forest Service to support healthy national forests and grasslands.[354] The Inflation Reduction Act provides additional investments to protect and strengthen the National Forest System as well as forests on non-federal land, including through support for forest landowners to support practices that boost carbon sequestration and for urban tree planting programs.[355]

A subset of key ongoing efforts includes:

- **Advancing the Conservation of Sensitive Lands:** Programs within the Farm Service Agency (FSA) and NRCS at USDA can help to reduce greenhouse gas emissions on high-carbon soils and sensitive lands. The Conservation Reserve Program (CRP) administered by the Farm Service Agency provides financial incentives to farmers to voluntarily convert environmentally sensitive land from agricultural production to native grasses, wildlife plantings, forested areas, restored wetlands, filter strips, or riparian buffers. The CRP sequesters large amounts of carbon on private lands by removing land from intensive agricultural production and avoiding the application of fertilizer or usage of farm equipment. FSA estimates that the CRP currently protects over 22 million acres of land and helps mitigate more than 19 MMTCO_2e annually. NRCS also protects the long-term viability and conservation benefits of working lands and wetlands through its suite of Conservation Easement programs. The NRCS Conservation Easement portfolio currently protects over 5 million acres, the majority

[351] The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2022/04/22/fact-sheet-president-biden-signs-executive-order-to-strengthen-americas-forests-boost-wildfire-resilience-and-combat-global-deforestation/
[352] U.S. Department of Agriculture. https://www.usda.gov/media/press-releases/2021/11/19/usda-announces-steps-restore-roadless-protections-tongass-national
[353] U.S. Department of the Interior. https://www.doi.gov/priorities/investing-americas-infrastructure/ecosystem-restoration
[354] U.S. Department of Agriculture. https://www.usda.gov/infrastructure
[355] The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2022/08/17/fact-sheet-how-the-inflation-reduction-act-helps-rural-communities/

of which have converted drained marginal cropland into wetland easements that increase carbon sequestration and improve water quality.

- **Promoting the Stewardship of Public and Private Forests:** The United States is committed to promoting forest conservation, avoiding deforestation, and restoring and expanding forests that can offset greater carbon pollution. As directed by President Biden's April 2022 Executive Order on Strengthening the Nation's Forests, Communities, and Local Economies, USDA and the Department of the Interior are creating an inventory of old-growth and mature forests on federal lands, developing policies to institutionalize climate-smart management and conservation strategies, and advancing reforestation targets and partnerships. Additionally, the USDA Forest Service supports sustainable forest management on private land: the Forest Legacy and Community Forest Programs partner with states and private landowners to conserve over 2.8 million acres of forest land and open spaces through easements, purchases, and support for community planning, and the Urban and Community Forestry Program provides financial and technical assistance to state and local agencies to ensure a resilient and equitable tree canopy. The Inflation Reduction Act invests an additional $5 billion to protect National Forest System lands from wildfire, restore federal forests, and work with forest landowners to increase climate mitigation and forest resilience on private lands.
- **Measuring and Monitoring the Carbon Sink:** As part of a broader federal initiative on greenhouse gas measurement, monitoring, reporting, and verification (MMRV), USDA is working to advance MMRV across cropland and forest-related conservation programs. For example, USDA is working to revise guidelines for entity-scale monitoring in forests, which will include additional information on calculating avoided emissions from future catastrophic wildfires and refinements to harvested wood product accounting. Work is also underway to better quantify stages of forest stand development and their influence on carbon dynamics across the diverse forests of the United States, with a particular focus on sequestration rates versus total carbon stocks which may be at risk to climate change and other disturbances.
- **Supporting Nature-Based Solutions:** The Biden-Harris Administration released the nation's first Nature-Based Solutions Roadmap, outlining five strategic areas of focus for the federal government: (1) updating policies, (2) unlocking funding, (3) leading with federal facilities and assets, (4) training the nature-based solutions workforce, and (5) prioritizing research, innovation, knowledge, and adaptive learning that will

advance nature-based solutions.[356] The Administration also released a companion guide, with over 150 resources to spur action—the "Nature-Based Solutions Resource Guide: Compendium of Federal Examples, Guidance, Resource Documents, Tools and Technical Assistance."[357]

NON-FEDERAL SPOTLIGHT:

- **Carbon Sequestration Across Tribal Nations:** The National Indian Carbon Coalition partners with Tribes to verify forest inventory data, determine carbon sequestration levels, and develop forest carbon sequestration projects that generate revenue while preserving the forest. For example, the Fond du Lac Band of Lake Superior Chippewa in northeastern Minnesota and the Keweenaw Bay Indian Community of Lake Superior Chippewa in Michigan's Upper Peninsula are advancing forest-based carbon sequestration projects.[358]
- **Hawai'i 30x30 Initiatives:** The State of Hawai'i is implementing a 30×30 Watershed Initiative to protect 30 percent of Hawai'i's priority watershed forests by the year 2030,[359] and has also committed to effectively manage 30 percent of Hawai'i's nearshore ocean waters by 2030.[360]

WASTE

Emissions from waste account for only 2.6 percent of total greenhouse gas emissions, but make up 20 percent of methane emissions, mostly from landfills.[361] Reducing emissions from

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[356] The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2022/11/08/fact-sheet-biden- percentE2 percent81 percentA0harris-administration-announces-roadmap-for-nature-based-solutions-to-fight-climate-change-strengthen-communities-and-support-local-economies/

[357] The White House. https://www.whitehouse.gov/wp-content/uploads/2022/11/Nature-Based-Solutions-Resource-Guide-2022.pdf

[358] National Indian Carbon Coalition. https://www.indiancarbon.org/carbon-projects/

[359] State of Hawai'i Department of Land and Natural Resources, Division of Forestry & Wildlife. https://dlnr.hawaii.gov/dofaw/30x30/

[360] State of Hawai'i Department of Land and Natural Resources, Division of Aquatic Resources. https://dlnr.hawaii.gov/dar/announcements/hawaii-30-by-30-oceans-target/

[361] U.S. Environmental Protection Agency. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020. https:// www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2020

landfills is therefore a pillar of the U.S. Methane Emissions Reduction Action Plan.[362] In 2016, the EPA finalized new emissions standards and guidelines for new and existing municipal solid waste landfills. Under these rules, new, modified, and existing landfills need to collect and control landfill gas at emission levels nearly a third lower than prior requirements. At the time these rules were finalized, they were estimated to reduce methane emissions by an combined 330,000 tonnes a year by 2025–equivalent to reducing 8.2 $MMTCO_2e$ – in addition to climate benefits totaling over $500 million in 2025.[363] Additionally, in May 2021 the EPA finalized a new federal plan establishing revised standards for landfills in areas without a state or Tribal implementation plan, and ensuring that existing large municipal landfills in the United States will be required to significantly reduce their methane emissions. As estimated, more than 1,500 landfills are covered by the final federal plan.[364]

To support landfills in reducing methane emissions, EPA also operates the Landfill Methane Outreach Program, a voluntary initiative working in nearly all states and territories to support landfill operators with the recovery and beneficial use of landfill biogas for energy use. Since 1995, LMOP has assisted more than 700 landfill biogas energy projects that have collectively reduced and avoided 600 $MMTCO_2e$.[365]

In November 2021, the EPA launched the National Recycling Strategy, and eighteen actions identified in the strategy are underway—including creating a national map of existing recycling infrastructure, conducting a financial needs assessment related to recycling infrastructure in the United States, researching domestic and international circular economy policies, providing grants to support community recycling programs, and developing a recycling measurement guide for state, local, and Tribal governments. The BIL supports implementation of EPA's Circular Economy Strategy Series and funds a Solid Waste Infrastructure for Recycling grant program and a Recycling Education and Outreach grant program.[366]

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[362] The White House. U.S. Methane Emissions Reduction Action Plan. https://www.whitehouse.gov/wp-content/uploads/2021/11/US-Methane-Emissions-Reduction-Action-Plan-1.pdf.

[363] U.S. Environmental Protection Agency. Municipal Solid Waste Landfills: New Source Performance Standards and Emission Guidelines. https://www.epa.gov/stationary-sources-air-pollution/municipal-solid-waste-landfills-new-source-performance-standards.

[364] U.S. Environmental Protection Agency. https://www.epa.gov/sites/default/files/2021-05/documents/landfills-fedplan-final-fact_sheet.pdf.

[365] U.S. Environmental Protection Agency. https://www.epa.gov/lmop/accomplishments-landfill-methane-outreach-program.

[366] U.S. Environmental Protection Agency. https://www.epa.gov/system/files/documents/2022-09/EPA_Circular_Economy_Progress_Report_Sept_2022.pdf

KEY NON-FEDERAL SPOTLIGHT:

- **Reducing Methane Emissions from Landfill Waste:** A wide range of U.S. jurisdictions are working to divert waste from landfills, with examples including the Austin Zero Waste Strategic Plan,[367] the Zero Waste Boston Initiative,[368] the Los Angeles Solid Waste Integrated Resources Plan,[369] Philadelphia's Zero Waste Initiatives,[370] San Francisco's zero waste goal,[371] the Santa Ynez Band of Chumash Indians zero waste initiatives,[372] the Environmental Zero Waste DC Plan,[373] and Zero Waste Guam.[374] States including California[375] and Oregon[376] have adopted regulations that specifically target landfill gas emissions.
- **Food Loss & Waste 2030 Champions:** USDA and the EPA recognize businesses that have committed to specific actions to reduce food loss and waste in their U.S. operations by 50 percent by 2030. Since the 2016 launch through May 2022, over 45 food businesses representing grocery stores, restaurants, food processors, food manufacturers, food service, hospitality, and entertainment companies have joined to become 2030 Champions.[377]

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[367] U.S. Environmental Protection Agency. https://www.epa.gov/transforming-waste-tool/zero-waste-case-study-austin
[368] City of Boston. https://www.boston.gov/environment-and-energy/zero-waste-boston
[369] LA Sanitation. https://www.lacitysan.org/san/faces/home/portal/s-lsh-wwd/s-lsh-wwd-s/s-lsh-wwd-s-zwswirp
[370] City of Philadelphia. https://www.phila.gov/programs/zero-waste-initiatives/
[371] U.S. Environmental Protection Agency. https://www.epa.gov/transforming-waste-tool/zero-waste-case-study-san-francisco
[372] Santa Ynez Chumash Environmental Office. https://www.santaynezchumash.org/environment#programs
[373] Government of the District of Columbia. https://zerowaste.dc.gov/zwdcplan
[374] Zero Waste Guam. https://zerowasteguam.eco/
[375] California Air Resources Board. https://ww2.arb.ca.gov/our-work/programs/landfill-methane-regulation
[376] Oregon Department of Environmental Quality. https://www.oregon.gov/deq/ghgp/Pages/Landfill-Methane-Emissions-Reduction.aspx
[377] U.S. Department of Agriculture. https://www.usda.gov/sites/default/files/documents/2030-Champions-2022.pdf.

CROSS-CUTTING

The United States undertakes a number of additional actions that help drive GHG emissions reduction across sectors. These cross-cutting efforts include:

- **Leveraging the Power of Federal Procurement**: As the single largest land owner, energy user, and employer in the Nation, the Federal Government is leveraging its scale and procurement power to lead by example, catalyze private sector investment, and expand the economy and American industry by transforming how we build, buy, and manage electricity, vehicles, buildings, and other operations to be clean and sustainable.[378] In December, 2021 the President signed Executive Order 14057 which directs the Federal government to achieve five ambitious goals to reduce emissions across Federal operations: 100 percent carbon pollution-free electricity by 2030, at least half of which will be locally supplied clean energy to meet 24/7 demand; 100 percent zero-emission vehicle acquisitions by 2035, including 100 percent zero-emission light-duty vehicle acquisitions by 2027; net-zero emissions from Federal procurement no later than 2050, including a Buy Clean policy to promote use of construction materials with lower embodied emissions; a net-zero emissions building portfolio by 2045, including a 50 percent emissions reduction by 2032; and net-zero emissions from overall federal operations by 2050, including a 65 percent emissions reduction by 2030.[379]
- **Accelerating Innovation for Net-Zero Emissions:** In 2022, the Biden-Harris Administration launched the Net-Zero Game Changers Initiative, an interagency effort to identify, prioritize, and accelerate innovation on game-changing technologies to support the national goal of reaching net-zero emissions by no later than 2050.[380] An initial report describes 37 research and development opportunities and outlines five priority areas: efficient building heating and cooling, net-zero aviation, net-zero power grid and electrification, fusion energy at scale, and industrial products and fuels for a net-zero circular economy.[381] There are additional climate and clean energy

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[378] Office of the Federal Chief Sustainability Officer. https://www.sustainability.gov/

[379] The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2021/12/08/fact-sheet-president-biden-signs-executive-order-catalyzing-americas-clean-energy-economy-through-federal-sustainability/

[380] The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2022/11/04/fact-sheet-biden-harris-administration-makes-historic-investment-in-americas-national-labs-announces-net-zero-game-changers-initiative/

[381] The White House. https://www.whitehouse.gov/wp-content/uploads/2022/11/U.S.-Innovation-to-Meet-2050-Climate-Goals.pdf

innovation initiatives underway across the federal government, including DOE's Energy Earthshots™ Initiative that is accelerating breakthroughs across technologies including clean hydrogen, long-duration storage, carbon dioxide removal, enhanced geothermal systems, floating offshore wind, and industrial heat decarbonization.[382]

- **Tracking Emissions through Mandatory Greenhouse Gas Reporting:** Since 2011, EPA has required the reporting of greenhouse gas emissions from approximately 8,000 facilities across 41 U.S. industry groups that emit 25,000 metric tons or more of CO_2e per year. The reporting program covers about 85 to 90 percent of total U.S. emissions sources and includes the gasses CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, and other fluorinated gases, including nitrogen trifluoride and hydrofluorinated ethers. In 2021, reported direct emissions totaled 2.71 billion metric tons of CO_2e. This program allows for the accurate and timely collection of emissions data to inform future policy decisions and the compilation of the U.S. Inventory of Greenhouse Gas Emissions and Sinks, which supports transparency reporting under the UNFCCC.[383]

Please see Annex 2 for a table summarizing policies and measures relevant to this reporting period.

[382] U.S. Department of Energy. https://www.energy.gov/policy/energy-earthshots-initiative
[383] U.S. Environmental Protection Agency. GHGRP. https://www.epa.gov/ghgreporting/ghgrp-reported-data

Chapter 5.

PROJECTED GREENHOUSE GAS EMISSIONS

Chapter 5. PROJECTED GREENHOUSE GAS EMISSIONS

CHAPTER SUMMARY

This chapter provides projections of U.S. greenhouse gas (GHG) emissions through 2035, including the effects of policies and measures implemented as of November 2021 in a "With Measures" scenario, hereafter referred to as the "2021 Policy Baseline" scenario.[384] Following this cutoff date, President Biden has signed significant legislation into law, including the Bipartisan Infrastructure Law (BIL)[385] and the Inflation Reduction Act (IRA),[386] which will substantially reduce U.S. GHG emissions. While a full analysis of the IRA and BIL is not available for the on-time submission of this report, the United States plans to submit a voluntary supplement to this report in 2023 that will include supplemental projections with a "With Measures" scenario that fully incorporates the BIL and IRA, and a "With Additional Measures" scenario that will show how the United States can go beyond existing measures to further reduce emissions and meet the NDC economy-wide target of reducing net GHG emissions by 50-52 percent below 2005 levels in 2030.

Ahead of the above-described supplement to be submitted in 2023, this chapter includes select preliminary results that will show how additional policies and programs in the process of implementation by the Biden-Harris Administration are poised to substantially reduce U.S. emissions and put the United States in a strong position to meet its emissions reduction targets. In particular, a preliminary assessment by the U.S. Department of Energy (DOE) finds that the IRA—in combination with the 2021 Bipartisan Infrastructure Law (BIL), as well as other enacted policies and past actions—will help drive 2030 economy-wide GHG emissions towards 40 percent below 2005 levels.

See Annex 4 for an explanation of the methodology used for this chapter on projected GHG emissions including information on key underlying factors and activity data.

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[384] The 2021 Policy Baseline scenario does not include the full effects of the legislation in the process of implementation, nor plans or programs in the process of implementation by the Biden administration.
[385] President Biden signed the BIL into law on November 15, 2021. The official short title of the BIL is the Infrastructure Investment and Jobs Act (Public Law 117-58).
[386] President Biden signed the Inflation Reduction Act into law on August 16, 2022 (Public Law 117-169).

PROJECTIONS FOR THE 2021 POLICY BASELINE

The projections of U.S. GHG emissions described here in the 2021 Policy Baseline reflect national estimates considering population growth, long-term economic growth potential, ongoing evolution of the energy system, and many of the implemented policies and measures discussed in Chapter 4. See Annex 4 for a detailed explanation of the methodology used for this chapter on projected GHG emissions.

The 2021 Policy Baseline scenario includes effects of policies and measures implemented during the first months of the current administration through November 2021, the cutoff date for the Energy Information Administration (EIA) Annual Energy Outlook 2022's baseline projections of energy-related carbon dioxide (CO_2) emissions. The projections notably include the phasedown of hydrofluorocarbons (HFCs) under the American Innovation and Manufacturing (AIM) Act and select provisions of the BIL.[387] Policies that are proposed or planned but had not been implemented as of November 2021, as well as sections of existing legislation that require implementing regulations that are not yet final, or funds that have not been appropriated, are not included in this chapter's 2021 Policy Baseline projections. For example, the projections do not include policies in the process of implementation at the analysis cutoff date, such as updated light-duty vehicle regulations that were finalized in December 2021, or oil and gas sector regulations that have been proposed, but not yet finalized. The United States plans to submit a voluntary supplement to this report in 2023 with more detailed emissions trends, including the impacts of new programs included in the IRA and BIL.

Given implementation of programs and measures in place as of November 2021 and economic projections from AEO2022, total net U.S. GHG emissions are projected to be about 18-20 percent below 2005 levels in 2025 and 18-21 percent below 2005 levels in 2030. These results represent ongoing progress in reducing GHG emissions including 1) shift in electricity production towards renewables as coal power plants are retired, 2) consistent progress in

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[387] AEO 2022 and the 2021 Policy Baseline are able to include the following limited set of provisions of the BIL: 1) BIL-related spending that affects overall economic activity; 2) industrial output, services, and mining revisions that affect the production of raw materials, intermediate and final goods, services, and potentially mining (oil, natural gas, coal, or uranium); 3) Strategic Petroleum Reserve (SPR) drawdown and sale; 4) Civil Nuclear Credit Program that provides funding over four years to assist nuclear power plants that might close because of economic factors. AEO 2022 and the 2021 Policy Baseline do not include the following provisions of the BIL: 1) Cost-effective code implementation for efficiency and resilience; 2) Broadband Equity, Access, and Deployment Program; 3) CO2 Infrastructure Finance and Innovation Act that would provide low-interest loans to eligible entities for carbon dioxide (CO_2) transportation projects that cost over $100 million.

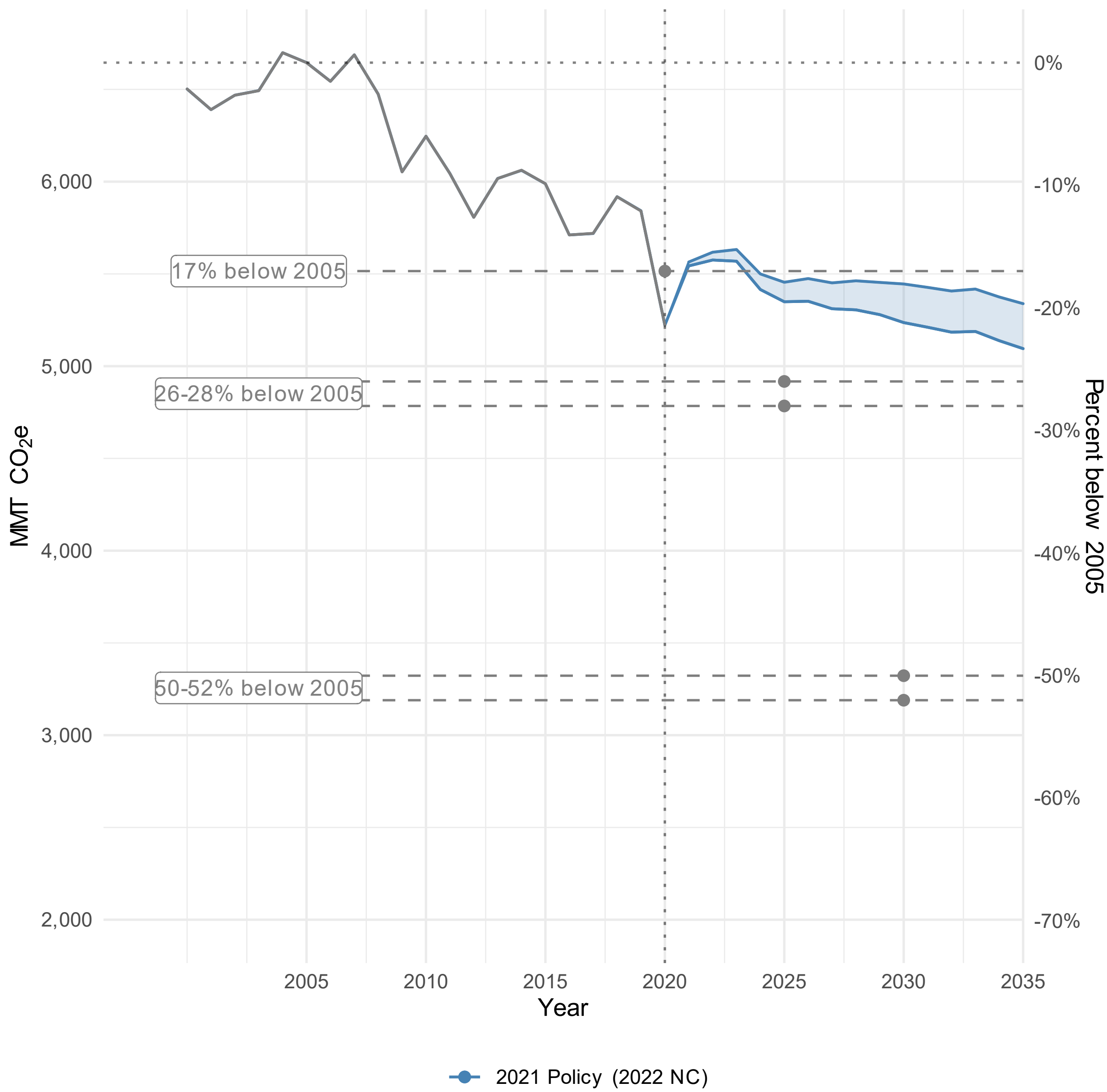
energy-efficiency of vehicles and buildings, and 3) control of non-CO_2 GHG emissions such as the phasedown of HFCs under the AIM Act. These results do not fully reflect policies, programs and measures adopted after November 2021.

Projections for the 2021 Policy Baseline are provided in total by gas and by sector. Gases included in this report are CO_2, methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF6), and nitrogen trifluoride (NF_3). Emissions are presented in CO_2-equivalent values using global warming potential (GWP) conversions from the fourth IPCC assessment report (AR4), which is in alignment with GWP values used for the U.S. Greenhouse Gas Inventory (chapter 3). Sectors reported include energy, transportation, industrial processes, agriculture, waste, and land-use, land-use change, and forestry (LULUCF). Projections for LULUCF through 2035 are presented as a range based on alternative high- and low-sequestration scenarios.

The tables in the chapter present emissions trends from 2005 through 2035.

Figure 5-1 shows emissions trends under the 2021 Policy Baseline.

Figure 5-1: U.S. Net GHG Emissions Projections



Source: See Annex #4 describing the methodology for this chapter, including a description of the sources of information.

U.S. GREENHOUSE GAS EMISSION TRENDS UNDER THE 2021 POLICY BASELINE

The U.S. Department of Energy's (DOE's) Energy Information Administration (EIA) Annual Energy Outlook 2022 (AEO2022) Reference case provided the projection of energy-related CO_2 emissions in the 2021 Policy Baseline scenario presented in this chapter (AEO2022). Projected CO_2 emissions in the AEO2022 Reference case were adjusted to match international GHG inventory convention. The U.S. Environmental Protection Agency (EPA) prepared the projections of non-energy-related CO_2 emissions and non-CO_2 emissions. The methodologies used to project non-CO_2 emissions are based on methodologies described in the background document Methodologies for U.S. Greenhouse Gas Emissions Projections: Non-CO_2 and Non-Energy CO_2 Sources[388] with incremental adjustments for changes in data inputs availability and policy characterization. The U.S. Department of Agriculture Forest Service (USDA/FS) and EPA collaborated on the projections of net CO_2 fluxes from LULUCF. Historical emissions are drawn from the Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020.[389] USDA provided estimates for agriculture-related CO_2 emissions projections. In general, the projections reflect long-run trends and may not fully capture short-run changes. More discussion of the methods used for projections is included in Annex 4.

TRENDS IN TOTAL GREENHOUSE GAS EMISSIONS

Given implementation of programs and measures in place as of November 2021 and economic projections from AEO2022, total net U.S. GHG emissions are projected to be about 18-20 percent below 2005 levels in 2025 and 18-21 percent below 2005 levels in 2030. This does not fully reflect policies, programs and measures adopted or implemented after November 2021. Between 2005 to 2020, net GHG emissions decreased about 21 percent. In

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[388] EPA (2013). Methodologies for U.S. Greenhouse Gas Emissions Projections: Non-CO2 and Non-Energy CO2 Sources. U.S. Environmental Protection Agency.
https://unfccc.int/sites/default/files/resource/USA%20methodologies%20got%20greenhouse%20gas%20
emissions%20projections_0.pdf

[389] EPA (2022). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020. U.S. Environmental Protection Agency, Washington, D.C. EPA Publication No. EPA 430-R-22-003.
https://www.epa.gov/ghgemissions/draft-inventory-us-greenhouse-gas-emissions-and-sinks-1990-2020.

2020, emissions dropped sharply in response to Coronavirus pandemic-related changes, resulting in a decrease of 11 percent in energy-related CO_2 emissions from 2019. [390]

Table 5-1: Historical and Projected U.S. GHG Emissions (2021 Policy Baseline), by Gas: 2005-2035 (MMT CO_2e)

Total Net U.S. GHG emissions are projected to be 18-21 percent lower than 2005 levels in 2030. Gross CO_2 emissions are projected to decline 22 percent over this period.

	Historical				Projected		
Gas	2005	2010	2015	2020	2025	2030	2035
CO_2	6,138	5,681	5,377	4,716	4,886	4,807	4,737
CH_4	698	705	667	650	653	653	651
N_2O	453	453	466	426	417	413	410
HFCs	127	155	168	179	160	165	132
PFCs	7	5	5	4	5	5	5
SF_6	12	7	6	5	5	4	4
NF_3	0	1	1	1	1	1	1
Total Gross Emissions	7,435	7,007	6,689	5,981	6,127	6,049	5,941
LULUCF (historical / low-sequestration)	−790	−761	−700	−759	−672	−604	−602
LULUCF (high-sequestration)	–	–	–	–	−778	−813	−846
Total Net Emissions (historical / low-sequestration)	6,645	6,246	5,989	5,222	5,455	5,445	5,339
Total Net Emissions (high-sequestration)	–	–	–	–	5,349	5,236	5,095

Note: LULUCF and Total Net GHG emissions are presented as a range between low-sequestration and high-sequestration scenarios. The U.S. will submit a supplement to this report in 2023 that fully incorporates the BIL and IRA in the "With Measures" policy baseline.

[390] https://www.eia.gov/todayinenergy/detail.php?id=48856

EMISSIONS PROJECTIONS AND TRENDS BY SECTOR

Table 5-2: Historical and Projected U.S. GHG Emissions Baseline (2021 Policy Baseline), by Sector: 2005-2035 (MMT CO_2e)

	Historical				Projected		
Sector	2005	2010	2015	2020	2025	2030	2035
Energy	4,416	4,153	3,800	3,263	3,297	3,241	3,181
Transportation	1,904	1,731	1,743	1,592	1,704	1,668	1,643
Industrial Processes	366	363	376	376	367	376	349
Agriculture	574	593	614	595	596	599	600
Waste	176	168	156	156	162	165	169
Total Gross Emissions	7,435	7,008	6,689	5,981	6,127	6,049	5,941
LULUCF (historical / low-sequestration)	−790	−761	−700	−759	−672	−604	−602
LULUCF (high-sequestration)	–	–	–	–	−778	−813	−846
Total Net Emissions (historical / low-sequestration)	6,645	6,246	5,989	5,222	5,455	5,445	5,339
Total Net Emissions (high-sequestration)	–	–	–	–	5,349	5,236	5,095

Note: Historical emission from Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020, consistent with Chapter 3 of this report. Data for 1990, 1995 and 2000 are presented in common tabular format electronically. The U.S. will submit a supplement to this report in 2023 that fully incorporates the BIL and IRA in the "With Measures" policy baseline.

The economic uncertainty presented by a variety of factors, including the COVID-19 pandemic and the conflict in Ukraine, continues to be a be a key driver of overall uncertainty in projecting future economic trends. The U.S. economy contracted by 3 percent in 2020. As of publication in 2022, oil prices have trended above the AEO2022 projections due to the ongoing war in Ukraine. This short-term economic environment has direct linkages to emission levels, although the longer-term expectations in the AEO2022 reference scenario are used in the 2021 Policy Baseline, as it represents a cohesive and reasonable long-term outlook.

ENERGY

The energy sector includes fuel combustion emissions associated with buildings, electric power generation, and industry, as well as emissions associated with fuel production. Transportation emissions are discussed in the next section. In the near-term, energy sector emissions are expected to rise relative to 2020 as the economy returns to pre-pandemic levels of economic activity.[391] Following this, they resume the long-term declining trend, reaching 28 percent below 2005 emissions for this sector in 2035 (see Table 5-2). Emissions decrease from 2022 to 2035 because of a transition away from more carbon-intensive coal to less carbon-intensive natural gas and renewable energy for electricity generation and because of an overall decrease in energy intensity (energy consumption per unit of GDP). This trend is not due to declining energy use. U.S. energy consumption grows through 2035, driven by population and economic growth. The projection scenario assumes long-term economic growth of 2.2 percent annually. (AEO2022)

ELECTRICITY

The most notable changes in energy use occur in the electric sector, where significant amounts of new renewable energy are expected to be deployed in response to falling technology costs, and incentives. As coal and nuclear generating capacity retire, new capacity additions come largely from wind and solar technologies. Electricity demand grows slowly across the projection period, growing at less than 1 percent per year through most of the projection period. This is in part due to an increase in onsite generation of electricity. The EIA projects that residential, commercial, and industrial onsite solar PV systems will account for more than 8 percent of total electricity generation by 2050. (AEO2022)

INDUSTRIAL

The EIA projects the U.S. industrial sector's energy consumption to grow more than twice as fast as any other end-use sector over 2021 to 2050. They expect industrial energy production to exceed pre-pandemic levels by 2022, though this rebound varies by industry. For example, glass and steel are not expected to return to 2019 levels of energy consumption, while energy use in bulk chemicals continues to grow. No clear trend in fuel switching or electrification is evident from energy use projections. Use of natural gas, liquid fuels, and electricity all grow from 2021 to 2035, while coal use is relatively flat. Over the projection most major energy-consuming industries are expected to have declining energy intensity (the amount of energy used to produce a unit of output) resulting from efficiency gains, but emissions still grow over 2021 to 2035. (AEO2022)

BUILDINGS

From 2021 to 2035 residential housing stocks and commercial floorspace are projected to grow while emissions from energy use in buildings (including indirect emissions from

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[391] Short-Term Energy Outlook, Energy Information Administration, accessed November 2022.

electricity usage) declines significantly. As a result of efficiency gains, delivered energy consumption in U.S. buildings grows at 0.3 percent per year, more slowly than housing stocks (0.8 percent per year) and commercial floorspace (1 percent per year). New single-family homes and commercial buildings are more energy-efficient than older buildings, leading to a decline in residential and commercial energy intensity per square foot. In addition, onsite generation, largely from solar photovoltaics, reduces the amount of energy that must be delivered to meet demand. These factors combined with ongoing decarbonization of electricity generation leads to falling emissions from building energy consumption. (AEO2022)

FOSSIL FUEL PRODUCTION

In the current projection crude oil and natural gas production are projected to continue increasing to record high levels. Natural gas exports increase with production, driven by global demand and continued construction of new LNG export facilities. (AEO2022) Emissions control regulations and voluntary mitigation activities prevent growth in CH_4 emissions in the context of expanding production. In 2021 and 2022, the Biden administration has proposed additional regulations to reduce CH4 from the oil and gas supply chain, but because these were not finalized by the analysis cutoff date, these new proposals are not included in the current emissions projections.

TRANSPORTATION

Behavioral changes in response to the COVID-19 pandemic resulted in decreased energy use in the transportation sector more than in other end-use sectors. Over the next few years, energy consumption is expected to nearly return to 2019 pre-pandemic levels in 2025 before declining slowly through 2035. In the 2021 Policy Baseline scenario new vehicle fuel economy improvements are driven by increasingly stringent fuel economy standards. This scenario only includes standards in place as of November 2021 (e.g., excluding changes made in December 2021 and moving forward), so we expect future revisions will show further technology improvement over time. Motor gasoline remains the dominant vehicle fuel over the projection period. The EIA projects that the market for alternative-fuel vehicles continues to grow, with battery-electric vehicles and plug-in hybrid electric vehicles combined accounting for 13 percent of total light-duty vehicle sales in 2050. However, the on-road vehicle stock shifts more slowly than sales. (AEO2022)

INDUSTRIAL PROCESSES

Major industrial processes and product use (IPPU) source categories continue to include use of HFCs in refrigeration and air conditioning, metals, cement, and chemicals production. In the AEO2022 reference scenario, the industrial sector becomes the largest consumer of natural gas starting in the early 2020s, including expanded use as a feedstock in chemical industries as well as for industrial heat and power. Industries such as bulk chemicals and cement have projected over 25 percent growth in value of shipments output between 2021 and 2035. Several trends impact projections of HFC emissions from use of ozone-depleting substances (ODS)-substitutes: (1) lower emissions due to the continued replacement of HFC-134a with HFO-1234yf in light duty vehicle air conditioning, due to compliance flexibilities in the light duty CO_2 emissions rule; (2) increasing emissions from the growth in sales of residential air conditioning with high-GWP HFC blend, including record-level air conditioning sales and upgrading during the pandemic; (3) Emission reductions from leak repair and recovery; and (4) replacement of high-GWP HFCs with low/zero-GWP substances in certain parts of the refrigeration, air conditioning, foams, fire suppression, and aerosols markets associated with the ongoing implementation of the American Innovation and Manufacturing (AIM) Act and its HFC allocation program to phase down hydrofluorocarbon production and consumption.

AGRICULTURE

Across commodities, crop production in the United States through 2035 is projected to increase modestly due to higher demands for food, livestock feed, and fiber products. These higher demands are primarily driven by increasing U.S. and global populations and income levels. With respect to area, however, land in crop production, both in aggregate and for individual commodities, is projected to remain relatively stable at current levels. The combination of increasing production and stable cropland area results from a projected continuation of trends in productivity (i.e., increasing yields per acre) that have been observed for the major crops over the last 10 – 20 years. For example, yields of corn and wheat are projected to continue to rise at annual rates of, respectively, 2.0 and 0.4 bushels per acre per year. The projected increases in yields per acre are adequate to meet the projected increases in commodity production without increasing the quantity of land in crop production.

As with the major crops, production of beef, pork, chicken, and dairy products are projected to increase modestly due to rising U.S and global populations and income levels. Unlike crops, projected increases in productivity (i.e., milk or meat per animal) are not sufficient to meet the growing demands for livestock products resulting in modest increases in projected herd and flock sizes.

With respect to GHG emissions from agricultural sources, the above changes in crop and livestock productivity result in a small increase in projected methane (CH_4) emissions from both enteric emissions and manure management. Projected emissions of manure nitrous oxide (N_2O) emissions and cropland N_2O emissions are relatively stable through 2035 at current levels. Agricultural soils (collectively the sum of cropland remaining cropland, land converted to cropland, grasslands remaining grasslands, and lands converted to grasslands) are also associated with CO_2 emissions and removals. Currently, these soils are a net source of emissions and they are projected to remain a source through 2035. The magnitude of the source is projected to increase through 2035, with average emissions between 2011-2020 and 2026-2035 rising from 20.1 million metric tonnes of carbon dioxide equivalent (MMT CO_2e) to 25.2 MMTCO_2e.

FOREST AND LAND USE

As described in the Inventory of Greenhouse Gas Emissions and Sinks 1990-2020, land use, land-use change, and forestry (LULUCF) activities in 2020 resulted in net CO_2 removals of nearly of 812 MMT CO_2e/year (EPA, 2022). Total net carbon sequestration in the LULUCF sector decreased by approximately 9 percent between 1990 and 2020. U.S. forest land attributes and area are continually changing as the demand for forest products change, as forest management techniques advance, as forests age, and as land use choices shift. Also, climate change is altering forest composition, structure, and dynamics via changes in forest growth, and higher frequency and greater intensity of natural disturbances such as droughts, wildfires and insect and disease outbreaks.

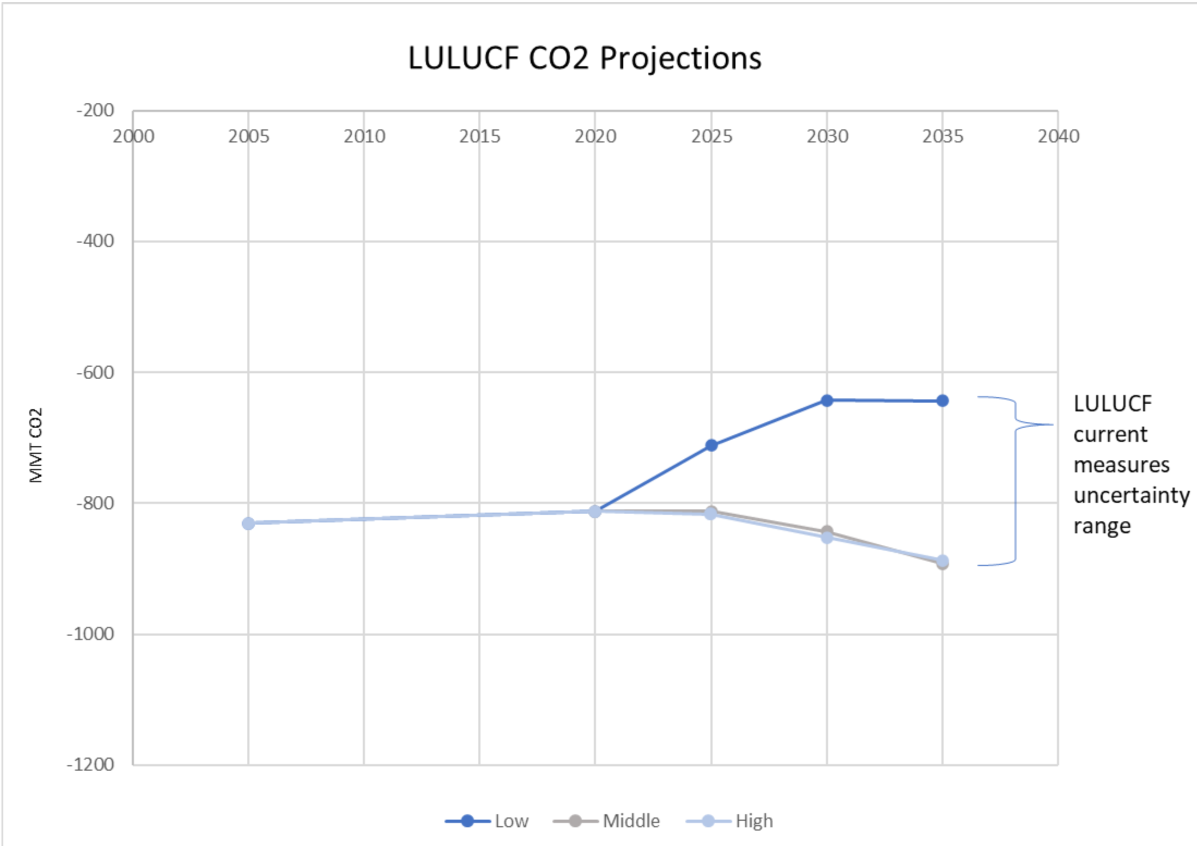
Projecting potential future emissions fluxes from LULUCF is challenging due to the uncertainties associated with estimating the complex carbon dynamics of different terrestrial ecosystems and related market interactions, and the potential extent of land use change between sectors. To reflect these uncertainties, the U.S. LULUCF projections through 2035 in this document are presented as a range (See Figure 5-2). This range incorporates results from three different modeling approaches that use alternate modeling techniques and different perspectives on future macroeconomic outlooks, land use and climate changes, and accounting of forest dynamics. Using a range from alternative models helps bolster the integrity of the projected results. The approaches used to develop this range are discussed further in the methods section, with a brief description of the results here.

The high end of the sequestration range reflects a maintained and slightly strengthened net forest sink (meaning carbon stocks increase at a flat or increasing rate) due to a variety of factors including recent market, policy, and environmental drivers. This projection indicates strong continued investment in productive private forest lands by landowners, as well as continued net increases in forest land area. Rising investment in silvicultural practices and forest expansion is driven largely by global demand growth for forest products and the evolving forest and climate policy landscape; rising forest market prices in this estimate engender new forest investments that stimulate increased carbon stocks. Some lands, especially in the Eastern U.S., see moderating harvests and management intensity as landowners increasingly value other outputs besides timber. There is also decreased harvest from less accessible regions over time and increased harvests from more accessible regions. Policy changes – both domestic and international – also affect future potential forest CO_2 fluxes, as policy changes influence landowner behavior and market outcomes, which is reflected in the data. These factors are augmented by continued atmospheric enrichment through CO_2 fertilization.

The lower sequestration range reflects the U.S. Forest sector becoming a smaller net sink of GHG emissions (as carbon stocks increase at a decreasing rate) under current policies and management approaches. This projection sees increases in forest harvest for products, a net decrease in forest area, and an aging forest resource influenced by increasing disturbance rates. This trajectory is largely driven by the interaction of increasing harvest with moderate increases in timber prices and the effects of future disturbance on an aging forest. The increasing price trends do result in investments in forest management and planting, yet in key forest production regions, for example the Southeast, this increased investment serves to shift away from recent decreases in forest plantation area to a stable plantation area in the future. In the United States, forest plantations account for 10 percent of the forest land base. The remaining 90 percent of the forest land base is typically less intensively managed for timber, managed for other ecosystem services (e.g., water, wildlife, aesthetics, recreation), or managed for multiple uses (see for example Butler et al. 2021). Decreased sequestration is anticipated over time in this larger portion of the forest land base as naturally regenerated forest lands are harvested to meet demand, and net forest growth slows due to aging and increased disturbance.

In the interest of transparency, we present this range of LULUCF uncertainty as it reflects many considerations about different possible future economic conditions, population dynamics and land sector response. Ultimately, the range reflects the broad set of activities currently being taken by the United States to maintain our carbon sink.

Figure 5-2: Current Measures CO_2 Projections for Forestry and Land Use



Source: See Annex #4 describing the methodology for this chapter, including a description of the sources of information.

WASTE

An increasing population and waste deposition results in more emissions from landfills and wastewater treatment, and corresponding projected increases in emissions.

BOX 5.1: PRELIMINARY ANALYSIS OF THE INFLATION REDUCTION ACT

The Inflation Reduction Act of 2022 (IRA) provides a historic, $370 billion investment in tackling the climate crisis. While the IRA became law too recently to be included in the 2021 Policy Baseline presented in this report, the United States plans to submit a voluntary supplement to this report in 2023 presenting a full "With Measures" scenario that includes the IRA, and a full "With Additional Measures" scenario that shows how the U.S. can go beyond the existing measures to further reduce its emissions and meet the NDC economy-wide target of reducing net GHG emissions by 50-52 percent below 2005 levels in 2030. In this report we present some information from a preliminary assessment by the U.S. Department of Energy (DOE) that finds that the IRA—in combination with the 2021 Bipartisan Infrastructure Law (BIL), as well as other enacted policies and past actions—will help drive 2030 economy-wide GHG emissions towards 40 percent below 2005 levels.[392] The legislation would get the U.S. a significant way towards our overall 2030 climate goals, positioning the U.S. to reach its NDC of 50-52 percent GHG emission reductions below 2005 levels in 2030 with continued actions from all levels of government and the private sector.

Beyond implementation of the IRA, the Federal government will continue to deliver additional emission reductions through forthcoming executive actions. In addition to Federal actions, the IRA and BIL enable and catalyze state, local, Tribal, and territorial government actions on climate change that will deliver GHG emissions reductions above and beyond what the IRA and BIL are estimated to achieve on their own. As one indication of how these sorts of additional measures may shape emissions trends, the U.S. Long-Term Strategy lays out pathways consistent with reaching net-zero emissions in 2050, requiring actions spanning every sector of the economy.[393]

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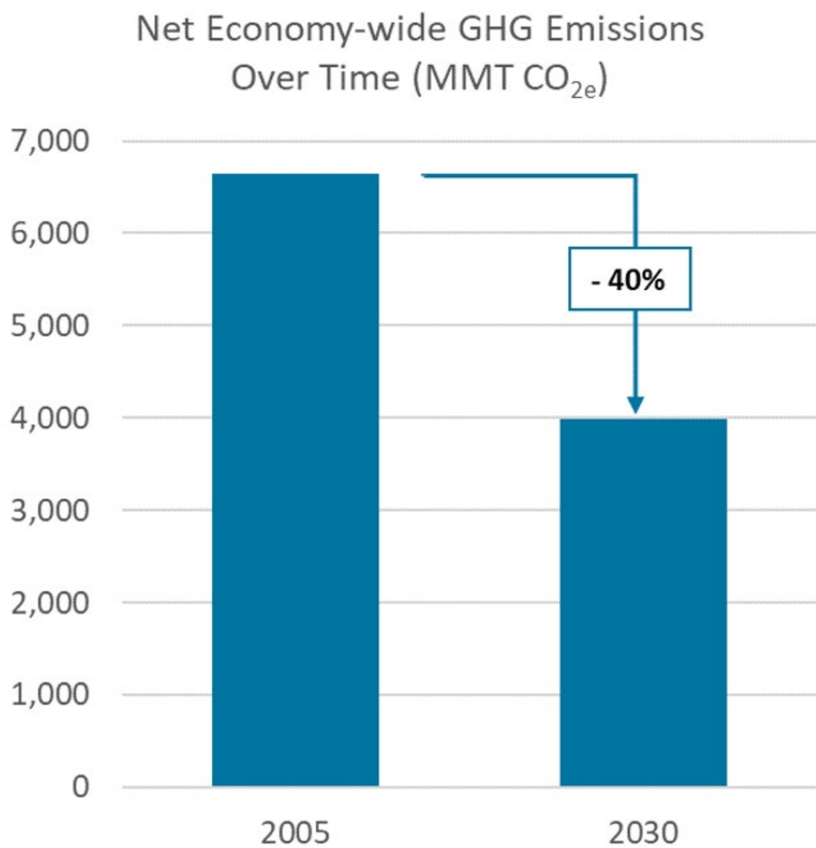
[392] U.S. Department of Energy (DOE) Office of Policy (2022). The Inflation Reduction Act Drives Significant Emissions Reductions and Positions America to Reach Our Climate Goals. https://www.energy.gov/sites/default/files/2022-08/8.18%20InflationReductionAct_Factsheet_Final.pdf.

[393] The Long-Term Strategy of the United States: Pathways to Net-Zero Greenhouse Gas Emissions by 2050. November, 2021. U.S. Department of State and the US Executive Office of the President. Available at: http://whitehouse.gov/wp-content/uploads/2021/10/US-Long-Term-Strategy.pdf.

Figure 5-3: The Inflation Reduction Act and Bipartisan Infrastructure Law, in Combination with Past Actions, Are Projected to Drive 2030 Economy-Wide GHG Emissions to 40% Below 2005 Levels



Source: U.S. Department of Energy[394]

POWER

The new and extended tax incentives in IRA will drive near-term power-sector pollution reductions by accelerating the growth of clean electricity generation, including wind and solar power. Various transmission programs and authorities, as well as a new tax incentive for energy storage, will help ensure that these new resources are reliably delivered to customers. Meanwhile, a new production tax credit in IRA and the Civil Nuclear Credit

[394] U.S. Department of Energy (DOE) Office of Policy (2022). The Inflation Reduction Act Drives Significant Emissions Reductions and Positions America to Reach Our Climate Goals, p.2. https://www.energy.gov/sites/default/files/2022-08/8.18%20InflationReductionAct_Factsheet_Final.pdf

program established by BIL will support the maintenance of the country's existing nuclear power fleet, ensuring that America does not lose these important clean power resources.

The combined effects of IRA and BIL will also drive technology innovation, enabling longer-term reductions in power-sector emissions. Enhanced funding for loans, research and development, and demonstration will support innovation and new deployments for a range of technologies, including nuclear, carbon capture and storage (CCS), long-duration energy storage, clean hydrogen, direct air capture, geothermal, and more. Long-term extensions of existing tax incentives and new and augmented tax incentives that collectively cover each of these technologies will help ensure strong commercial interest and provide a basis for potential large-scale deployment.

INDUSTRY

Programs that support direct emissions abatement at industrial facilities and within manufacturing and recycling processes, incentives for clean fuels, and procurement measures for low-carbon materials all work together to drive industrial-sector emissions reductions. IRA's $5.8 billion Advanced Industrial Facilities Deployment Program plays a significant role, providing financial assistance for facilities to use advanced industrial technologies, such as electrification, low-carbon fuels, carbon capture, and other advanced-manufacturing processes. This will drive emissions reductions in key, emission-intensive industrial sectors, such as iron and steel, cement, and chemicals. IRA also leverages the purchasing power of the Federal government to support demand for low-carbon construction materials through procurement provisions and supports standardizing Environmental Product Declarations to make it easier for the federal government as well as other climate-conscious buyers to select and purchase cleaner materials. The hydrogen production tax credit will leverage the hydrogen hub and demonstration investments from BIL to drive hydrogen production and subsequent use in subsectors, such as ammonia, petroleum refining, biofuels, heavy-duty transportation, and steel. Similarly, the extension and enhancement of the tax credit for industrial applications of CCS will leverage BIL investments in CCS demonstrations and CO_2 transportation infrastructure to abate emissions in ethanol, cement, and refining.

BUILDINGS

IRA provides a landmark expansion of new and existing incentives for building efficiency and electrification. Residential incentives include new rebates for home retrofits and expansion of energy efficiency tax credits for existing and new homes. Many of these programs are targeted in whole or in part to low-moderate income households, such as funding for HUD-assisted affordable housing. IRA also significantly expands tax credits for commercial buildings. Direct funding to building owners is complemented by funding for state agencies, such as funding to assist with state and local building-code adoption and compliance.

Reductions also come from a variety of BIL programs, including $3.5 billion in Weatherization Assistance Program funding and support for the Energy Efficiency and Conservation Block Grant Program, State Energy Program, Capitalization for Efficiency Revolving Loan Funds, and Efficiency and Renewable Energy Grants for public schools. IRA and BIL build on existing programs from DOE, EPA, and the Department of Housing and Urban Development. These include DOE's Appliance and Equipment Standards and EPA's ENERGY STAR Program that pushes efficiency beyond these requirements.

Many of these provisions support the electrification of buildings with efficient equipment that takes advantage of low-carbon electricity, such as electric heat pumps for heating, air conditioning, and hot water – building on efforts already moving forward on the state level. Other investments in building shell improvements – efficient windows, doors, and insulation materials – will generate further emissions reductions. These investments in our nation's buildings, which can operate for 100 years or longer, will ensure lower emissions, lower costs, and improved safety and comfort for decades beyond 2030.

TRANSPORTATION

Tax credits for clean cars, trucks, vans, SUVs, commercial vehicles, and heavy-duty vehicles will help drivers and fleets adopt advanced technologies that lower operating costs and reduce emissions. IRA's Clean Vehicle Credit will support the transition to a clean transportation future, reducing GHG emissions and local air pollution while accelerating the expansion of American supply chains for critical minerals and battery production. Together with BIL investments of $7 billion to strengthen the American battery supply chain, IRA establishes a production tax credit to manufacture battery modules and creates programs to support advanced vehicle technologies and revitalize automotive manufacturing facilities. Moreover, IRA will help more Americans access clean transportation through tax credits for lower-income drivers who purchase previously owned, clean vehicles.

Expanding upon the states' efforts to deploy a national network of charging infrastructure, largely funded by $7.5 billion in the BIL, an alternative refueling tax credit will help install charging equipment in low-to-moderate-income and rural communities. In addition, funding for electric federal fleet vehicles such as U.S. Postal Service trucks will help reduce pollution from mail deliveries and other activities. To further decarbonize all modes of transportation, IRA creates tax credits to facilitate the use of clean fuels including biodiesel, renewable diesel, advanced biofuel, and sustainable aviation fuel. It also provides incentives to deploy alternative-fuel infrastructure and advanced aviation technology, and to reduce diesel emissions from freight and ports.

These investments build on efforts by the Department of Transportation and the Environmental Protection Agency to update fuel economy and tailpipe emissions standards for vehicles, which will work in concert with these new investments to drive toward meeting the President's goal of 50 percent zero emissions vehicles sold in 2030.

AGRICULTURE AND FORESTRY

Combined with BIL and other investments already underway, IRA makes a significant investment in part through the U.S. Department of Agriculture that will support agricultural producers, rural communities and their infrastructure needs, while responding and adapting to the climate crisis. Recognizing the critical role American agriculture and forestry play in the addressing the climate crisis, IRA will invest $21 billion in climate-smart activities pursued by farmers, ranchers, and forest landowners to reduce GHG pollution, increase carbon storage in soils and trees, and make their operations more productive. IRA will also invest $5 billion to protect communities from the risks of extreme wildfires, conserve forests with significant carbon sequestration benefits, and cool communities vulnerable to the threats of extreme heat. These investments will give farmers, ranchers, forest landowners and rural communities the resources and tools they need to prepare for and adapt to a changing climate, saving lives, property, and livelihoods.

REDUCTIONS BEYOND BIL AND IRA

BIL and IRA combined would get the U.S. a significant way toward achieving our NDC emissions reduction target, with the remainder coming from continued executive branch, state, local, Tribal, territorial, and private sector actions. The 2021 Long-Term Strategy (LTS) of the United States illustrates multiple pathways to a net-zero economy no later than 2050. The LTS pathways involve five key transformations: decarbonizing electricity, electrify end-uses and switch to other clean fuels, cut energy waste, reduce methane and other non-CO_2 emissions, and scale up CO_2 removal. The Bipartisan Infrastructure Law and Inflation Reduction Act represent important federal leadership towards these transformations. The LTS further describes that sustained, coordinated action will be required spanning four strategic pillars: federal leadership, innovation, non-federal leadership, and all-of-society action. The incentives and other enabling provisions in BIL and IRA will enable further ambition in all of these pillars.

The LTS analysis offers insights into what the overall emissions profile for the United States could look like between now and 2050. The eventual U.S. pathway to net-zero emissions will depend on the evolution of technologies, the specifics of policy and regulatory packages, and factors such as economic growth, sociodemographic shifts, and market prices for commodities and fuels across the next three decades.

TOTAL EFFECT OF POLICIES AND MEASURES

This section provides an estimate of the total effect of policies and measures using a top-down approach. The approach used is to compare current projections under the 2021 Policy Baseline to “with measures” projections under past National Communications and Biennial Reports. In particular, current projections are compared against the 2014 National Communication because that is the furthest-back projection which included GHG projections for 2030, making it useful to observe changes in projected emissions for 2020, 2025, and 2030.

CHANGES IN GROSS EMISSION PROJECTIONS BETWEEN THE 2014 AND 2021 NATIONAL COMMUNICATIONS

Projections of gross GHG emissions in the 2021 Policy Baseline scenario presented in this report are significantly lower than the emission projection presented in the 2014 National Communication. These differences result from a combination of changes in policies, cost of technologies, and economic growth. While responses to the COVID-19 pandemic have led to large changes in activities and emissions in the short run, these are occurring within the context of overall shifts towards a less GHG emissions-intensive economy. This can be observed, for example, by the fact that 2019 GHG emissions, before the start of the pandemic, were lower than had been previously projected. The current 2021 Policy Baseline projection and the corresponding projections from previous reports are displayed in Table 5-3 and Figure 5-4 for comparison. Adjustments have been made to previous Climate Action Report (CAR) projections to reflect IPCC Fourth Assessment Report (AR4) GWPs.

Table 5-3: Comparison of Total Gross GHG Emissions under the 2021 Policy Baseline Projections to Previous U.S. Climate Action Reports and Biennial Reports

	2005	2010	2015	2020	2025	2030	2035
2022 NC	7,435	7,007	6,689	5,981	6,127	6,049	5,941
2021 NC	7,423	6,991	6,671	6,103	6,191	6,194	6,192
2016 BR	7,350	6,899	6,772	6,641	6,580	6,392	–
2014 NC	7,283	6,908	6,732	6,921	7,074	7,160	–
2010 NC	7,257	7,237	7,407	7,604	–	–	–
2006 NC	7,246	7,648	8,043	8,433	–	–	–

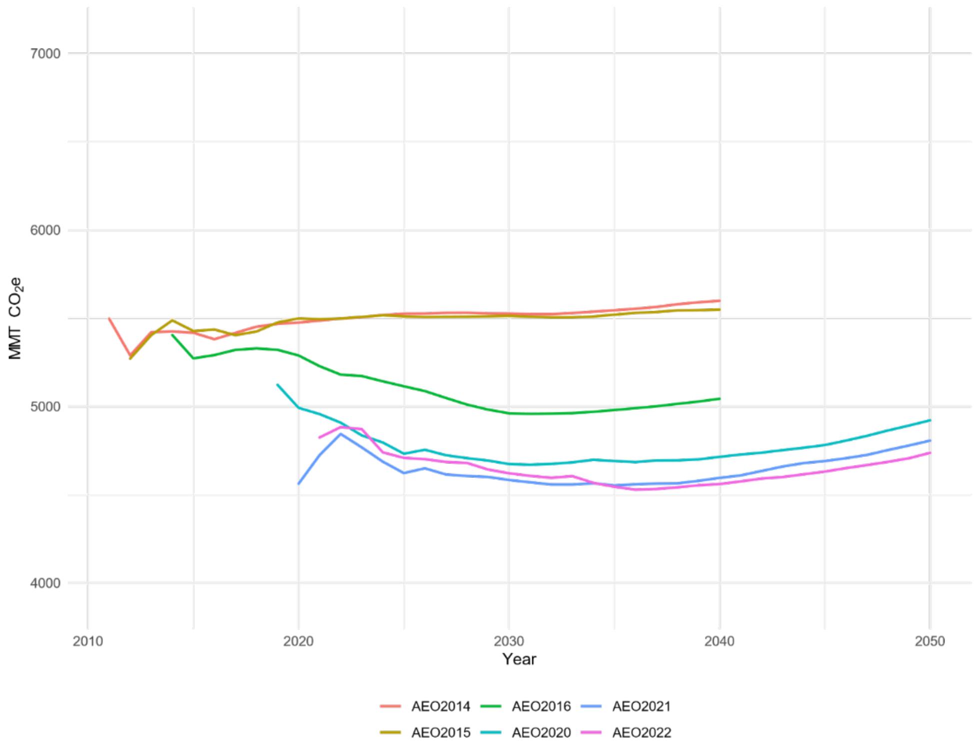
Notes:

- Historical and projected years vary between reports. For the 2022 National Communication the base year is 2020, for the 2021 National Communication it was 2019; for the 2016 BR it was 2013; for the 2014 National Communication it was 2011; for the 2010 CAR it was 2007; for the 2006 National Communication it was 2004.
- Previous National Communication projections have been adjusted for comparability and may vary from tables published in those reports. Where Fourth Assessment Report (AR4) GWP values were not used, CO2-equivalent projections have been adjusted to reflect AR4 GWPs. LULUCF emissions sources that were previously reported as part of gross emissions are now excluded from gross emissions.
- Historical estimates can vary between National Communication and BR reports because as part of the process of revising inventory methodologies and data sources there are often historical timeseries recalculations.

Figure 5-4: Comparison of 2021 "With Measures" Baseline to Previous "With Measures" Projections

Source: 2006, 2010, 2014 National Communications of the United States to the UNFCCC (NatCom); 2016 Biennial Report of the United States to the UNFCCC (BR). "2020 Policy" is from the 2021 NatCom/BR. For "2021 Policy," see Annex #4 describing the methodology for this chapter, including a description of the sources of information.

Figure 5-5: Comparison of Energy-Related CO_2 Projections from Annual Energy Outlook 2022 (AEO2022) Reference Case to Previous AEO Projections

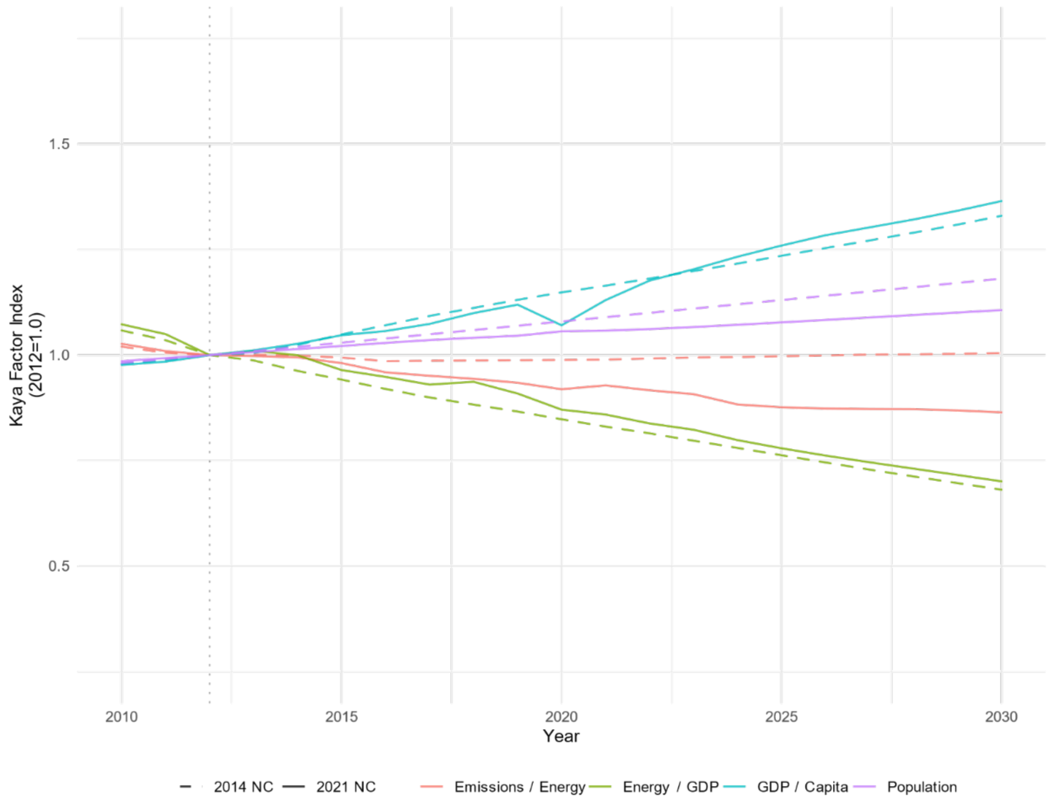


Source: U.S. EIA Annual Energy Outlook 2014,2015 2016, 2020, 2021, 2022. See Annex #4 describing the methodology for this chapter, including a description of the sources of information.

TOPDOWN ESTIMATE OF THE EFFECTS OF NEW POLICIES AND MEASURES

An analysis was conducted to disaggregate changes in emission projections due to macroeconomic factors from changes resulting from policies and measures and technology improvements. The analysis decomposes emissions into factors representing population, per capita GDP, energy intensity, and carbon intensity of energy, referred to as a Kaya analysis. Between the 2014 and 2022 National Communications, projections of population, GDP, energy use, and emissions all changed. By changing individual factors, the Kaya analysis can be used to associate proportions of the total change in emissions with each factor in the decomposition equation. By removing the portion of emission change due to population and GDP changes, the remaining emissions change associated with energy and emissions intensity is assumed to relate to new policies and measures, technological change, and energy market conditions over the time period when the two sets of projections were prepared.

Figure 5-6: Normalized Kaya Identity Factors Used for Assessing the Effects of New Policies and Measures



Source: See Annex #4 describing the methodology for this chapter, including a description of the sources of information.

KAYA ANALYSIS RESULTS:

- Within the macroeconomic drivers, population has consistently trended lower than had been projected in the 2014 National Communication. In 2020, the Coronavirus pandemic resulted in a gap between current projections of GDP/capita and the 2014 estimates. However, through 2030, GDP projections match those from 2014, which at lower population levels mean higher GDP per capita.
- The result of lower population and higher GDP/capita than had been projected in the 2014 National Communication balances out. Without improvements in energy or emissions intensity, we should expect similar energy use and emissions projections

in the 2021 Policy Baseline as in the 2012 policy baseline presented in the 2014 National Communication.

- While energy-intensity and emissions-intensity were both projected to decline over time in the 2012 Policy Baseline, the Kaya decomposition shows how those factors are now expected to evolve independently of macroeconomic drivers. Energy-intensity is somewhat higher than had been projected in 2014, while emissions-intensity is significantly lower.
- Very little of the change in gross emissions projections between the 2014 National Communication and 2022 National Communication for the years 2020, 2025, and 2030 are attributable to changes in macroeconomic expectations, most or all of the change, particularly in 2025 and 2030, is associated with the Kaya decomposition factors for energy-intensity and emissions-intensity. This indicates a total effect of policies and measures and technological change of about 1000 MMTCO_2e in 2025 and 1000 MMTCO_2e in 2030.

Table 5-4: Estimates of the Total Effect of New Policies and Measures and Technology Change

Changes Between 2014 NC and 2022 NC	2020	2025	2030
Gross Emissions (MMT CO_2e)	-940	-949	-1112
Percent of change associated with energy- and emissions-intensity factors	70 percent	100 percent	100 percent
Emissions change associated with energy- and emissions-intensity factors (MMT CO2e)	600	1000	1000

Notes:

[A] Due to uncertainty and sensitivity of Kaya analysis results, percent associations and MMT are presented with 1 significant figure.

[B] The approach used here to attribute relative share of emissions changes to different Kaya decomposition factors can lead to the conclusion that factors are responsible for more than 100 percent of changes. This happens here because current projected real GDP for 2025 and 2030 is higher than projected GDP was in the 2014 NC, so comparing projected emissions with normalized GDP projections would indicate an even larger emissions change than a simple comparison of projected emissions would.

While indicative, the Kaya decomposition is somewhat sensitive to methodological choices and adjustments. For example, to ensure comparability, it was necessary to convert the emissions projections from 2014 to AR4 GWP values, and to convert the GDP projections from 2014 to more recent year constant dollar values. Even after these conversions there were discrepancies in the historical series resulting from recalculations and methodological adjustments in the intervening years which limit comparability. Relative to the results of a similar analysis conducted in 2021, the current projected GDP is higher, which has led to a larger portion of emissions changes being attributed to energy- and emissions-intensity factors than in the 2021 National Communication analysis. Annex 4, Table A4-1 provides a summary of key factors underlying the current estimates for 2030 in comparison to previous projections.

Chapter 6.

CLIMATE CHANGE IMPACTS AND ADAPTATION

Chapter 6. CLIMATE CHANGE IMPACTS AND ADAPTATION

INTRODUCTION

Human activities have dramatically altered the world's climate, oceans, land, ice cover, and ecosystems, resulting in impacts on human health, agriculture, infrastructure, natural resources, and other sectors of the economy. In the United States, climate change has already resulted in more frequent heat waves, extreme precipitation, larger wildfires, and water scarcity. The last few years have seen record-breaking, climate-related weather extremes and continued decline in Arctic Sea ice. These are serious challenges that directly affect individuals, communities, and jobs across the nation and all over the world, and these trends are expected to continue in the future. The United States has scaled up actions that enhance the resilience of communities, infrastructure, and natural resources to the impacts of climate change domestically.[395] (The United States also supports partners around the world in building resilience to climate change; relevant information on these programs is reported in Chapter 7.)

The United States, with its geographic and economic diversity, is exposed to many different types of climate impacts, including droughts and wildfires, inland and coastal flooding, extreme heat, loss of permafrost and sea ice, ecosystem and biodiversity loss, and more. Chapter 2 outlines some of the changes in temperature and precipitation already experienced in the United States. Such climate impacts are expected to increasingly disrupt and damage critical infrastructure and property, labor productivity, and the vitality of rural and urban communities. The rising number of billion-dollar weather and climate disasters, shown in Figure 2-5 (2021 disasters) is one indication of the scale and costs of disasters affecting the United States.

Vulnerabilities are spread widely, but unevenly, across the United States. Disadvantaged communities are often at greater risk to harm from climate impacts. Future climate change is expected to further disrupt many areas of life, exacerbating existing challenges to prosperity posed by aging and deteriorating infrastructure, stressed ecosystems, and economic inequality. Thus, impacts will not be distributed equally. People who are already vulnerable, including lower-income and other historically marginalized communities, are

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[395] The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2022/08/01/fact-sheet-10-ways-the-biden-harris-administration-is-making-america-resilient-to-climate-change/

often at greater risk to harm from climate impacts and have lower capacity to prepare for and cope with extreme weather and climate-related events and are expected to experience greater impacts.

Regional economies and industries that depend on natural resources and favorable climate conditions, such as agriculture, forestry, outdoor recreation, tourism, and fisheries, are especially vulnerable to the growing impacts of climate change. Rising temperatures are projected to reduce the efficiency of power generation while increasing energy demands, resulting in higher electricity costs and energy burden for disadvantaged communities. Climate change also poses occupational threats to worker's health and safety. Without significant, rapid, and sustained reductions in global greenhouse gas (GHG) emissions, projected warming is expected to cause substantial net damage to the U.S. economy. In the 2020 report "Managing Climate Risk in the U.S. Financial System", the U.S. Commodity Futures Trading Commission found that climate change is already impacting nearly every facet of the economy and poses a major risk to the stability of the U.S. financial system.[396] The Congressional Budget Office projects that climate change will, on net, reduce average annual real Gross Domestic Product (GDP) growth by 0.03 percentage points from 2020 to 2050, relative to growth that would occur under the climatic conditions that prevailed at the end of the 20th century.[397] The growth differential accumulates to a 1.0 percent reduction in the projected level of real GDP in 2050.

Climate change increasingly threatens the livelihoods, economies, health, and cultural identities of all people, but the impacts are especially acute on Native Americans as interconnected social, physical, and ecological systems are disrupted. Many Tribes rely on, but face institutional barriers to~~,~~ self-determined management of water, land, other natural resources, and infrastructure that will be impacted increasingly by changes in climate. These institutional barriers include limited access to traditional territory and resources, which severely limits their adaptive capacities.

New observations and research have increased our understanding of past, current, and future climate change. An assessment of climate trends, impacts, and risks was published in the two volumes of the Fourth National Climate Assessment (NCA4), developed under the direction of the U.S. Global Change Research Program. The first volume, the Climate Science

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[396] U.S. Commodity Futures Trading Commission, https://www.cftc.gov/sites/default/files/2020-09/9-9-20%20Report%20of%20the%20Subcommittee%20on%20Climate-Related%20Market%20Risk%20-%20Managing%20Climate%20Risk%20in%20the%20U.S.%20Financial%20System%20for%20posting.pdf

[397] U.S. Congressional Budget Office, https://www.cbo.gov/system/files/2020-09/56505-Climate-Change.pdf

Special Report, published in 2017, provides a detailed analysis of how climate change is affecting the physical earth system. The second volume, published in 2018, focuses on the human, societal, and environmental elements of climate change and variability for 10 regions and 18 national topics, with particular attention paid to current and projected risks and impacts under different mitigation pathways and implications for risk reduction. Key findings of NCA4 are summarized in the Expected Impacts of Climate Change section below.

Actions to adapt to these present and future impacts of climate change are being taken at every scale of government and in every region. Adaptation actions across the nation have been supported by the U.S. federal government through many mechanisms and agencies, and also by state and local governments.

This chapter outlines, discusses, and provides examples of the following key topics:

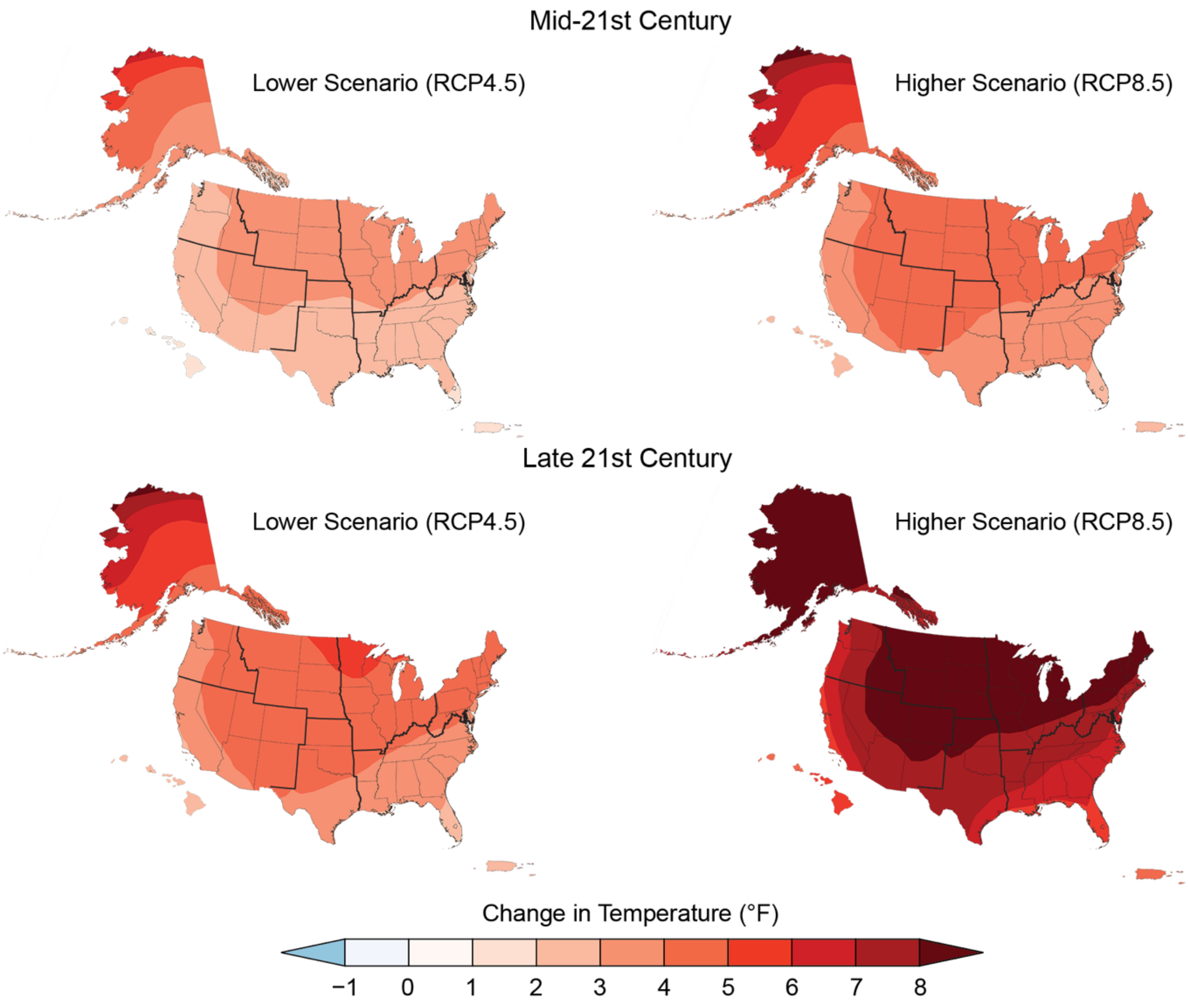
- Expected Impacts of Climate Change: Physical changes to the U.S. climate, driven by human activity
- Vulnerability Assessment: Climate risks to human activities in different regions and economic sectors of the U.S.
- Adaptation Actions: U.S. Government programs to support climate adaptation within the United States

EXPECTED IMPACTS OF CLIMATE CHANGE

The climate of the United States is strongly connected to the changing global climate. Global averaged surface air temperature has increased by about 1.0°C since the beginning of the 20th century, bringing us the warmest period in the history of modern civilization, and this trend is expected to continue. These warmer temperatures will bring changes in precipitation, a rise in sea levels, and more extreme weather events globally, including within the United States.

As described in Chapter 2, annual average temperature over the United States has risen, and observations are consistent with rapid warming since 1979. There have been marked changes in temperature extremes, with a decrease in the frequency of cold waves and an increase in the frequency of heat waves. Temperatures are projected to continue to rise. In the contiguous U.S., the period 2021-2050 is projected to be about 1.4°C warmer than the period 1976-2005 even in a future with substantial reductions in carbon emissions. Extreme temperatures are projected to increase even more than average temperatures, with less intense cold waves and more intense heat waves.

Figure 6-1: Projected Changes in U.S. Annual Average Temperatures



Source: USGCRP[398]

Annual average temperatures across the United States are projected to increase over this century, with greater changes at higher latitudes as compared to lower latitudes, and under a higher scenario (Representative Concentration Pathway (RCP)8.5; right) than under a lower one (RCP4.5; left). Figure 6-1 shows projected differences in annual average temperatures

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[398] Vose, R.S., D.R. Easterling, K.E. Kunkel, A.N. LeGrande, and M.F. Wehner, 2017: Temperature changes in the United States. In: *Climate Science Special Report: Fourth National Climate Assessment, Volume I* [Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 185-206, doi: 10.7930/J0N29V45.U.S. Global Change Research Program,

for mid-century (2036–2065; top) and end of century (2071–2100; bottom) relative to the near present (1986–2015).[399]

Precipitation patterns have changed, with some areas receiving more precipitation, some less, and warmer temperatures leading to a higher proportion of precipitation falling as rain than snow as compared to the past. Heavy precipitation events in most parts of the United States have increased in both intensity and frequency. Figure 2-4 in Chapter 2 illustrates these observed changes. Heavy precipitation events are projected to continue to increase over the 21st century with important regional and seasonal differences. The largest increases are expected to occur in the northeastern U.S.

The average sea level across the globe has risen at an alarming rate, with about 2.8 inches (7 cm) of rise occurring just since 1993. Sea level along the U.S. coastline is projected to rise, on average, 10 - 12 inches (0.25 - 0.30 meters) in the next 30 years (2020 - 2050), which will be as much as the rise measured over the last 100 years (1920 - 2020). Sea level rise will vary regionally along U.S. coasts because of changes in both land and ocean height. Sea level rise will create a profound shift in coastal flooding over the next 30 years by causing tide and storm surge heights to increase and reach further inland. By 2050, "moderate" (typically damaging) flooding is expected to occur, on average, more than 10 times as often as it does today and can be intensified by local factors. Current and future emissions matter. About 2 feet (0.6 meters) of sea level rise along the U.S. coastline is increasingly likely between 2020 and 2100 because of emissions to date. Failing to curb future emissions could cause an additional 1.5 - 5 feet (0.5 - 1.5 meters) of rise for a total of 3.5 - 7 feet (1.1 - 2.1 meters) by the end of this century.[400]

Recent droughts and heat waves have reached record intensity in some regions of the United States. Higher temperatures are driving increased evapotranspiration, reducing soil moisture. Further decreases in soil moisture are likely as the climate warms. This, along with the reduction in snowpack in the western U.S., means that chronic, long-duration hydrological drought is increasingly likely. This combination of factors has led to the increase in large forest fires in the western U.S. and Alaska, and forest fires are projected to further increase, with profound changes to certain ecosystems.[401]

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[399] *Ibid*.
[400] U.S. National Oceanic and Atmospheric Administration, https://oceanservice.noaa.gov/hazards/sealevelrise/noaa-nostechrpt01-global-regional-SLR-scenarios-US.pdf
[401] U.S. Department of Agriculture, https://doi.org/10.2737/WO-GTR-93b

VULNERABILITY ASSESSMENT

Climate change creates new risks and exacerbates existing vulnerabilities in communities across the United States, presenting growing challenges to human health and safety, quality of life, and the rate of economic growth. In a 2017 report, the U.S. Government Accountability Office reviewed two modeling frameworks focused on the U.S. with internally consistent climate and socioeconomic scenarios to analyze a broad range of sectoral impacts, finding that fiscal risks to the federal government could be large and that effects could be unevenly distributed across sectors and regions (GAO, 2017). [402]This section of the report describes identified vulnerabilities and summarizes some of the actions taken to address these vulnerabilities.

EPA's Climate Impacts and Risk Analysis project quantifies potential physical and economic damages of climate change to a large number of sectors in the U.S.,[403] [404]Projected impacts and damages across sectors reveal highly complex patterns, with each region of the country projected to experience a unique mix of physical and economic effects, with some regions experiencing compounding impacts (i.e., high vulnerability across multiple impact sectors, such as poor air quality and extreme temperature mortality). Recent additions to the project focus on the implications of climate change on ozone and fine particulates, health effects

[402] U.S. Government Accountability Office. 2017. Information on Potential Economic Effects Could Help Guide Federal Efforts to Reduce Fiscal Exposure. GAO-17-720

[403] Martinich, J., and A. Crimmins (2019). Climate damages and adaptation potential across diverse sectors of the United States. Nature Climate Change, 9, 397–404.

[404] U.S. Environmental Protection Agency, 2017: Multi-model Framework for Quantitative Sectoral Impacts Analysis: A Technical Report for the Fourth National Climate Assessment. EPA 430-R-17-001. U.S. Environmental Protection Agency (EPA), Washington, DC

from climate-driven wildfire emissions, extreme temperature effects on outdoor labor, Valley Fever incidence, and the effects of high-tide flooding on traffic delays.[405],[406],[407],[408],[409]

NCA4 found that impacts in many sectors fall disproportionately on those communities that are least able to anticipate, cope with, and recover from adverse impacts. For instance, it concluded that populations experiencing greater health risks include children, older adults, low-income communities, and some communities of color. To investigate these potential disparities, the U.S. Environmental Protection Agency (EPA) released a report Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts quantifying the degree to which four socially vulnerable populations— defined based on income, educational attainment, race and ethnicity, and age—may be more exposed to the highest impacts of climate change.[410]

WATER RESOURCES AND INFRASTRUCTURE

Water systems in the United States face considerable risk, even without anticipated future climate changes. Across the nation, much of the critical water and wastewater infrastructure is nearing the end of its useful life. Limited surface water storage, as well as a limited ability to make use of long-term drought forecasts and to trade water across uses and basins, has led to a significant depletion of aquifers in many regions in the country.[411]

A central challenge to water planning and management is learning to plan for plausible future climate conditions that are wider in range than those experienced in the 20th century.

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[405] Fann, N., C. Nolte, M. Sarofim, J. Martinich, and N. Nisokolas (2021). Associations between simulated future changes in climate, air quality, and human health. JAMA Network Open, doi:10.1001/jamanetworkopen.2020.32064.

[406] Neumann, J.E., M. Amend, S. Anenberg, P.L. Kinney, M. Sarofim, J. Martinich, J. Lukens, J.W. Xu, and H. Roman (2021). Estimating PM2.5-related premature mortality and morbidity associated with future wildfire emissions in the western US. Environmental Research Letters, 16.

[407] Neidell, M., J. Graff Zivin, M. Sheahan, J. Willwerth, C. Fant, M. Sarofim, and J. Martinich (2021). Temperature and work: Time allocated to work under varying climate and labor market contexts. PLOSONE, 16(8), 1–14.

[408] Gorris, M.E., J.E. Neumann, P.L. Kinney, M. Sheahan, and M.C. Sarofim (2020). Economic valuation of Coccidioidomycosis (Valley Fever) projections in the United States in response to climate change. Weather, Climate, and Society, 13, 107–123, doi:10.1175/WCAS-D-20-0026.1.

[409] Fant, C., J. Jacobs, P. Chinowsky, W. Sweet, N. Weiss, J. E. Sias, J. Martinich, and J. Neumann (2021). Mere Nuisance or Growing Threat? The Physical and Economic Impact of High Tide Flooding on US Road Networks. Journal of Infrastructure Systems Volume 27 Issue 4 - December 2021.

[410] U.S. Environmental Protection Agency, www.epa.gov/cira/social-vulnerability-report

[411] Reyes et al., 2019
https://www.sciencedirect.com/science/article/pii/S037837741931368X?via%3Dihub

Doing so requires approaches that evaluate plans over many possible futures instead of just one, incorporate real-time monitoring and forecast products to better manage extremes when they occur, and update policies and engineering principles based on an understanding and projection of climate-related changes.

To this end, federal agencies are establishing a long-term research and monitoring program to improve the understanding of the hydroclimatological changes in the major river basins of the Western United States. The program will include methodological evaluation and probabilistic modeling of future changes in the volumes of water naturally available and natural water cycle in the different regions of the West, taking into consideration the impacts of rising temperatures, changes to snowpack, hydrologic extremes, changes in the timing and quantity of runoff, and identify sources of uncertainty in the hydroclimatological outlook. The program will also include an assessment of associated impacts on ecosystems, aquatic biology, and food production.

While this represents a break from historical practice, recent examples of adaptation responses undertaken by large water management agencies, including major metropolitan water utilities and the U.S. Army Corps of Engineers, are promising. New York City, for example, altered existing operational guidelines to implement adaptive reservoir operations based on current hydrologic conditions to better meet new concerns for ecological flow requirements in addition to water supply goals.[412] Tampa Bay Water employed 1,000 scenarios of future demand and future supply to evaluate their preparedness for future conditions.[413] In another example, the International Joint Commission adopted a new operating plan for Upper Great Lakes water levels; the plan is based on the ability to provide acceptable performance, as defined by stakeholders, over thousands of possible future climates.[414] The plan includes forecast-based operations and a funded adaptive management process linking observatories and information systems to water-release decisions to address unanticipated change.[415] The U.S. Army Corps of Engineers is exploring

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[412] Kolesar, P., and J. Serio, 2011: Breaking the deadlock: Improving water-release policies on the Delaware River through operations research. Interfaces, 41 (1), 18–34. doi:10.1287/inte.1100.0536.
[413] Asefa, T., A. Adams, and N. Wanakule, 2015: A level-of-service concept for planning future water supply projects under probabilistic demand and supply framework. JAWRA Journal of the American Water Resources Association, 51 (5), 1272–1285. doi:10.1111/1752-1688.12309
[414] Brown, C., W. Werick, W. Leger, and D. Fay, 2011: A decision-analytic approach to managing climate risks: Application to the Upper Great Lakes. JAWRA Journal of the American Water Resources Association, 47 (3), 524–534. doi:10.1111/j.1752-1688.2011.00552.x.
[415] IUGLSB, 2012: Lake Superior Regulation: Addressing Uncertainty in Upper Great Lakes Water Levels. Final Report to the International Joint Commission. March 2012. International Upper Great Lakes Study Board, Ottawa, ON , 236 pp.

robustness to a wide range of trends and expected regret as metrics for evaluating flood management strategies,[416] including the increased incorporation of natural infrastructure.[417]

ENERGY INFRASTRUCTURE

The United States' economic security is dependent on an affordable and reliable supply of energy. Every sector of the economy depends on energy, from manufacturing to agriculture, banking, healthcare, telecommunications, and transportation. Increasingly, climate change and extreme weather events are affecting the energy system, threatening more frequent and longer-lasting power outages and fuel shortages. Such events can have cascading impacts on other critical sectors, potentially affecting the nation's economic and national security.

Hurricane Harvey, which struck Houston, Texas, in August 2017, provides a clear example of how impacts from extreme weather events can cascade through tightly connected natural, built, and social systems exposed to severe climate-related stressors. Harvey knocked out power to 300,000 customers in Texas,[418]with cascading effects on critical infrastructure facilities such as hospitals, water and wastewater treatment plants, and refineries. Eleven percent of U.S. refining capacity and a quarter of oil production from the U.S. Gulf of Mexico were shut down. Actual and anticipated gasoline shortages caused price spikes regionally and nationally. The energy sector is undergoing substantial policy, market, and technology-driven changes that are projected to affect this type of vulnerability.

The impacts of extreme weather and climate change on energy systems will differ across the United States. Low-lying energy facilities and systems located along inland waters or near the coasts are at increasing risk of flooding from more intense precipitation, rising sea levels, and more intense hurricanes. Increases in the severity and frequency of extreme precipitation are projected to affect inland energy infrastructure in every region. Rising temperatures and extreme heat events are projected to reduce the generation capacity of thermoelectric power plants and decrease the efficiency of the transmission grid. Rising temperatures are projected to also drive greater use of air conditioning and increase

[416] Spence, C. M., and C. M. Brown, 2016: Nonstationary decision model for flood risk decision scaling. Water Resources Research, 52 (11), 8650–8667. doi:10.1002/2016WR018981

[417] Poff, N. L., C. M. Brown, T. E. Grantham, J. H. Matthews, M. A. Palmer, C. M. Spence, R. L. Wilby, M. Haasnoot, G. F. Mendoza, K. C. Dominique, and A. Baeza, 2016: Sustainable water management under future uncertainty with eco-engineering decision scaling. Nature Climate Change, 6, 25–34. doi:10.1038/nclimate2765

[418] ERCOT, 2017: ERCOT Responds to Hurricane Harvey [web page]. Electric Reliability Council of Texas (ERCOT), http://www.ercot.com/help/harvey

electricity demand, likely resulting in increases in electricity costs and energy burden for disadvantaged communities. The increase in annual electricity demand across the country for cooling is offset only marginally by the relatively small decline in electricity demand for heating. Extreme cold events, including ice and snow events, can damage power lines and impact fuel supplies. Severe drought, along with changes in evaporation, reductions in mountain snowpack, and shifting mountain snowmelt timing, is projected to reduce hydropower production and threaten oil and gas drilling and refining, as well as thermoelectric power plants that rely on surface water for cooling. Drier conditions are projected to increase the risk of wildfires and damage to energy production and generation assets and the power grid.

COASTAL ECONOMIES

Rising water temperatures, ocean acidification, retreating Arctic Sea ice, sea level rise, hightide flooding, coastal erosion, higher storm surge, and heavier precipitation events threaten our oceans and coasts. These effects are projected to continue, putting ocean and marine species at risk, decreasing the productivity of certain fisheries, and threatening communities that rely on marine ecosystems for livelihoods and recreation, with particular impacts on fishing communities in Hawai'i and the U.S.-Affiliated Pacific Islands, the U.S. Caribbean, and the Gulf of Mexico.

Lasting damage to coastal property and infrastructure driven by sea level rise and storm surge is expected to lead to financial losses for individuals, businesses, and communities, with the Atlantic and Gulf Coasts facing above-average risks. Impacts on coastal energy and transportation infrastructure driven by sea level rise and storm surge have the potential for cascading costs and disruptions across the country. Nationally, a sea level rise of 1 meter could expose dozens of power plants that are currently out of reach to the risks of a 100-year flood (a flood having a 1 percent chance of occurring in a given year). This would put an additional cumulative total of 25 gigawatts (GW) of operating or proposed power capacities at risk.[419] In Florida and Delaware, sea level rise of 1 meter would double the number of vulnerable plants (putting an additional 11 GW and 0.8 GW at risk in the two states, respectively); in Texas, vulnerable capacity would more than triple (with an additional 2.8 GW at risk).

Even if significant emissions reductions occur, many of the effects from sea level rise over this century—and particularly through mid-century—are already locked in due to past emissions, and many communities are already dealing with the consequences. Actions to

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[419] U.S. Global Change Research Program, doi: 10.7930/J0N29V45.

adapt to more frequent, widespread, and severe coastal flooding, such as shoreline protection and conservation of coastal ecosystems, would decrease direct losses and cascading impacts on other sectors and parts of the country. More than half of the damages to coastal property are estimated to be avoidable through well-timed adaptation measures. Substantial and sustained reductions in global GHG emissions would also significantly reduce projected risks to fisheries and communities that rely on them.

AGRICULTURE

Climate change presents numerous challenges to sustaining and enhancing crop productivity, livestock health, and the economic vitality of rural communities. While some regions (such as the Northern Great Plains) may see conditions conducive to expanded or alternative crop productivity over the next few decades, overall, yields from major U.S. crops are expected to decline as a consequence of increases in temperatures and possibly changes in water availability, soil erosion, and disease and pest outbreaks. In 2012, severe drought impacted 80 percent of agricultural land in the United States, causing more than two-thirds of its counties to be declared disaster areas. The drought greatly affected livestock, wheat, corn, and soybean production in the Great Plains and Midwest and accounted for $14.5 billion in loss payments by the federal crop insurance program. In 2015, drought impacts to California's agricultural sector resulted in $1.84 billion in direct costs and a loss of 10,100 seasonal jobs.[420]

Increases in temperatures during the growing season in the Midwest are projected to be the largest contributing factor to declines in the productivity of U.S. agriculture. Projected increases in extreme heat conditions are expected to lead to further heat stress for livestock, which can result in large economic losses for producers. Climate change is also expected to lead to large-scale shifts in the availability and prices of many agricultural products across the world, with corresponding impacts on U.S. agricultural producers and the U.S. economy. These changes threaten future gains in commodity crop production and put rural livelihoods at risk. Numerous adaptation strategies are available to cope with adverse impacts of climate variability and change on agricultural production. These include altering what is produced, modifying the inputs used for production, adopting new technologies, and adjusting management strategies. However, these strategies have limits under severe climate change impacts and would require sufficient long – and short-term investment in changing practices.

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[420] U.S. National Oceanic and Atmospheric Administration, https://www.drought.gov/sectors/agriculture

FORESTS

Over the past two decades, a warm, dry climate has contributed to an increased area burned across the western United States.[421] Increased temperatures, drier conditions, and longer fire seasons with climate change will likely lead to increased fire frequency, area burned, and incidence of large fires in fire-prone forests across the country, including those in the West and Southeast.[422],[423]Annual area burned in the U.S. may increase by 2-6 times by mid-21st century compared to present, depending on ecosystem and local climate.[424], [425], [426]Wildfires will also likely be more difficult to suppress[427], with climbing costs for fire suppression. These changes in fire under projected climate change will likely result in increased smoke production, with implications for human health.[428],[429],[430]Decreases in forest stand density, coupled with hazardous fuel treatments, can increase forest resilience to fire. However, fuel treatments must be maintained over time to remain effective.[431]

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[421] Abatzoglou, J.T. and C.A. Kolden, 2013: Relationships between climate and macroscale area burned in the western United States. International Journal of Wildland Fire 22 (7): 1003–1020. Figure 1.

[422] Barbero, R., J.T. Abatzoglou, N.K. Larkin, C.A. Kolden, and B. Stocks. 2015. Climate change presents increased potential for very large fires in the contiguous United States. International Journal of Wildland Fire 24: 892–899.

[423] Liu, Z., M.C. Wimberly, A. Lamsal, T.L. Sohl, and T.J. Hawbaker, 2015: Climate change and wildfire risk in an expanding wildland–urban interface: A case study from the Colorado Front Range Corridor. Landscape Ecology 30 (10): 1943–1957.

[424] McKenzie, D., Z. Gedalof, D.L. Peterson, and P. Mote, P. 2004. Climatic change, wildfire, and conservation. Conservation Biology 18: 890–902.

[425] Litschert, S.E., T.C. Brown, and D.M. Theobald, 2012: Historic and future extent of wildfires in the Southern Rockies ecoregion, USA. Forest Ecology and Management 269: 124–133.

[426] Kitzberger, T., D.A. Falk, A.L. Westerling, and T.W. Swetnam, T.W. 2017. Direct and indirect climate controls predict heterogeneous early-mid 21st century wildfire burned area across western and boreal North America. PloS ONE 12: e0188486.

[427] Fried, J.S., J.K. Gilless, W.J. Riley, T.J. Moody, C.S. De Blas, K. Hayhoe, M. Moritz, S. Stephens, and M. Torn. 2008. Predicting the effect of climate change on wildfire behavior and initial attack success. Climatic Change 87: 251–264.

[428] McKenzie, D., U. Shankar, R.E. Keane, E.N. Stavros, W.E. Heilman, D.G. Fox, and A.C. Riebau. 2014. Smoke consequences of new wildfire regimes driven by climate change. Earth's Future 2(2): 35–59.

[429] Stavros, E.N., D. McKenzie, and N. Larkin. 2014. The climate–wildfire–air quality system: interactions and feedbacks across spatial and temporal scales. Wiley Interdisciplinary Reviews: Climate Change 5(6): 719–733.

[430] Litschert et al. 2012, Kitzberger et al. 2017.

[431] Agee. J.K., and C.N. Skinner. 2005. Basic principles of forest fuel reduction treatments. Forest Ecology and Management 211: 83–96.

Increasing extremes in precipitation, hurricanes, decreasing snowpack accumulation, and increasingly severe heatwaves are producing a number of other risks for forests and infrastructure supporting forest management and recreation. In many parts of the country worsening drought conditions are causing forest mortality through insect outbreaks, disease, and wildfire.[432] Drought-related mortality and resultant time-concentrated thinning and harvest efforts are producing shocks to lumber supplies for mills,[433] ,[434]yielding reduced investment and more mobile or temporary investments in mills in the western U.S.

Floods are endangering roads and bridges used to access forests for management, harvest, and recreation. Hydrologic projections are being used to improve road facility design and location in light of expected changes.[435] Increased drought, flooding, and heat waves are also disrupting water-related ecosystem services from forests, such as provision of clean drinking water and miles of high-quality aquatic habitat.[436] Riparian restoration activities, including development of more complex channels that better connect with floodplains, increase local habitat quality, reduce downstream flooding, and reduce thermal shocks to streams.[437]

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432 Vose, J. M., Clark, J. S., Luce, C. H., Patel-Weynand, T. (Eds.), 2016. Effects of Drought on Forests and Rangelands in the United States: A Comprehensive Science Synthesis. Gen. Tech. Rep. WO-93b. U.S. Department of Agriculture, Forest Service, Washington Office, Washington, D.C.

433 Insley, M., Lei, M., 2007, Hedges and trees: incorporating fire risk into optimal decisions in forestry using a no-arbitrage approach, Journal of Agricultural and Resource Economics, 492-514.

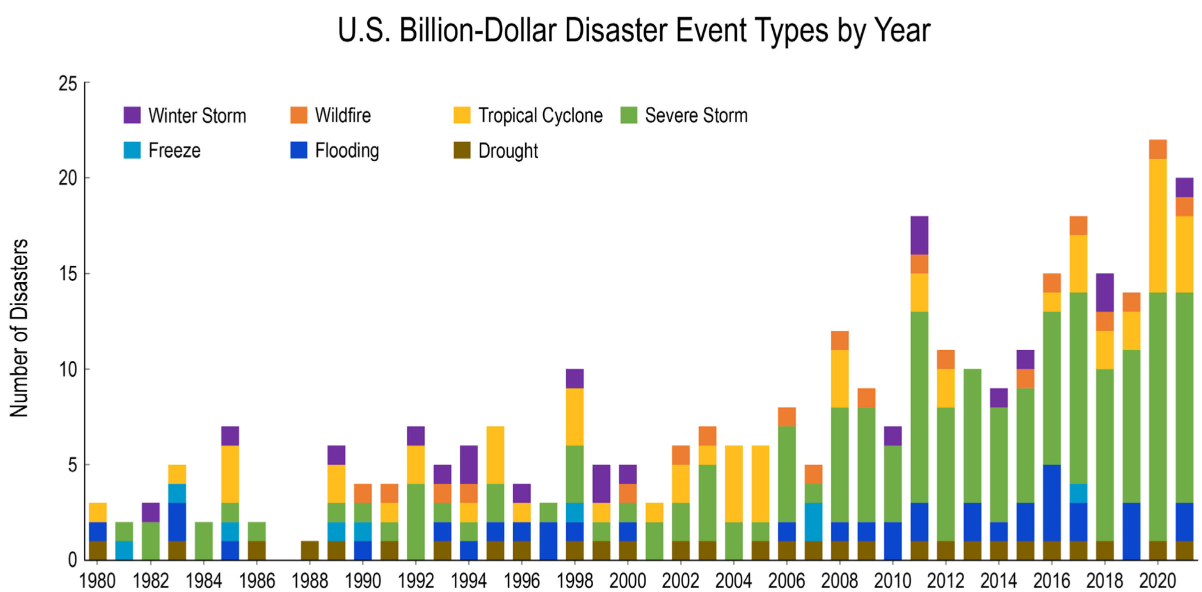
434 Sims, C., 2011, Optimal timing of salvage harvest in response to a stochastic infestation, Natural Resource Modeling, 24, 383-408.

435 Vose, J. M., Peterson, D. L., Domke, G. M., Fettig, C. J., Joyce, L. A., Keane, R. E., Luce, C. H., Prestemon, J. P., L.E. Band, Clark, J. S., Cooley, N. E., D'Amato, A., J.E. Halofsky. 2018. Forests [Ch. 6], pp. 232-267, In Reidmiller, D. R., Avery, C. W., Easterling, D. R., Kunkel, K. E., Lewis, K. L. M., Maycock, T. K., and Stewart, B. C., editors. Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II. U.S. Global Change Research Program, Washington, DC, USA.

436 Wenger, S. J., Isaak, D. J., Luce, C. H., Neville, H. M., Fausch, K. D., Dunham, J. B., Dauwalter, D. C., Young, M. K., Elsner, M. M., Rieman, B. E., Hamlet, A. F., Williams, J. E., 2011, Flow regime, temperature, and biotic interactions drive differential declines of trout species under climate change, Proceedings of the National Academy of Sciences, 108, 14175-14180, doi:10.1073/pnas.1103097108.

437 Luce, C. H., Morgan, P., Dwire, K., Isaak, D., Holden, Z., Rieman, B. 2012. Climate Change, Forests, Fire, Water, and Fish: Building resilient landscapes, streams, and managers, General Technical Report RMRS-GTR-290. USDA Forest Service, Fort Collins, CO.

Figure 6-2: Billion Dollar Disasters



Source: USGCRP[438]

Note: The bar graph shows the number of individual climate and weather events that caused more than one billion dollars of direct losses each year. The length of each bar corresponds to the annual number of events. These events are binned into seven hazard types, each represented by its own color.

In recent decades, the U.S. has experienced a rising number of weather and climate disasters that cause significant economic damages and societal losses. From 1980 to 2021, the annual average number of billion-dollar events was 7.7. For the most recent 5 years (2017–2021), the annual average was 17.8 events. 2021 had the second-highest number of events (20) following the year 2020 that set a new annual record of 22 events. 2021 is the seventh consecutive year (2015-2021) in which 10 or more billion-dollar weather and climate disaster events have impacted the United States. Events are included if they are estimated to cause more than one billion U.S. dollars in direct losses. The cost estimates of these events are adjusted for inflation using the Consumer Price Index and are based on costs documented in several Federal and private-sector databases.[439]

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[438] USGCRP, https://www.globalchange.gov/browse/indicator-details/4049.

[439] Smith, Adam B. (2020). U.S. Billion-dollar Weather and Climate Disasters, 1980 - present (NCEI Accession 0209268). [indicate subset used]. NOAA National Centers for Environmental Information. Dataset. https://doi.org/10.25921/stkw-7w73.

TRANSPORTATION

Transportation is the backbone of economic activity, connecting manufacturers with supply chains, consumers with products and tourism, and people with their workplaces, homes, and communities across both urban and rural landscapes. However, the ability of the transportation sector to perform reliably, safely, and efficiently is undermined by a changing climate. Heavy precipitation, coastal flooding, heat, wildfires, freeze–thaw cycles, and changes in average precipitation and temperature impact individual assets across all modes. These impacts threaten the performance of the entire network, with critical ramifications for economic vitality and mobility, particularly for vulnerable populations and urban infrastructure.

Sea level rise is progressively making coastal roads and bridges more vulnerable and less functional. On the U.S. East Coast alone, more than 7,500 miles of roadway are located in high tide flooding zones.[440] Many coastal cities across the United States have already experienced an increase in high tide flooding that reduces the functionality of low-elevation roadways, rail, and bridges, often causing costly congestion and damage to infrastructure. U.S. Route 17 in Charleston, South Carolina, for example, currently floods more than 10 times per year and is expected to experience up to 180 floods annually by 2045, with each flood costing the city approximately $13.75 million (in 2015 dollars).[441]

Inland transportation infrastructure is highly vulnerable to intense rainfall and flooding. Inland flooding, projected to increase over the coming century, threatens approximately 2,500 to 4,600 bridges across the United States and is anticipated to result in average annual damages of $1.2 to $1.4 billion each year by 2050 (in 2015 dollars, undiscounted, five-model average).220 In some regions, the increasing frequency and intensity of heavy precipitation events reduce transportation system efficiency and increase accident risk.

Record-breaking summer temperatures and heat waves have immediate and long-term impacts on transportation. Across the United States, 5.8 million miles of paved roads are susceptible to increased rutting, cracking, and buckling when sustained temperatures

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[440] Jacobs, J. M., L. R. Cattaneo, W. Sweet, and T. Mansfield, 2018: Recent and future outlooks for nuisance flooding impacts on roadways on the US East Coast. Transportation Research Record, doi:10.1177/0361198118756366.

[441] Sweet, W. V., R. E. Kopp, C. P. Weaver, J. Obeysekera, R. M. Horton, E. R. Thieler, and C. Zervas, 2017: Global and Regional Sea Level Rise Scenarios for the United States. NOAA Tech. Rep. NOS CO-OPS 083. National Oceanic and Atmospheric Administration, National Ocean Service, Silver Spring, MD, 75 pp. https://tidesandcurrents.noaa.gov/. publications/techrpt83_Global_and_Regional_SLR_Scenarios_for_the_US_final.pdf.

exceed 90°F.[442] High temperatures can stress bridge integrity and have caused more frequent and extended delays to passenger and freight rail systems and air traffic.

Transportation is not only vulnerable to impacts of climate change but also contributes significantly to the causes of climate change. In 2016, the transportation sector became the top contributor to U.S. GHG emissions. The transportation system is rapidly growing and evolving in response to market demand and innovation. This growth could make climate mitigation and adaptation progressively more challenging to implement and more important to achieve. However, transportation practitioners are increasingly invested in addressing climate risks, as evidenced in more numerous and diverse assessments of transportation sector vulnerabilities across the United States.

HUMAN HEALTH

Climate change has contributed to health risks. Increasing intensity and frequency of extreme heat can lead to fatalities. These impacts also disproportionately affect disadvantaged communities, Blacks in the United States are 52 percent more likely to reside in areas that are prone to heat-related risks, as are non-Hispanic Asians (32 percent) and Hispanics (21 percent), compared with non-Hispanic Whites. Additionally, warmer temperatures and changes to other meteorological variables can contribute to higher concentrations of fine particles and ozone.[443] The human health risks associated with these pollutants are well-established and can include premature mortality from cardiovascular and respiratory disease.[444] Wildfire smoke is also continuing to increase health risk. There are an estimated 7.4 million children in the United States affected by wildfire smoke annually, many of them in the Southeast, Pacific Northwest, and California. The increase in wildfires in recent years suggests that this population at risk has only grown. In parts of the USA, up to 20 percent of the fine particulate matter to which children are exposed results from wildfires. Due to our warming climate, the exposure to wildfire smoke is likely to only increase, with more children exposed to wildfire smoke as the century goes on.

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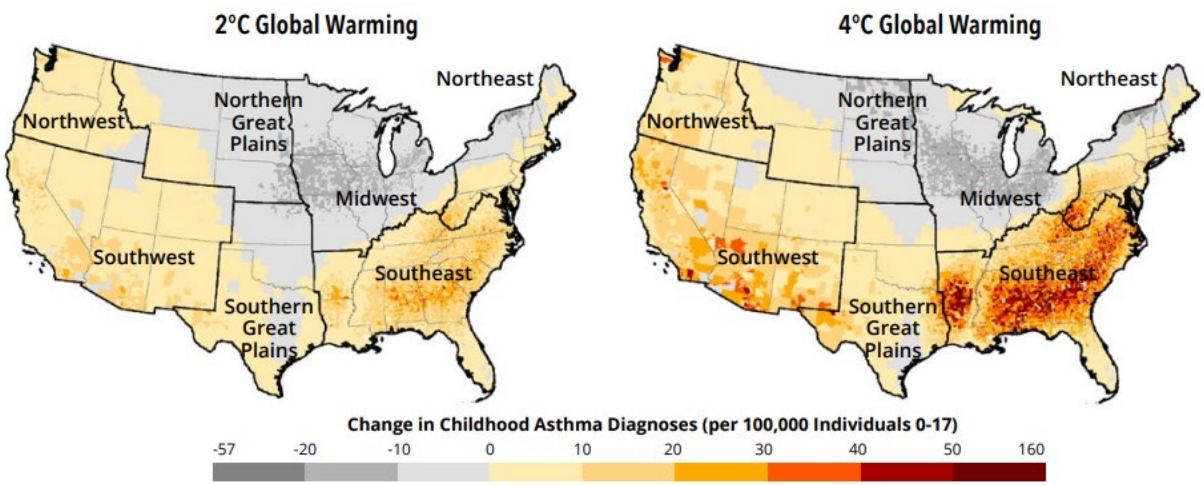
[442] Childress, A., E. Gordon, T. Jedd, R. Klein, J. Lukas, and R. McKeown, 2015: Colorado climate change vulnerability

[443] Fann et al., (2021). doi:10.1001/jamanetworkopen.2020.32064.

[444] USEPA (2019). Integrated Science Assessment (ISA) for Particulate Matter (Final Report, Dec 2019). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-19/188, 2019.

Figure 6-3: Projected Changes in Annual Childhood Asthma Diagnoses Due to Climate Change-Driven Effects on PM2.5



Source: U.S. EPA[445]

This figure shows the projected changes in childhood asthma diagnoses each year, by Census tract, due to climate-driven changes in $PM_{2.5}$ (levels of global warming are relative to the 1986-2005 average). Climate change is projected to increase the annual number of asthma diagnoses in children ages 0 to 17 in many regions of the United States, particularly the Southwest and Southeast. But these risks will not be equally distributed across populations of the country. For example, Black and African American children are 34 percent more likely to currently live in areas with the highest risk with 2°C global warming, and 41 percent more likely with 4°Celsius of global warming.[446]

Rising air and water temperatures and more intense extreme events are expected to increase exposure to waterborne and foodborne diseases, affecting food and water safety. The frequency and severity of allergic illnesses, including asthma and hay fever, are expected to increase as a result of a changing climate. Climate change is also projected to alter the geographic range and distribution of disease-carrying insects and pests, exposing more people to ticks that carry Lyme disease and mosquitoes that transmit viruses such as Zika,

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[445] EPA. 2021. Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts. U.S. Environmental Protection Agency, EPA 430-R-21-003. www.epa.gov/cira/social-vulnerability-report ; Figure 3.3.

[446] EPA. 2021. Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts. U.S. Environmental Protection Agency, EPA 430-R-21-003. www.epa.gov/cira/social-vulnerability-report.

West Nile, and dengue, with varying impacts across regions. Communities in the Southeast, for example, are particularly vulnerable to the combined health impacts from vector-borne disease, heat, and flooding. Extreme weather and climate-related events can have lasting mental health consequences in affected communities, particularly if they result in degradation of livelihoods or community relocation. Populations including older adults, children, low-income communities, and some communities of color are often disproportionately affected by, and less resilient to, the health impacts of climate change. Adaptation and mitigation policies and programs that help individuals, communities, and states prepare for the risks of a changing climate reduce the number of injuries, illnesses, and deaths from climate-related health outcomes.

ADAPTATION MEASURES

Across the United States, many regions and sectors are already experiencing the direct effects of climate change. For these communities, climate impacts—from extreme storms made worse by sea level rise, to longer-lasting and more extreme heat waves, to increased frequency and severity of wildfires and floods—are an immediate threat, not a far-off possibility. Because these impacts are expected to increase over time, communities throughout the United States face the challenge not only of reducing GHG emissions, but also of adapting to current and future climate change to help mitigate climate risks. This section describes some of the actions undertaken to adapt to climate change, in addition to the measures taken to address vulnerabilities described above.

Adaptation takes place at many levels—national and regional leadership is important for providing support, and most adaptation actions are implemented locally —as governments, businesses, communities, and individuals respond to today's altered climate conditions and prepare for future change based on the specific climate impacts relevant to their geography and vulnerability. It remains difficult to tally the extent of adaptation implementation in the United States because there are no common reporting systems, and many actions that reduce climate risk are not labeled as climate adaptation.[447] The 2018 NCA4 found that community awareness and planning for extreme climate events is underway throughout the United States, but more widespread and robust on-the-ground implementation efforts are needed to increase community resilience. Identifying strategies that deliver co-benefits for

[447] Vogel, J., K. M. Carney, J. B. Smith, C. Herrick, M. Stults, M. O'Grady, A. S. Juliana, H. Hosterman, and L. Giangola, 2016: Climate Adaptation–The State of Practice in U.S. Communities. Kresge Foundation, Detroit. http://kresge.org/ sites/default/files/library/climate-adaptation-the-state-of-practice-in-us-communities-full-report.pdf.

mitigation of GHGs and other pollution, public health, economic growth and job creation, national security and environmental justice will be central to building a more resilient future.

As part of an all-of-government approach to tackling the climate crisis, President Biden directed his cabinet-level National Climate Task Force to "increase resilience to the impacts of climate change."[448] As detailed in the United States' 2021 Adaptation Communication, the Administration is advancing a multi-prong strategy for better assisting communities and their leaders, institutions, businesses, and residents to build a more resilient future, by: (1) improving community resilience planning; (2) promoting the design and construction of resilient infrastructure; (3) measuring, disclosing, managing, and mitigating climate-related financial risks to communities and the U.S. economy; (4) conserving and restoring lands and waters; and (5) advancing innovative and measurable resilience solutions.[449]

Domestically, key adaptation and resilience initiatives of the Biden-Harris Administration include:

- **Strengthening interagency coordination on major threats:** The National Climate Task Force has established Interagency Working Groups, led by high-level agency leaders, that focus on specific, high-impact climate threats. These groups are leading new federal efforts to address coastal impacts,[450] drought,[451] extreme heat,[452] flooding,[453] and wildfires.[454] The Administration has also launched major new

[448] The White House. https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/27/executive-order-on-tackling-the-climate-crisis-at-home-and-abroad/

[449] November 2021 Adaptation Communication of the United States. https://unfccc.int/sites/default/files/resource/USA%20Full%20Adaptation%20Communication%202021.11.2%209am_.pdf.

[450] Coastal Resilience Interagency Working Group. https://www.noaa.gov/coastal-resilience-interagency-working-group.

[451] Drought Resilience Interagency Working Group 1-Year Summary Report. https://www.usda.gov/media/press-releases/2022/06/01/biden-harris-administration-drought-resilience-interagency-working.

[452] The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2022/07/26/fact-sheet-10-ways-the-biden-harris-administration-is-responding-to-extreme-heat/.

[453] The White House. https://www.whitehouse.gov/ceq/news-updates/2021/08/27/readout-of-the-first-white-house-flood-resilience-interagency-working-group-meeting-on-implementation-of-the-federal-flood-risk-management-standard/.

[454] The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2022/07/28/fact-sheet-the-biden-harris-administration-continues-efforts-to-address-growing-wildfire-threat/.

interagency efforts to accelerate adoption of modern building codes[455] and to address climate-related financial risk.[456]

- **Securing historic new resilience funding:** Both the Bipartisan Infrastructure Law and the Inflation Reduction Act provide significant new investments to help communities build resilience to extreme weather. For example, the Federal Emergency Management Agency (FEMA) is using Bipartisan Infrastructure Law funding to expand the Building Resilient Infrastructure and Communities program, which provides grants to local communities taking action to reduce disaster suffering and avoid future disaster costs. In line with the White House's Justice40 Initiative, these Administration is working to deliver at least 40% of overall program benefits to disadvantaged communities.[457]
- **Enhancing climate data and planning tools for communities:** The Administration launched a Climate Mapping for Resilience and Adaptation Portal with a live dashboard to help communities see extreme weather and other hazards from climate change they are facing, as well as maps projecting how each community could be impacted in the future and guides on federal resources to assist state, local, Tribal, and territorial governments.[458] This new web portal is part of a broader National Climate Task Force initiative to provide more accessible climate information and decision tools, including a redesigned Climate.gov and a new Heat.gov.[459]
- **Advancing nature-based solutions:** The Administration issued a Nature-Based Solutions Roadmap to help scale up actions to protect, sustainably manage, or restore natural or modified ecosystems in order to provide a range of benefits, including

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455 The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2022/06/01/fact-sheet-biden-harris-administration-launches-initiative-to-modernize-building-codes-improve-climate-resilience-and-reduce-energy-costs/.
456 The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2021/10/15/fact-sheet-biden-administration-roadmap-to-build-an-economy-resilient-to-climate-change-impacts/.
457 The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2022/08/01/fact-sheet-10-ways-the-biden-harris-administration-is-making-america-resilient-to-climate-change/.
458 The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2022/09/08/fact-sheet-biden-harris-administration-launches-new-climate-portal-to-help-communities-navigate-climate-change-impacts/.
459 The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2021/10/12/fact-sheet-biden-administration-makes-climate-information-and-decision-tools-more-accessible/.

climate resilience.[460] This Roadmap builds on other key Administration efforts to enlist nature in the fight against climate change, including the America the Beautiful challenge to conserve 30% of U.S. lands and waters by 2030[461] and President Biden's Executive Order on Strengthening the Nation's Forests, Communities, and Local Economies.[462]

- **Leading by example across federal operations:** As directed by President Biden, in October 2021 more than 20 federal agencies released plans outlining steps to ensure their facilities and operations adapt to and are increasingly resilient to climate change impacts.[463] Building on these plans, in October 2022 agencies released Climate Adaptation Progress Reports on actions to address a broad range of climate risks, including to programs, facilities, worker safety, supply chains, grants, and contracts.[464]

These new and expanded initiatives build on longstanding federal efforts. For example, the U.S. Global Change Research Program coordinates the interagency Federal Adaptation and Resilience Group (FARG), which brings together over 100 experts from bureaus and agencies across the Federal Government. The FARG helps share information and experience, produce publications, and support co-investment and co-development of tools and information resources to help agencies align their climate adaptation strategies and priorities. Additionally, the Climate Resilience Toolkit, operated under the U.S. Global Change Research Program and managed by the National Oceanic and Atmospheric Administration's (NOAA) Climate Program Office, is designed to help people find and use tools, information, and

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[460] The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2022/11/08/fact-sheet-biden-%E2%81%A0harris-administration-announces-roadmap-for-nature-based-solutions-to-fight-climate-change-strengthen-communities-and-support-local-economies/.
[461] The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2021/12/20/fact-sheet-biden-harris-administration-celebrates-expansion-of-locally-led-conservation-efforts-in-first-year-of-america-the-beautiful-initiative/.
[462] The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2022/04/22/fact-sheet-president-biden-signs-executive-order-to-strengthen-americas-forests-boost-wildfire-resilience-and-combat-global-deforestation/.
[463] The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2021/10/07/fact-sheet-biden-administration-releases-agency-climate-adaptation-and-resilience-plans-from-across-federal-government/.
[464] The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2022/10/06/fact-sheet-biden-harris-administration-strengthens-the-federal-governments-resilience-to-climate-change-impacts/.

subject matter expertise to build resilience. The Toolkit includes case studies, the "Steps to Resilience" framework to help guide decision-making, and the Climate Explorer, an interactive tool to view historic and projected climate parameters for any county in the contiguous United States, as well as other resources.[465]

As noted above, climate change impacts many sectors and regions of the United States, and so adaptation measures have to address many fronts. Below are illustrative examples of federal agencies taking adaptation actions in response to the vulnerabilities identified above.

WATER INFRASTRUCTURE

EPA's Office of Water is supporting water utilities nationwide in preparing for the impacts of climate change through many publicly available tools and resources. For example, the Climate Resilience Evaluation and Awareness Tool (CREAT) is a risk assessment application that helps utilities adapt to climate change impacts by providing a better understanding of current and long-term weather conditions. Utility managers and policy makers can find out which extreme weather events pose significant challenges in their area and build scenarios to identify potential impacts, identify critical assets and potential actions to protect those assets from the consequences of extreme weather on utility operations, and generate reports describing the costs and benefits of risk reduction strategies. CREAT is just one of a range of tools and resources available under the Creating Resilient Water Utilities initiative.

Additionally, to help plan and design water treatment systems to prevent overflow of untreated water into rivers, lakes, and other water bodies, EPA scientists are investigating the increased occurrence and intensity of extreme precipitation events. This research is important to help states, cities, and communities better prepare for increases in precipitation to reduce potential public health and environmental impacts. The information also can enable cities and rural areas to better prepare and respond to frequent flooding from extreme precipitation to protect public health and property.
The U.S. Bureau of Reclamation is leveraging a range of tools to mitigate drought impacts, including new water supply and infrastructure projects to increase drought resiliency, reduce reliance on declining water sources, and increase efficiency in deliveries. Reclamation is also collaborating with partners across the West on projects to improve water management through the development of science and technologies, improved modeling and forecasting tools, and long-term planning efforts to develop innovative strategies to address hydrologic changes. The Inflation Reduction Act provided an additional $4 billion for activities to mitigate

[465] U.S. Climate Resilience Toolkit. https://toolkit.climate.gov/

the impacts of drought in the Reclamation States, with priority given to the Colorado River Basin and other basins experiencing comparable levels of long-term drought.

COASTAL IMPACTS

The Coastal Resilience Interagency Working Group (IWG) was formed by the National Climate Task Force in June 2021 (see box above) and is co-led by the Council on Environmental Quality and National Oceanic and Atmospheric Administration. It aims to elevate, coordinate, and accelerate the federal government's efforts to increase the resilience of the nation's coasts and coastal communities by aligning major grant, data-sharing, and mapping programs to more efficiently and equitably meet the investment decision-making needs of state, local, Tribal, and territorial.

In early 2022, NOAA released an application guide for its 2022 Sea Level Rise Technical Report.[466] The guide is intended to help community planners and decision makers plan for sea level rise, by arriving at an approach that is best suited for their communities based on local considerations. The Federal government also funded many coastal resilience efforts around the country and increased funding support for Tribal communities at risk from sea level rise and coastal storms. Through the Bipartisan Infrastructure Law, over $200 million went to the Bureau of Indian Affairs to support community-led relocation efforts and Tribal climate resilience and adaptation projects.

AGRICULTURE AND FORESTRY

The U.S. Department of Agriculture (USDA) addresses climate adaptation through many of its programs and activities, one example of which is the Climate Hubs, a unique cross-agency collaboration. The USDA Climate Hubs[467] develop and deliver science-based information and technologies to natural resource and agricultural managers to enable climate-informed decision making, reduce agricultural risk, and build resilience to climate change. Since 2014, the ten regional Climate Hubs have been helping farmers, ranchers, forest and land managers, and rural communities plan for and manage weather – and climate-related risks and vulnerabilities. The Climate Hubs are a unique collaboration across USDA's agencies. The regional Hubs are led and hosted by the Agricultural Research Service and United States Forest Service, with contributions from many USDA agencies including the NRCS, among others. The Climate Hubs link USDA research and program agencies in their regional delivery

[466] National Oceanic and Atmospheric Administration.
https://oceanservice.noaa.gov/news/jun22/sealevelrise-report-guide.html
[467] https://www.climatehubs.usda.gov

of timely and authoritative tools and information to forest managers, farmers, ranchers and other stakeholders.

The Climate Hubs are a focal point for delivering accessible, usable research and tools for both climate adaptation and mitigation in the agriculture and forestry sectors and rural economies, towards building resilience. The USDA Climate Hubs' work focuses on three main areas: 1) science and data synthesis, 2) tool and technology co-development and support and 3) outreach, convening, and training to help stakeholders implement climate-smart adaptation strategies. In each of these areas, the Hubs work closely with extension organizations, universities, technical service providers, and the private sector to be a source of user-friendly information and tool developed from a wide variety of sources. The Hubs work at the regional, state, Tribal and local levels to improve access to usable regional information and climate change projections and forecasts in support of risk management and climate adaptation planning.

In 2021, the National Institute of Food and Agriculture under USDA initiated a new competitive grants program, "Extension, Education & USDA Climate Hubs Partnerships." Funded projects will provide effective, translatable, and scalable approaches to address climate change through regional partnerships. The Cooperative Extension System will utilize its nationwide network of local county/parish extension offices and staff to expand the reach of the Climate Hubs and support private landowners and agricultural producers in implementing climate-smart agriculture and forestry practices.

TRANSPORTATION

The 2021 Bipartisan Infrastructure Law (BIL) initiated a number of new programs targeted at mitigating the impacts of climate change and increasing the resilience of the surface transportation system. This includes programs targeted at reducing the emissions of the transportation system as a whole, including pavement as well as the vehicles, advancing electric vehicle infrastructure, and supporting low-emissions alternative transportation modes. The BIL also includes the Department of Transportation's new Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation (PROTECT) program, providing $8.7 billion over five years to states, localities, and other agencies to bolster the resilience of their transportation infrastructure and improve evacuation routes and coastal resilience. In addition, the Federal Highway Administration (FHWA) under the Department of Transportation is promoting climate resilience through its technical guides and trainings aimed at informing the design and maintenance of highways across the nation. This includes published National Highway Institute courses on understanding future climate conditions and adaptation analysis for highway project managers.

HUMAN HEALTH

On January 27, 2021, President Biden directed the Secretary of the Department of Health and Human Services to establish an Office of Climate Change and Health Equity to address the impact of climate change on the health of the American people.[468] Under the direction of the Assistant Secretary for Health, the Office of Climate Change and Health Equity (OCCHE) was established later that year. OCCHE addresses the impact of climate change on the health of the American people, serving as a department-wide hub for climate change and health policy, programming, and analysis, in pursuit of environmental justice and equitable health outcomes. Major products from OCCHE have included the Climate and Health Outlook[469] -- a first-ever seasonal forecast on the health impacts of climate hazards -- and a compendium of federal resources to support health sector resilience and emissions reduction.[470] As part of meeting the commitments made to the COP26 Health Program,[471] OCCHE also coordinates across the federal government – including the Veterans Health Administration, Indian Health Service, and Military Health System – to prepare federal health systems for the effects of climate change and achieve net-zero emissions by 2050.

The Centers for Disease Control and Prevention (CDC) Environmental Public Health Tracking Heat and Health Tracker with input from NOAA and the National Weather Service provides local heat and health information so communities can better prepare for and respond to extreme heat events. This includes monthly and future projections of the expected number of days that are at or above a dangerous level of heat based on climatological norms. The Heat and Health Tracker also includes a Heat Related Illness and Temperature map of the rate of emergency department (ED) visits associated with heat-related illness per 100,000 ED visits by region.

BUILDING ON PROGRESS

The Biden Administration has made significant strides on supporting adaptation planning and implementation, through legislation like the Infrastructure Investment and Jobs Act and Executive Orders such as Tackling the Climate Crisis at Home and Abroad. From updating

[468] https://www.federalregister.gov/documents/2021/02/01/2021-02177/tackling-the-climate-crisis-at-home-and-abroad.
[469] https://www.hhs.gov/climate-change-health-equity-environmental-justice/climate-change-health-equity/climate-health-outlook/index.html.
[470] https://www.hhs.gov/climate-change-health-equity-environmental-justice/climate-change-health-equity/actions/health-care-sector-pledge/federal-resources/index.html.
[471] https://www.who.int/initiatives/alliance-for-transformative-action-on-climate-and-health/cop26-health-programme

flood standards to investing in research and technology development, the whole-of-government approach to preparing for the impacts of climate change is making progress and will have benefits for many years to come. Many of these policies and investments are just getting underway, and future National Communications will provide a look at their implementation.

Chapter 7.

SUPPORTING THE GLOBAL COMMUNITY

Chapter 7. SUPPORTING THE GLOBAL COMMUNITY

INTRODUCTION

This chapter provides information on U.S. climate finance by channels and instruments, thematic pillar, and region; describes U.S. efforts to mobilize private climate finance; and illustrates examples of U.S. support for the development and deployment of technology and capacity building in developing countries. Consistent with the United Nations Framework Convention on Climate Change (UNFCCC) reporting guidance, the data and examples in this chapter focus on programs funded in Fiscal Years (FY) 2019-2020 (October 1, 2018-September 30, 2020). Data and examples related to strategies and initiatives since October 1, 2020 will be provided in the first Biennial Transparency Report submitted under the Paris Agreement in 2024.

The climate crisis represents an existential threat to the security and prosperity of communities around the world. Tackling the climate crisis is a central priority for U.S. foreign policy and national security and has been integrated into the core of U.S. foreign assistance. The United States is committed to leading efforts to mobilize resources for developing countries in their efforts to mitigate and adapt to climate change. This commitment is underscored in President Biden's January 2021 Executive Order on Tackling the Climate Crisis at Home and Abroad, the April 2021 U.S. International Climate Finance Plan, the March 2022, the U.S. Department of State (DOS)-United States Agency for International Development (USAID) Joint Strategic Plan, the July 2022 USAID Climate Strategy 2022-2030, the October 2022 U.S. National Security Strategy, and many other U.S. government strategies and initiatives.

Climate finance, technology development and transfer, and capacity building are fundamental to these efforts. The United States is using the full range of institutions—bilateral and multilateral—to scale up financial flows for climate action, mobilize public and private finance, and invest strategically in a sustainable future. This includes helping communities anticipate, prepare for and manage climate change impacts; establishing the enabling conditions for climate-resilient, low-emissions development; reducing land-based emissions through conservation, sustainable management, and restoration; supporting the transition to clean energy; facilitating the establishment of high-integrity markets; supporting partner countries to establish and achieve ambitious NDC targets; and mobilizing public and private climate finance. The United States is working to ensure that its capacity-building and investment support is efficient, effective, innovative, based on country-owned plans and strategies, and focused on achieving measurable results with a long-term view toward economic prosperity, inclusion of historically marginalized and underprivileged populations, and environmental sustainability.

The United States has made tackling the climate crisis at home and abroad a top priority. The United States has consistently maintained support for developing countries to address the climate crisis, including through technical assistance, capacity building, technology development and transfer, and investments. The Biden Administration is committed to enhancing this leadership and pledged in 2021 to work with Congress to quadruple, by 2024, its international public climate finance to developing countries, relative to the previous high-water mark for U.S. climate finance, FY 2013- 2016, to over $11 billion per year. As part of this effort, adaptation finance would be increased six-fold to over $3 billion per year. Future reports on the relevant fiscal years will contain additional detail on this renewed leadership.

The United States also remains committed to working with other developed countries to collectively mobilize $100 billion per year in climate finance as soon as possible, drawing on a wide variety of sources to respond to the needs and priorities of developing countries in the context of meaningful mitigation actions and transparency on implementation.

FINANCING CLIMATE CHANGE ACTION–OVERVIEW OF U.S. CLIMATE FINANCE IN FISCAL YEARS 2019-2020

Between FY 2019-2020, the United States committed $3.34 billion to help developing countries mitigate and adapt to the adverse effects of climate change. As illustrated in Table 7-1, this finance can be explored across a number of dimensions—including the institutional channels through which it is delivered, the financial instruments used, the geographies targeted, and its ultimate end use in terms of building resilience, reducing emissions, or conserving, restoring, and sustainably-managing land.

Table 7-1: Dimensions of U.S. Climate Finance

Channels	Instruments	Geography	Use (or "Pillar")

Bilateral channels
• Grant-based bilateral climate assistance
• Development finance
• Export credit
	• Grants
	• Loans
	  • Concessional
	  • Market Rate
	• Loan Guarantees
	• Insurance
		• Country-specific activities
		• Global, regional, and multi-country activities
			• Adaptation
			• Clean Energy
			• Sustainable Landscapes

Multilateral channels • Multilateral climate change funds • Multilateral development banks			

CLIMATE FINANCE CHANNELS

The United States provides climate finance through both bilateral and multilateral channels.

BILATERAL CHANNELS

From FY 2019-2020, the United States committed more than $3.07 billion in bilateral climate finance to its developing country partners. This finance was provided in one of three forms:

Grant-based bilateral climate assistance—This finance is programmed directly through country-specific, regional, and global programs. Grant-based programs, and those supported by cooperative agreements and contracts, are mainly administered by USAID but are also supported by the Department of State, the Millennium Challenge Corporation (MCC), and other U.S. government agencies. This assistance amounted to $1.58 billion from FY 2019-2020.

Development finance—The United States, primarily through the Development Finance Corporation (DFC) (formerly the Overseas Private Investment Corporation and USAID's Development Credit Authority), is one of the world's largest financiers of clean energy projects in developing countries, committing more than $1.47 billion through bilateral development finance agencies from FY 2019-2020. In addition to standard lending, DFC provides senior secured loans to private equity funds—making it one of the largest supporters of private equity funds in developing countries—and political risk insurance to project lenders and equity investors operating in emerging markets.

Export credit—From FY 2019-2020, the Export-Import Bank of the United States (EXIM) committed $13.8 million of financing to support climate-specific activities in developing countries.

MULTILATERAL CHANNELS

Multilateral climate change funds—These entities feature institutional structures governed jointly by governments. They play an important role in promoting a coordinated, global response to climate change. From FY 2019-2020, the United States committed $274.3 million to multilateral climate change funds. This includes funding for the Global Environment Facility (GEF) ($184.4 million).

Multilateral development banks (MDBs)—U.S. contributions to the MDBs, as well as those from other development partners, play a key role in enabling these institutions to provide billions in climate support to developing countries. From 2019-2020, the MDBs committed more than $79.5 billion in total climate finance for low- and middle-income economies. However, since countries' contributions to MDBs are not earmarked for specific purposes, it is not possible to specify the exact proportion of U.S. support that ultimately finances climate change activities in developing countries. Thus, U.S. contributions to the ordinary capital resources of the MDBs are not included in figures presented in this chapter. Although we do not include it here, MDB financing for climate activities is included in the $100 billion climate finance goal according to the methodology developed by the Organization for Economic Co-operation and Development (OECD).

Annex 5 contains information on U.S. provision of public financial support: contributions through multilateral channels for FY 2019 and 2020 (biennial report common tabular format 7a). It also contains a summary of U.S. provision of public financial support: contributions through bilateral, regional and other channels. The full version of common tabular format 7b can be found in the electronic common tabular format submissions for Biennial Report 5.

Annex 6 describes the methodology for reporting information about the provision of public financial support.

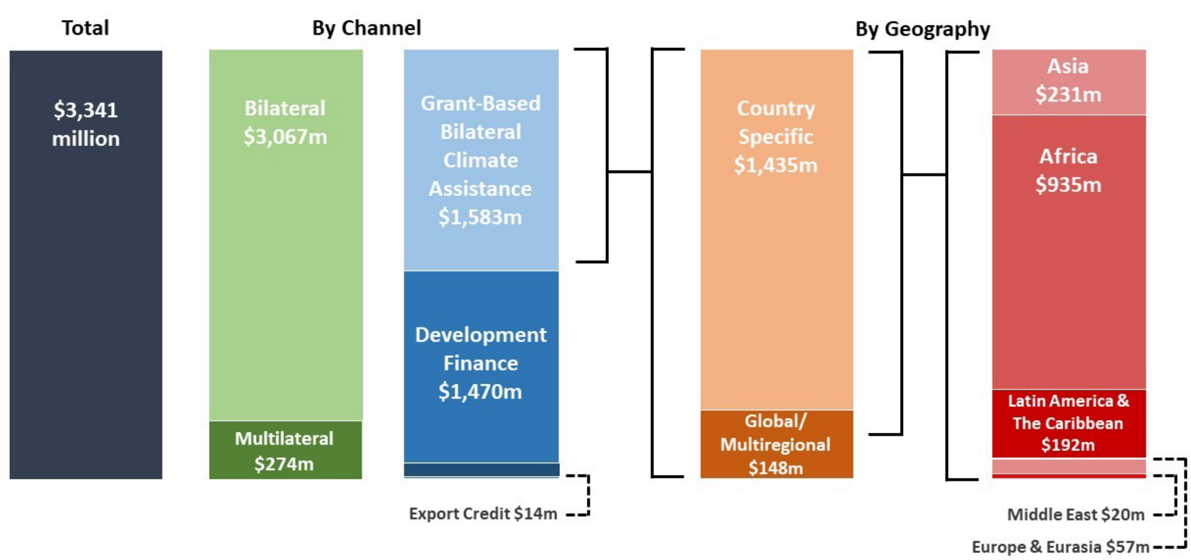
FINANCIAL INSTRUMENTS

The United States uses a range of financial instruments and interventions to mobilize climate finance through these channels. These include grants; risk mitigation tools such as guarantees and insurance; and low-cost, long-term debt financing, including both concessional and market-rate loans. Together, these instruments are helping to mobilize finance by providing a robust, yet flexible, toolkit that is prioritized and adapted according to each country's unique needs, circumstances, and specific financing and investment barriers. From FY 2019-2020, the U.S. provided climate finance predominantly in the form of grants ($1.86 billion), followed by concessional and market-rate loans ($1.36 billion), loan guarantees ($73.9 million), and insurance products ($51.9 million).

GEOGRAPHY

U.S. climate finance is provided through both country-specific programs and multi-country programs that often have a regional or global focus. While finance provided by DFC and EXIM is more demand-driven and available for all eligible countries to access, U.S. grant-based assistance (other than funds used for multilateral activities) is often designated by Congress for specific countries or regions, with the exception of funds that are appropriated for multilateral climate activities. Figure 7-1 presents a geographic breakdown of U.S. congressionally appropriated assistance that can be attributed to a particular region. From FY 2019-2020, approximately 14.6 percent of this finance went to Asia, 59.1 percent to Africa, 12.1 percent to Latin America and the Caribbean, 9.3 percent to global or multi-regional programming, and the balance to developing economies in Europe and the Middle East.

Figure 7-1: Geographic Breakdown of U.S. Climate Finance: FY2019-2020



Note: Figures are in millions of USD

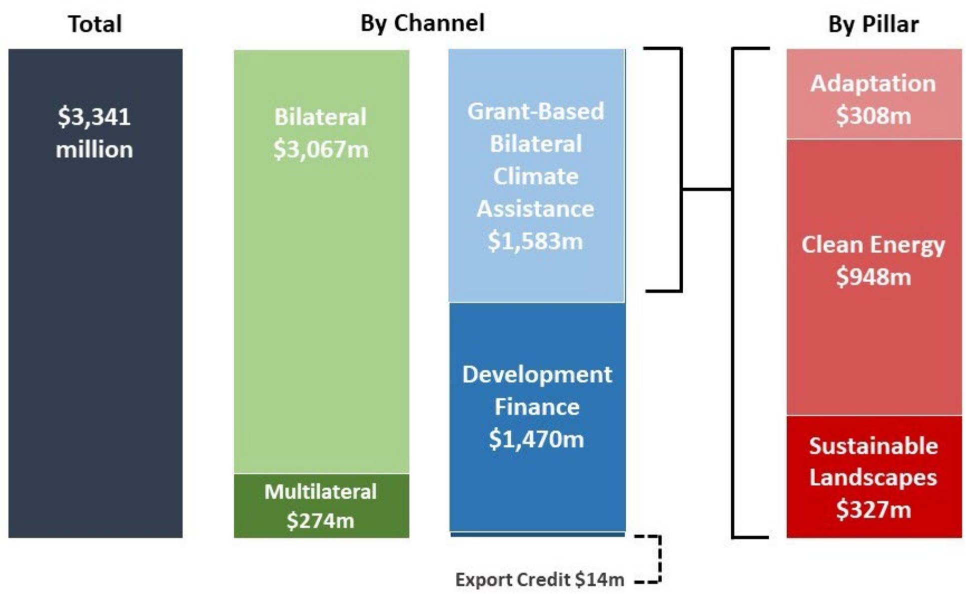
Source: U.S. Department of State[472]

[472] U.S. Department of State (2022).

PILLARS

U.S. climate finance supports activities across three main pillars: adaptation, clean energy, and sustainable landscapes (forests, agriculture, and other land uses). As illustrated in Figure 7-2, for FY 2019-2020 approximately 59.9 percent of U.S. congressionally appropriated climate finance supported clean energy activities, 19.4 percent supported adaptation activities, and 20.7 percent supported sustainable landscape activities. Finance committed through more demand-driven U.S. climate finance channels, such as DFC and EXIM, typically supported clean energy activities. The following sections provide a sample of initiatives within each pillar.

Figure 7-2: Breakdown of U.S. Climate Finance by Pillar: FY2019-2020



Note: Figures are in millions of USD

Source: U.S. Department of State[473]

ADAPTATION

The impacts of climate change are already being felt around the world. They threaten national security, undermine global economic development, exacerbate geopolitical tensions, and result in greater global and local instability, as well as a rising need for

[473] U.S. Department of State (2022).

humanitarian assistance. Working with partners to catalyze and scale adaptation action remains a priority of the United States.

The United States is committed to helping vulnerable countries adapt to climate change and enhance the resilience of their communities and economies. The United States committed $308.0 million from FY 2019-2020 to activities that promote climate resilience in developing countries.

The United States has prioritized climate adaptation assistance for countries, regions, and populations that are highly vulnerable to the impacts of climate change, with particular emphasis on small island developing states (SIDS), and least-developed countries (LDCs), especially in sub-Saharan Africa. By increasing resilience in areas such as food security, water, coastal management, and public health, U.S. support helps vulnerable countries prepare for and respond to increasing climate – and weather-related risks.

The magnitude of the challenge requires not only dedicated adaptation programming and finance flows, but also a broader approach to international development that fully integrates resilience to climate change. Development investments in areas as diverse as preventing and treating malaria, building hydropower facilities, improving agricultural yields, and developing urban infrastructure will not be effective in the long term if they do not account for such impacts as shifting ranges of disease-carrying mosquitoes, changing water availability, or rising sea levels. Examples of U.S. supported adaptation activities in FY2019-FY2020 include:

NATIONAL ADAPTATION PLANNING

U.S. support helps developing countries advance their National Adaptation Planning (NAP) processes, including through programs such as the NAP Global Network. In 2014, the United States spearheaded the creation of the network to build capacity for and accelerate national adaptation planning. Today, the network connects over 1500 individual members across more than 150 countries involved in developing and implementing NAPs. The network accelerates national adaptation planning and action in developing countries through facilitating peer learning and exchange, supporting national-level action, and synthesizing and sharing knowledge. In line with the vision that all least developed countries have a national adaptation plan, the United States supports the network to provide vulnerable countries with technical support for NAPs, translate NAP priorities into implementation, and assess the effectiveness of NAPs and adaptation actions.

PRIVATE INVESTMENT FOR ENHANCED RESILIENCE

The Private Investment for Enhanced Resilience (PIER) project mobilizes private-sector investment to strengthen resilience to climate change in Bangladesh, Ghana, Guyana, Indonesia, Mozambique, Peru, Tanzania, and Vietnam. PIER supports the development and implementation of National Adaptation Plans by working with for-profit companies to build climate change resilience through strategic investments that support technology deployment in climate risk-reducing products, services, and infrastructure. For example, In Peru, PIER built the capacity of the Development Bank of Peru (COFIDE) to design climate proof credit and lending products, enabling the bank to invest more than $45 million towards climate risk reduction measures for major road infrastructure. In Indonesia, PIER has supported financing and market development for solar irrigation pumps for small holder farmers. In Ghana, PIER designed and deployed a financial tool to determine returns on investment in resilient cocoa farms, which was utilized to make major investment decisions in climate smart cocoa across West Africa.

NATURAL INFRASTRUCTURE FOR WATER SECURITY IN PERU

The Natural Infrastructure for Water Security (NIWS) program in Peru increases resilience to drought, flood, and landslide risks that are intensifying with climate change. Supported by USAID and Canada, NIWS works with upstream communities and downstream water users to scale-up efforts to protect and restore natural infrastructure while addressing gender inequities that are incompatible with a water- and climate-secure future. In FY 2019 and 2020, NIWS collaborated with dozens of partners to build a natural infrastructure investments portfolio valued at more than $106 million and trained 964 professionals to design, monitor, and manage natural infrastructure projects across the country.

USAID CLIMATE READY

USAID Climate Ready helps Pacific Island countries to become more resilient through drafting and implementing policies to achieve adaptation goals; accessing larger amounts of financing from international adaptation funds; and improving skills and systems to better manage and monitor adaptation projects. In FY 2020, Climate Ready trained 622 persons, 48 percent of which were women, on disaster resilience and business continuity planning for small and medium enterprises (Fiji, Palau and Vanuatu), Resilience (Solomon Islands and regionally), Project Management Practice (Fiji, PNG, Samoa and Vanuatu), Asset Management (Fiji and Samoa), and Monitoring & Evaluation (Tonga). The project also improved the institutional capacity of 15 organizations to address climate change risks and access climate finance. Climate Ready helped in the preparation of project proposals totaling over $27 million including proposals to GCF and GEF.

WATER EQUITY GLOBAL ACCESS FUND

In 2020, DFC committed a $100 million investment guaranty to finance Water Equity's Global Access Fund that will lend to microfinance institutions that serve low-income populations, specifically women, in East Asia, Latin America, South Asia and Sub-Saharan Africa. The downstream loans will support micro-borrowers and small or medium enterprises (SMEs) for water-related purchases such as water tanks, wells, toilets, septic tanks, sewer connections, water filters, and bathrooms. By 2025, the Global Access Fund aims to enable 5 million consumers access to household water or sanitation facilities. Because women are disproportionately impacted by poor access to water and sanitation, the Fund aims to ensure that 60% of their downstream borrowers are women or women-owned enterprises.

CLEAN ENERGY

From FY 2019-2020, the United States committed $947.8 million to finance clean energy activities in developing countries. This climate assistance focused on countries and sectors offering significant emission reduction potential over the long term, as well as countries that offered the potential to demonstrate leadership in sustained, large-scale deployment of clean energy. In terms of sector coverage, clean energy includes renewable energy and energy efficiency, and excludes direct expenditures on natural gas and other fossil fuel power plant construction or retrofits.

The United States supports countries with the building blocks to scale-up renewable energy, for example, by providing technical assistance to energy system planners, regulators, and grid operators to improve the capability of regional energy grids to distribute clean energy. The United States also supports global programs that focus on information sharing and building coalitions for action on clean energy technologies and practices. Examples of U.S. supported clean energy activities in FY2019-FY2020 include:

CLEAN ENERGY MINISTERIAL (CEM)

The United States actively supports the Clean Energy Ministerial (CEM), a high-level global forum of 28 countries and the European Commission to promote policies and programs that advance clean energy deployment, share lessons learned and best practices, and support the transition to a global clean energy economy. Members represent over 80 percent of global climate-related emissions. The CEM combines annual Ministerial discussions with year-round voluntary, cooperative workstreams that are based on areas of common interest among participating governments and other stakeholders. The United States supports several CEM initiatives, including the 21st Century Power Partnership, Nuclear Innovation: Clean Energy Future initiative (NICE Future), Carbon Capture Utilization, and Storage initiative

(CCUS), International Smart Grid Action Network (ISGAN), Clean Energy Solutions Center, Hydrogen Initiative, and the Biofuture Platform Initiative. CEM successes include the Global Lighting Challenge, a race to reach cumulative global sales of 10 billion high-efficiency, high-quality, and affordable advanced lighting products, such as light-emitting diode (LED) lamps, as quickly as possible; this Challenge ultimately achieved a cumulative commitment of 14 billion energy-saving lighting products.

LOW EMISSION DEVELOPMENT STRATEGIES

The United States supports efforts to identify and pursue country-driven, low-carbon development strategies through the Low Emission Development Strategies Global Partnership (LEDS GP). The LEDS GP serves as a central global initiative for advancing technical work on low emissions strategies in key sectors. The United States launched the LEDS Partnership in 2011 and it has grown to 150 partners and serves as a forum for thousands of climate officials and practitioners to engage in regional and global initiatives that advance climate action and ambition. LEDS GP was rebranded as the Global Climate Action Partnership in 2022.

INDONESIA

Through its Indonesia Clean Energy Development II project (ICED II), USAID provides technical assistance to Indonesia's State-Owned Power Company (PLN), the Ministry of Energy and Mineral Resources, the National Development Planning Agency, the Financial Services Authority, local governments, financial institutions and the private sector. These efforts supported an effective policy, regulatory, and incentive environment for low-emission growth in the energy sector, attracting public and private sector investment in renewable energy. In 2019, USAID supported the Government of Indonesia’s newly launched Low-Carbon Development Initiative. Together with other development partners, USAID provided technical assistance to provincial governments to transition from the national and local action plans for GHG emissions reductions to the Initiative. USAID continued to support the PLN to plan, procure, and integrate renewable energy into Indonesia's power grid. In 2019, USAID also provided technical inputs to project developers, banks, and PLN, to evaluate 34 renewable energy projects at various stages of development. In total, since 2015, USAID has mobilized around $1.58 billion worth of investments in renewable energy (with a leverage ratio of 1 to 120 of U.S. Government to private investment) providing 1.6 million people with access to clean electricity.

RENEW SUN ENERGY PVT LTD

In 2020, DFC committed $53.5 million to finance the construction of a ReNew Power 105-megawatt solar power generation plant in Gujarat, India. This project is part of the $350 million ReNew Power Master Financing Facility II. The solar plant is expected to supply solar power for retail, industrial and commercial use. At the time of commitment, in 2020 DFC estimated that the electricity generated from this power plant will produce 261,000 megawatts of renewable solar energy annually. In 2021, the first year that DFC received impact data for ReNew Sun Energy Pvt Ltd, the solar plant generated 244,000 megawatts of renewable solar energy.

SENEGAL POWER COMPACT

The Senegal Power Compact is designed to strengthen the power sector, by increasing the reliability and access to electricity, especially in the capital city of Dakar, increase electricity access in peri-urban and rural areas in the central and southern regions of Senegal, and support the Government of Senegal establish a modern and efficient foundation upon which the nation's power system can grow. Comprised of a $550 million compact investment from the U.S. Government's Millennium Challenge Corporation (MCC), along with a supplemental $50 million from the Senegalese government, the $600 million program aims to provide a reliable and modern high-voltage transmission network in and around Dakar through infrastructure investments in transmission lines, high-voltage transformers, and battery storage; increase the supply and demand for quality electricity in rural and peri-urban areas of Senegal through, and provide technical and strategic support to the utility (Senelec). MCC's climate investments are focused on supporting energy efficiency, support for new, lower-cost renewable energy sources such as wind and solar, and technical assistance. This five-year MCC-Senegal partnership was signed on December 10, 2019.

SUSTAINABLE LANDSCAPES

GHG emissions from deforestation, agriculture, and other land uses constitute approximately one-quarter of global emissions. In some developing countries, land sector GHG emissions can account for as much as 80 percent of total emissions. At the same time, natural climate solutions that conserve, sustainably manage, and restore forests and other ecosystems could contribute around one-third of the pre-2030 mitigation potential needed to align with the Paris Agreement temperature goal. To meet the challenge of reducing these emissions, the United States works with partner countries to put in place the systems and institutions necessary to reduce global land-use-related emissions, supports the provision of data and information about forests and land use, and works to create new models for rural development that generate climate benefits, while conserving biodiversity, protecting watersheds, and improving livelihoods.

For activities related to land-use mitigation (or "sustainable landscapes"), including reducing emissions from deforestation and forest degradation (REDD+), U.S. assistance works to (1) reduce GHG emissions from deforestation and other land uses; (2) increase the sequestration of carbon stored in trees, plants, and soils; and through these actions; and (3) generate additional social and environmental benefits, such as good governance, enhanced resilience, and biodiversity conservation.

FY 2019-2020, the United States committed $327.1 million to support developing countries in protecting and restoring carbon-rich ecosystems; improving agricultural practices; enhancing land-use planning; building monitoring capacity; attracting investment that supports forest and climate objectives; and enhancing the systems that underpin these activities. U.S. support prioritizes the mitigation potential of investments; countries with the political will to implement large-scale efforts to reduce emissions from deforestation, forest degradation, and other land-use activities; and potential for complementary investments in monitoring, reporting, and verification of forest cover and GHG emission reductions.

FOREST MONITORING, RESULTS-BASED PAYMENTS AND CARBON MARKETS

The United States has continued to support countries in accessing finance for forests through REDD+ and results-based payments, including carbon markets. Programs such as Offsetting Emissions Through Sustainable Landscapes (ONE-SL) and the Support Hub for Forest Finance and Landscapes Engagement (SHuFFLE) provide decision-making tools as well as direct technical support to countries that are pursuing REDD+ implementation. This capacity building and technical support enables governments to implement large-scale programs that address deforestation and ensure that activities benefit communities through sustainable, ongoing finance tied to results.

SUSTAINABLE WETLANDS ADAPTATION AND MITIGATION PROGRAM (SWAMP)

The Sustainable Wetlands Adaptation and Mitigation Program (SWAMP) is a collaborative effort by the Center for International Forestry Research and the U.S. Forest Service with support from the USAID. SWAMP generates critical information on tropical wetland ecosystem values, develops insights on how to effectively conserve, manage, and restore wetlands, and increases awareness of the role these ecosystems have in climate change mitigation and adaptation. Carbon stocks in these ecosystems are very high and land cover change in these ecosystems results in significant emissions of GHG. Most countries do not have sufficient information to include wetlands in their national reports nor to develop plans for conserving or restoring wetlands as a strategy to avoid GHG emissions. SWAMP scientists collaborate with government, academic, and non-governmental partners around the world to better understand the carbon dynamics in these ecosystems and to support country-led efforts to reduce GHG emissions from mangrove and peatland ecosystems.

FOREST DATA PARTNERSHIP

The Forest Data Partnership aims to halt and reverse forest loss from commodity production by collaboratively improving global monitoring and supply chain tracking and accelerating restoration. It aligns partners around the data and ensures access for stakeholders across sectors to consistent, validated open-source geospatial forest-risk commodity data. The result is credible, systematic monitoring, verification, and accountability towards progress in reducing commodity-driven deforestation and restoring degraded lands. The core partners include the World Resource Institute, the UN Food and Agriculture Organization, NASA, Google, Unilever, USAID and the Department of State.

CENTRAL AFRICA

USAID's Central Africa Regional Program for the Environment is the agency's main effort to protect, conserve, and improve management of the Congo Basin, the world's second largest tropical rainforest – and it is implemented in partnership with the U.S. Fish and Wildlife Service and U.S. Forest Service. Since its founding in 1995, it has invested more than $600 million to build inclusive markets, improve law enforcement, support civil society's role in environmental monitoring and advocacy, and strengthen land use management.

SOUTHEAST ASIA

USAID is supporting agriculture and forestry businesses in Southeast Asia to adopt low-emissions practices and connect with investors through its Green Invest Asia program. By the end of 2020, Green Invest Asia had signed Memorandum of Understandings (MOUs) to provide technical assistance for 28 companies and mobilized more than $27 million in private sector investments that will reduce nearly 7 million tons of GHG emissions.

COLOMBIA

USAID supported the Government of Colombia to design a carbon market whereby businesses pay a reduced tax if they support projects that offset their carbon emissions. This carbon market generates about $30 million a year for projects that combat climate change and has provided $25 million to Afro-Colombian and Indigenous communities supporting conservation of carbon-rich lands since its inception in 2020. USAID continues to support the Government to monitor and verify carbon credits while connecting private sector companies with offset projects through the Paramos y Forests project.

Annex 5 contains information on U.S. provision of public financial support: contributions through multilateral channels for FY 2019 and 2020 (Biennial Report common tabular format 7a). It also contains a summary of U.S. provision of public financial support: contributions through bilateral, regional, and other channels. The full version of common tabular format 7b can be found in the electronic common tabular format submissions for Biennial Report 5. Annex 6 describes the methodology for reporting information about the provision of public financial support.

PROMOTING EFFECTIVENESS

To promote effective use of climate finance, the United States works to ensure that its support is efficient, effective, and innovative; based on country-owned plans and strategies; and focused on achieving measurable results, with a long-term view of economic and environmental sustainability.

SUPPORTING COUNTRY-DRIVEN APPROACHES

U.S. support across all pillars is country-driven, responding to the needs and priorities of partner countries. This is achieved in a variety of ways, including reviewing country-specific documents such as NDCs, Biennial Update Reports, national GHG inventories, and NAPs to target projects; working directly with partner governments and other in-country stakeholders to identify needs and develop implementation plans; and building multi-country programs around challenges or priorities identified across multiple countries during prior work.

BUILDING EFFECTIVE ENABLING ENVIRONMENTS

The United States recognizes the critical role that partner countries play in promoting the effectiveness of climate finance. Where partners set in place systems that reflect high standards of transparency, good governance, and accountability, climate finance contributors and investors are better able to respond directly to country priorities, making new contributions in line with established national strategies and country development plans based on broad participation and consultation. This in turn empowers partner governments to drive development and sustain outcomes by working through national institutions, rather than around them.

Experience has shown that the ability of any public financial instrument or intervention to mobilize and deploy additional finance in a given country depends on the domestic policy framework in place. This can involve climate-specific policies, such as energy sector regulations and carbon pricing, as well as broader, non-climate-specific policies and legal frameworks. The United States remains committed to working with its development partners to identify complementary solutions to address domestic investment barriers and achieve their low-carbon, climate-resilient development strategies.

SCALING DOWN SUPPORT FOR CARBON-INTENSIVE FOSSIL FUELS

Achieving shared climate objectives depends not only on investing in low-carbon activities, but also on scaling down support for high-carbon activities. Shifting investment from those that support fossil fuel use, or other high-emission activities, towards lower-emission alternatives remains a priority of the United States.

The United States recognizes that climate action is most effectively achieved through inclusive engagement with local, marginalized, and underrepresented groups. These groups include, but are not limited to, impoverished people and communities, women and girls, youth, persons with disabilities, religious minorities, ethnic and racial groups, LGBTQI+ people, displaced persons, migrants as well as Indigenous Peoples and other marginalized communities. To ensure climate finance enables development outcomes and a just transition to a low-carbon economy, it should:

- Ensure participation of local, marginalized, and underrepresented groups in program design, planning, and management;
- Secure sizeable benefit-sharing directly to local communities under carbon markets and other payment for ecosystem services;
- Promote empowerment of civil society, including equitable ownership over development programs, initiatives and outcomes.

ENSURING TRANSPARENCY

The United States views transparent tracking and reporting of climate finance as key to ensuring accountability, promoting effectiveness, and building trust. To ensure robust reporting, each implementing government agency or entity follows strict guidelines and eligibility criteria when collecting information on support of activities related to adaptation, clean energy, and sustainable landscapes. For instance, activity descriptions provided by USAID missions are reviewed by climate change specialists to ensure compliance with USAID climate change goals. For the purpose of climate finance reporting to the UNFCCC, the United States only includes programs that have mitigation and/or adaptation as a primary objective, or as an intentional significant co-benefit (e.g., for relevant biodiversity and food security activities). In the case of programs for which only part of the activity is targeted toward a climate objective, only the relevant portion of financial support is counted, rather than the entire program budget.

NEW AND ADDITIONAL CLIMATE FINANCE

Scaling up international assistance for climate change is a significant priority for the United States. The U.S. Congress appropriates new and additional funding to support international climate efforts on an annual basis, in response to the President's budget request. As described above, this funding supports programs to advance adaptation, clean energy, and sustainable landscapes efforts internationally. It also underpins efforts by agencies such as the Millennium Challenge Corporation, Development Finance Corporation, and Export-Import Bank to incorporate climate change into their programming. Since ratifying the UNFCCC in 1992, U.S. international climate finance increased from virtually zero to around $1.67 billion per year during the period FY 2019- 2020.

MOBILIZING PRIVATE FINANCE

While maintaining a strong core of public climate finance is essential, the United States pursues strategies to maximize private investment in low-carbon, climate-resilient activities in developing countries. More efficient leveraging of private investment can allow limited public resources to be concentrated in areas and sectors where the private sector is less likely to invest on its own, particularly in adaptation activities in the most vulnerable countries and LDCs. This effectively multiplies the financing available to support partner countries' climate objectives. The key role of public finance in de-risking private investments can catalyze significant additional resources.

In many cases, the barriers to mobilizing private finance relate to a combination of factors, including poor incentives, challenges in engaging with host government regulatory processes, processes, real or perceived risk, and lack of knowledge in the commercial banking sector about climate-friendly opportunities. As noted above, U.S. bilateral assistance through agencies such as USAID and the Department of State targets technical assistance to address these and other issues. Moreover, the United States is committed to working with partners to make finance flows consistent with a pathway towards low GHG emission and climate-resilient development, shifting the trillions of dollars under financial management to support climate action at scale. The following are examples of ways the United States has worked to achieve these outcomes.

AMAZON BIODIVERSITY FUND

For example, USAID is bringing the private sector to bear to protect the lungs of the Earth through the Amazon Biodiversity Fund, which also avoids GHG emissions from deforestation and increases carbon storage through forest conservation. The Fund, launched in 2019, receives private sector funding to support businesses with sustainable development models that benefit biodiversity and the climate. It provides a 50 percent guarantee from the U.S.' Development Finance Corporation for loans and long-term investments and aims to leverage $60 million in investment by 2023.

BUSINESS CASE FOR COLLECTIVE LANDSCAPE ACTION

The Business Case for Collective Landscape Action initiative is a transformational public-private partnership implemented by Rainforest Alliance, CDP, Clarmondial, Conservation International, and USAID. This initiative convenes the private sector, governments, and local producers and organizations to address global environmental challenges associated with commodity-driven deforestation. The approach is to facilitate development of landscape action plans and reporting; connect these to international disclosure mechanisms; and ultimately unlock international financing to stabilize critical deforestation frontiers. This initiative contributes to global climate and biodiversity goals, and drives investment and inclusive development across some of the world's most important tropical landscapes, currently working in Indonesia, Ecuador, Peru, and Brazil.

IMPROVING THE TRACKING OF MOBILIZED PRIVATE FINANCE

For the common methodological framework and tracking progress toward the collective $100 billion goal, mobilized climate finance includes private finance for climate-relevant activities that has been mobilized by public finance or by a public policy intervention, including technical assistance to enable policy and regulatory reform.

The United States and other developed countries continue to work to enhance the ability to track the amount of private finance mobilized by public interventions. Building on the work of the Research Collaborative on Tracking Private Climate Finance,[239] the United States has worked with other developed countries to reach a common understanding of the scope of mobilized climate finance and a common methodology for tracking and reporting toward the collective goal. The institutions and agencies of participating countries continue to use this framework as a basis going forward, and the United States works with multilateral and other institutions to harmonize our approaches over time.

While developing our methodology, we have been guided by the following principles: (1) ensure that only finance mobilized by developed country governments is counted toward the $100 billion goal and that, where multiple actors are involved, the resulting finance is only counted once in tracking our collective progress; and (2) ensure that our reporting framework encourages and incentivizes the most effective use of climate finance.

To account for mobilized private climate finance, we assess the amount of private finance mobilized on an activity-by-activity basis and to report on private finance associated with activities both where there is a clear causal link between a public intervention and private finance and where the activity would not have moved forward, or moved forward at scale, in the absence of our government's intervention. In recognition of the role that developing countries play in mobilizing private finance, our governments will report only on our share of private finance mobilized, excluding the share of private finance that developing countries' public finance has mobilized.

It is important to note that current data and methodological limitations prevent us from accounting for the full range of flows that we are mobilizing toward the $100 billion goal at this time—in particular, those mobilized through public policy interventions, and those mobilized through improvements in institutional capacity and the enabling environment. As such, estimates throughout this chapter are necessarily partial, and omit some—possibly a substantial amount of—climate finance mobilized. We intend to continue to improve our methodology as data availability increases and measurement methods evolve. As a result, we expect our reporting to become more complete over time.

TECHNOLOGY DEVELOPMENT AND TRANSFER

As with climate finance, accelerating climate-related technology transitions abroad is a powerful lever for the United States and its international partners to address the climate crisis. This section outlines the U.S. government's approach to technology development and transfer, highlights challenges in this area, and provides several illustrative examples of U.S.-supported activities.

Accelerating climate-related technology transitions abroad is a powerful lever for the United States and its international partners to address the climate crisis. Developing and driving down the costs of climate technologies enables countries to raise ambition, mitigate emissions, and strengthen resilience to climate impacts at the necessary scale, cost-effectively and quickly. Foreign assistance that incorporates a strategic approach to cooperation on technology development and transfer on voluntary and mutually agreed terms advances sustainable development internationally and provides immediate domestic benefits to the United States.

As multitrillion-dollar international markets for clean energy and other climate-related technologies emerge, the United States supports the development of technologies that other countries need to decarbonize and aligns its clean energy diplomacy and investments with its domestic industrial agenda. This applies to technologies that support reduced emissions from land use, and technologies that support adaptation and resilience to climate impacts. The United States supports technology transfer on voluntary and mutually agreed terms and promotes enabling environments conducive to trade and investment in climate-related technology, including the protection of intellectual property, to incentivize technology innovation and deployment.

UNFCCC TECHNOLOGY MECHANISM

The United States continued to play a leading role in the UNFCCC Technology Mechanism, composed of the Technology Executive Committee (TEC) and the Climate Technology Center & Network (CTCN). The TEC provides policy guidance to the parties of the Convention and the Paris Agreement. The CTCN is the implementation body of the Technology Mechanism. It accelerates the development and transfer of technologies on voluntary and mutually agreed terms through three services: 1) providing technical assistance at the request of developing countries on technology issues; 2) creating access to information and knowledge on climate technologies; and 3) fostering collaboration among climate technology stakeholders via its network of regional and sectoral experts. This included supporting activities aligned with the Technology Framework, which the parties to the Paris Agreement adopted in December 2018 (Decision 15/CMA.1).

The Department of Energy's National Renewable Energy Laboratory (NREL) continued to play an active role in the CTCN as one of eleven core consortium partners. NREL's engagement helped enable the CTCN to fulfill its mission to help the global community expand access to the advanced knowledge and policy planning expertise necessary to advance clean-energy and climate-resilient technologies at the national level.

CHANGES IN POLICIES AND ACTIVITIES SINCE THE FOURTH BIENNIAL REPORT

In addition to the information contained herein and in Table 7-2, we encourage readers to review U.S. contributions in connection with the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS Agreement), specifically its reporting in connection with obligations under Article 66.2 (similar to the UNFCCC Biennial Report obligation with some notable differences, including that, under Article 66.2, developed country Members have committed to provide incentives to enterprises and institutions in their territories for the purpose of promoting and encouraging technology transfer to LDC World Trade Organization (WTO) members in order to enable them to create a sound and viable technological base, which is not otherwise scoped by reference to particular technologies). The United States' most recent report provides a small sample of these technology transfer programs conducted in fiscal year 2022. The United States also submits a parallel report in connection with Article 67 of the TRIPS Agreement regarding technical and financial cooperation. The United States' most recent report provides a chronological list of programs conducted by the United States from September 2021 to September 2022.

CHALLENGES IN DELIVERING TECHNOLOGY TRANSFER AND DEVELOPMENT

While the initiatives listed in Table 7-2 provide insight into some of the success stories related to U.S engagement in technology transfer and development, challenges remain. One key challenge has been to attract the finance necessary to successfully develop, demonstrate and deploy climate technologies. This may be due to limited domestic capacity in host countries, but also to insufficient domestic frameworks to foster trade and investment (i.e., including how to manage market adoption risk in parallel with managing technology risk) and protect intellectual property. Lack of investment in demonstration, or limited work to understand the deployment economics across a value chain to ensure economically sustainable business models for every player to drive deployment, and a lack of connection between domestic needs and domestic technology development are other common barriers. To address these challenges, the United States has supported a number of programs such as those highlighted below.

ILLUSTRATIVE EXAMPLES OF TECHNOLOGY-ORIENTED ACTIVITIES

The United States financed a wide range of programs that support climate-related technology development and transfer, including through funding for the Global Environment Facility. Several examples of these activities are highlighted below and in Table 7-2. In addition, several activities highlighted elsewhere in this chapter also advance technology development and transfer.

RENEWABLE ENERGY AUCTIONS IN COLOMBIA

USAID supported the Colombian Government in the design and implementation of renewable energy auctions with an aim to promote greater competition, cleaner generation, and lower prices. The successful auction held on October 21, 2019 resulted in eight projects being awarded 15-year contracts. These eight new solar and wind projects will add 1.5

gigawatts of variable renewable energy to the grid with new investments estimated at $1.3 billion. Furthermore, the auction's average awarded price was 40 percent below the Government of Colombia's (GOC) expectations. This positive price reflects the rules set by the auction that required that the price benefits be passed on to consumers, making Colombian producers and consumers of all social strata more competitive and better off. The new investments are also expected to have significant positive employment impacts. It also appears that the USAID-supported renewable energy auction has opened the floodgates to new variable renewable energy private sector investment. Since the auction, the Ministry reports that 129 new projects have registered with the government for development throughout the country, with new generation potential of 7,700 megawatts in new wind and solar.

CLEAN ENERGY IN INDIA

USAID/India's clean energy program strengthened an enabling environment to promote energy efficiency technologies and a faster and more cost-effective renewable energy deployment. The program developed policies and regulations, strengthened utilities, and supported a variety of activities, such as more efficient planning, skills development and training, market-based deployment approaches, technology pilots, and new business models and procurement instruments through both public- and private sector partnerships. USAID partnered with two states, Assam and Jharkhand, to develop a state-of-the-art Strategic Energy Planning Framework and Tool to help distribution companies establish robust demand forecasts and renewable energy resource plans to optimize power systems and minimize costs. This tool was used to develop medium- and long-term demand forecasts, including accurately estimating the impact of COVID-19 on the power demand due to the lockdown. In 2020, the Solar Energy Corporation incorporated USAID-provided best practices and launched the second round of tender to a bid of 5GW ($4 billion) of round-the-clock power, marking a significant transition toward system-friendly renewable energy procurements in India that lower the overall generation and integration costs. USAID is enabling the integration of large-scale renewable energy into the power grid by testing a variety of innovative technologies and solutions, undertaking analysis and simulation studies, supporting policies and regulatory frameworks, and enhancing the capacity of system operators and regulators. In addition, through the U.S.-India Strategic Clean Energy Partnership (SCEP), the Department of Energy (DOE) and U.S. National Laboratories have provided a range of technical assistance and capacity building support across energy sectors.

SERVIR

In partnership with the National Aeronautics and Space Administration (NASA), USAID, and technical institutions around the world, the SERVIR program strengthens capacity in more than 50 countries, helping partners access and use satellite information and geospatial technologies to better manage climate risks, strengthen food security, prepare for and adapt to climate variability and change, and reduce greenhouse gas (GHG) emissions from land use land use change and forestry. In FY 2019 and 2020, SERVIR trained more than 3,000 people to predict, monitor, and assess risks. By collaborating to integrate science into useful services and decision-making for improved livelihoods, disaster management, and development, SERVIR strengthened the capacity of more than 200 institutions worldwide in this two-year timeframe.

AFRICA GROUNDWATER EXPLORATION AND ASSESSMENT PROGRAM

The Africa Groundwater Exploration and Assessment Program supports groundwater exploration and assessment and is building local capacity to plan and manage groundwater resources under varying climate change scenarios.

SILVACARBON

SilvaCarbon is a whole-of-government technical cooperation program that draws on the strengths of various technical agencies in the U.S. government, nongovernmental organizations, academia, and industry. SilvaCarbon and its partners work with more than 25 developing countries to build capacity for monitoring and managing forest and terrestrial carbon. SilvaCarbon helps to identify, test, and disseminate good practices and cost-effective, accurate technologies, building on the needs and priorities identified by partner countries. SilvaCarbon has assisted countries in enhancing national forest inventories and national GHG inventories, develop NDC and REDD+ baselines, improve national forest monitoring systems, access and interpret remove sensing data, and integrate data and information into improved policymaking and land-use planning.

CLEAN AND ADVANCED TECHNOLOGIES FOR SUSTAINABLE LANDSCAPES PROGRAM (CTSL)

Organized in 2020 and coordinated by DOE's National Renewable Energy Laboratory, the Clean and Advanced Technologies for Sustainable Landscapes Program (CTSL) provides technical assistance to several countries in Africa and Southeast Asia on analyzing and implementing advanced energy technologies to improve and scale up agricultural production.

Table 7-2: Examples of U.S. Technology Development and Transfer Activities Funded in FY2019-2020

Name of activity and recipient country or region	Targeted area/sector	Measures and activities related to technology development and transfer	Sources of funding and implementation
Renewable Energy Auctions in Colombia Colombia	Mitigation/Energy	USAID supported the Colombian Government in the design and implementation of renewable energy auctions with an aim to promote greater competition, cleaner generation, and lower prices. The auction held on October 21, 2019 resulted in eight projects being awarded 15-year contracts. These eight new solar and wind projects will add 1.5 giga watts of VRE to the grid with new investments estimated at $1.3 billion.	Public
Clean Energy in India India	Mitigation/ Energy	USAID/India's clean energy program strengthened an enabling environment to promote energy efficiency technologies and a faster and more cost-effective renewable energy deployment. The program developed policies and regulations, strengthened utilities, and supported a variety of activities, such as more efficient planning, skills development and training, market-based deployment approaches, technology pilots, and new business models and procurement instruments through both public- and private	Public

Name of activity and recipient country or region	Targeted area/sector	Measures and activities related to technology development and transfer	Sources of funding and implementation
		sector partnerships. As one example, in 2020, the Solar Energy Corporation incorporated USAID-provided best practices and launched the second round of tender to a bid of 5GW ($4 billion) of round-the-clock power, marking a significant transition toward system-friendly renewable energy procurements in India that lower the overall generation and integration costs. USAID is enabling the integration of large-scale renewable energy into the power grid by testing a variety of innovative technologies and solutions, undertaking analysis and simulation studies, supporting policies and regulatory frameworks, and enhancing the capacity of system operators and regulators.	
SERVIR 50 + Countries, global	Adaptation and Sustainable Landscapes	In partnership with the National Aeronautics and Space Administration (NASA), USAID, and technical institutions around the world, the SERVIR program strengthens capacity in more than 50 countries, helping partners access and use satellite information and geospatial technologies to better manage climate risks, strengthen food security, prepare for and	Public

Name of activity and recipient country or region	Targeted area/sector	Measures and activities related to technology development and transfer	Sources of funding and implementation
		adapt to climate variability and change, and reduce GHG emissions from land use land use change and forestry. In FY 2019 and 2020, SERVIR trained more than 3,000 people to predict, monitor, and assess risks. By collaborating to integrate science into useful services and decision-making for improved livelihoods, disaster management, and development, SERVIR strengthened the capacity of more than 200 institutions worldwide in this two-year timeframe.	
The Africa Groundwater Exploration and Assessment Program Kenya	Adaptation	The Africa Groundwater Exploration and Assessment Program supports groundwater exploration and assessment and is building local capacity to plan and manage groundwater resources under varying climate change scenarios.	Public
SilvaCarbon 25+ countries	Sustainable Landscapes	SilvaCarbon is a whole-of-government technical cooperation program that draws on the strengths of various technical agencies in the U.S. government, nongovernmental organizations, academia, and industry. SilvaCarbon and its partners work with more	Public

Name of activity and recipient country or region	Targeted area/sector	Measures and activities related to technology development and transfer	Sources of funding and implementation
		than 25 developing countries to build capacity for monitoring and managing forest and terrestrial carbon. SilvaCarbon helps to identify, test, and disseminate good practices and cost-effective, accurate technologies, building on the needs and priorities identified by partner countries. SilvaCarbon has assisted countries in enhancing national forest inventories and national GHG inventories, develop NDC and REDD+ baselines, improve national forest monitoring systems, access and interpret remove sensing data, and integrate data and information into improved policymaking and land-use planning.	
Clean and Advanced Technologies for Sustainable Landscapes Program (CTSL) Africa, Southeast Asia	Mitigation/Sustainable Landscapes	Organized in 2020 and coordinated by DOE's National Renewable Energy Laboratory, the Clean and Advanced Technologies for Sustainable Landscapes Program provides technical assistance to several countries in Africa and Southeast Asia on analyzing and implementing advanced energy technologies to improve and scale-up agricultural production.	Public

Name of activity and recipient country or region	Targeted area/sector	Measures and activities related to technology development and transfer	Sources of funding and implementation
NOTE: The full version of common tabular format 8 can be found in the electronic common tabular format submissions for Biennial Report 5.			

CAPACITY BUILDING

Since a long-term view of climate change and development is crucial to sustainability and results, the United States approaches capacity building for climate change in an integrated manner. Linking capacity building directly to projects and programs helps ensure that capacity built is relevant, effective, and tied to results.

ILLUSTRATIVE EXAMPLES OF CAPACITY BUILDING ACTIVITIES

Capacity-building needs are addressed throughout all U.S. support activities, not as separate line items or projects, and are provided as a means for taking action on a mutually shared goal. As such, the other projects highlighted in this chapter contain capacity-building elements. Several additional illustrative examples are highlighted below:

NATIONAL ADAPTATION PLANNING GLOBAL NETWORK

The National Adaptation Planning Global Network (NAP-GN) builds capacity in developing countries to meet their medium and long-term adaptation needs, implement national adaptation plans, and identify climate risks to protect key development sectors from climate change. The NAP-GN Secretariat facilitates activities and technical workshops, provides strategic guidance to relevant planning ministries, and improves donor coordination to build capacities and accelerate the formulation and implementation of national adaptation processes. Since it was founded in 2015, NAP-GN has provided direct technical support to over 50 countries and connected over 150 countries and practitioners on national adaptation planning and action.

MARSHALL ISLANDS

USAID also strengthens the capacity of national governments, regional institutions and civil society organizations to build resilience to the negative effects of climate change. For example, from USAID worked to improve the capacity of the Republic of the Marshall Islands to prepare for and respond to disasters in coordination with the National Disaster Management Office. USAID strengthened the capacity of local, state, and national disaster response networks, providing training on essentials of humanitarian assistance, and disaster search and rescue.

SOUTHERN AFRICA ENERGY PROGRAM (SAEP)

The Southern Africa Energy Program (SAEP) provides technical assistance and capacity building to South Africa's clean energy sector as a Power Africa-funded regional Program (2017-2022). South Africa Low Emissions Development Program assisted South Africa in developing the skills and resources needed to build a more sustainable and green economy (2015-2020).

AMAZONIA CONNECT

Amazonia Connect works with public and private sector actors in Peru, Brazil, and Colombia to reduce habitat loss and commodity-driven deforestation in the Amazon rainforest. The activity uses an end-to-end supply chain approach, engaging actors throughout the supply chain to promote low carbon agriculture and deforestation-free production. Amazonia Connect builds the capacity of producers and other stakeholders to scale up sustainable agriculture, monitor supply chains, access green investments, and use research and information.

CLIMATE FELLOWS

This Department of State-U.S. Forest Service program enhances the capacity of partner developing countries to measure, monitor, and report on forest landscapes with respect to GHG inventories, forest management and/or forest monitoring. Climate Fellows are technical experts embedded in relevant ministries. They provide long-term in-depth, and accountability-enhancing technical assistance for forest inventories, monitoring, and reporting systems. To date, Climate Fellows have supported the design of national forest monitoring systems, adoption of harmonized mapping methodologies, and monitoring, reporting, and verification institutional frameworks.

Table 7-3 highlights examples of U.S. capacity-building support. Please note that this table is illustrative and does not represent an exhaustive list of U.S. capacity building activities.

Table 7-3: Examples of U.S. Capacity Building Activities Funded in FY 2019-2020

Recipient country/region	Targeted area	Program or project title	Description of program or project
Global	Adaptation	National Adaptation Planning Global Network (NAP-GN)	The National Adaptation Planning Global Network builds capacity in developing countries to meet their medium and long-term adaptation needs, implement national adaptation plans, and identify climate risks to protect key development sectors from climate change. The NAP-GN Secretariat facilitates activities and technical workshops, provides strategic guidance to relevant planning ministries, and improves donor coordination to build capacities and accelerate the formulation and implementation of national adaptation processes. Since it was founded in 2015, NAP-GN has provided direct technical support to over 50 countries and connected over 150 countries and practitioners on national adaptation planning and action.
Marshall Islands	Adaptation	Marshall Islands	USAID worked to improve the capacity of the Republic of the Marshall Islands to prepare for and respond to disasters in coordination with the National Disaster Management Office. USAID strengthened the capacity of local, state, and national disaster response networks, providing training on essentials of humanitarian assistance, and disaster search and rescue.

Recipient country/region	Targeted area	Program or project title	Description of program or project
South Africa	Mitigation	The Southern Africa Energy Program (SAEP)	The Southern Africa Energy Program (SAEP) provides technical assistance and capacity building to South Africa's clean energy sector as a Power Africa-funded regional Program (2017-2022). South Africa Low Emissions Development Program assisted South Africa in developing the skills and resources needed to build a more sustainable and green economy (2015-2020).
South America	Mitigation	Amazonia Connect	Amazonia Connect works with public and private sector actors in Peru, Brazil, and Colombia to reduce habitat loss and commodity-driven deforestation in the Amazon rainforest. The activity uses an end-to-end supply chain approach, engaging actors throughout the supply chain to promote low carbon agriculture and deforestation-free production. Amazonia Connect builds the capacity of producers and other stakeholders to scale up sustainable agriculture, monitor supply chains, access green investments, and use research and information.

Recipient country/region	Targeted area	Program or project title	Description of program or project
Global	Mitigation	Climate Fellows	This Department of State-U.S. Forest Service program enhances the capacity of partner developing countries to measure, monitor, and report on forest landscapes with respect to GHG inventories, forest management and/or forest monitoring. Climate Fellows are technical experts embedded in relevant ministries. They provide long-term in-depth, and accountability-enhancing technical assistance for forest inventories, monitoring, and reporting systems. To date, Climate Fellows have supported the design of national forest monitoring systems, adoption of harmonized mapping methodologies, and monitoring, reporting, and verification institutional frameworks.

U.S. CLIMATE AMBITION REPORT

Chapter 8.

RESEARCH AND SYSTEMATIC OBSERVATIONS

Chapter 8. RESEARCH AND SYSTEMATIC OBSERVATIONS

OVERVIEW

Global change research and systematic observations are the foundation for understanding the significant changes occurring in our climate system and their impacts, for developing response measures and for evaluating the effectiveness of those measures over time. Recent assessments from the Intergovernmental Panel on Climate Change (IPCC) and the U.S. National Climate Assessment (NCA) show that global change related impacts such as drought and wildfire, flooding, changing sea levels and changing precipitation patterns are being experienced now and may be accelerating. With their effects on, for example, the energy, agriculture, health, transportation, housing and water sectors, the effects can be extensive and costly. In 2020, the National Oceanic and Atmospheric Administration (NOAA) reported a record-setting 22 separate billion-dollar weather and climate disasters across the United States alone, with $95billion in damages.

The United States enacted the Global Change Research Act (GCRA) in 1990, which established the U.S. Global Change Research Program (USGCRP) to develop and coordinate "a comprehensive and integrated United States research program which will assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change." Its 13 member agencies[474] conduct and use fundamental and translational research to advance scientific understanding and provide information and tools to help the nation and the world prepare for and respond to global change. For the period 2016–2020, the USGCRP member agencies invested roughly $12.5 billion in global change science.

USGCRP's flagship product is the Congressionally mandated National Climate Assessment (NCA), with the 5th NCA now under development. Intended for a scientifically interested but not expert audience, the report synthesizes and distills climate science and climate impacts literature for key sectors and the different regions of the U.S. and Caribbean, and produces climate trends and projections for the next 25 and 100 years. The NCA and USGCRP special assessments (e.g., on carbon cycle, climate and health, climate and food security) are published on the globalchange.gov website where content is searchable and shareable. USGCRP assessments use the Global Change Information System (GCIS) to provide metadata

[474] https://www.globalchange.gov/agencies.

traceability from key findings to the underlying literature sources and data sets. The assessments have embedded clickable links to citations in the narrative and references to data sets used in figures, making it an outstanding research and teaching tool.

RESEARCH ON GLOBAL CHANGE

U.S. global change research is distributed across USGCRP's member agencies, each according to their mandates and missions, with USGCRP playing a coordinating role. An increasing number of non-member science-using agencies also participate in USGCRP. Key areas include Earth observations, model development and use, assessments of climate change and impacts in the United States and worldwide, science for adaptation and data and information sharing. USGCRP agencies are greatly improving integrated natural and human system models and the spatial and temporal resolution of climate change models, and are building much faster computers that will enhance climate modeling. USGCRP is increasing its work in adaptation science and aims to increase its integration of socioeconomic sciences with natural-system global change science.

USGCRP works closely with a number of international science coordination groups, reflecting the inherently international nature of global change and the directives of the GCRA. USGCRP provides partial funding support to the World Climate Research Program (WCRP), the System for Analysis, Research and Training (START) and Future Earth. Member agencies support the Belmont Forum's Collaborative Research Actions (CRAs), and the U.S. has played a major role in development of the first and second CRAs on Climate, Environment and Health.

OBSERVING SYSTEMS

The United States maintains an extensive and diverse observing portfolio that includes in-situ, airborne, autonomous vehicle and satellite-based sensors on land, and in the oceans, atmosphere and cryosphere. Observing field campaigns are sometimes combined with other approaches to provide comprehensive understanding of shorter- and longer-term processes on local scales, nested regionally or globally. For an extensive list of examples of ongoing, planned, and completed observational efforts through Fiscal Year 2021 that illustrate the breadth and depth of the Program's capabilities, please see the USGCRP Observations Compendium.[475]

Small satellites, artificial intelligence, and new sensor development are providing new and improved ways to observe the Earth and ingest data. USGCRP member agencies often support private-public partnerships to promote innovation in observing approaches and

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[475] https://www.globalchange.gov/content/usgcrp-observations-compendium-fiscal-year-2021.

data treatment. The National Academies of Sciences, Engineering and Medicine (NASEM) prepared the second Decadal Strategy for Earth Observations from Space[476] for the National Aeronautics and Space Administration (NASA), NOAA and USGS in 2018, which is helping to inform future satellite mission planning.

The United States remains committed to making observing data freely and openly available to all. The agencies most active in satellite observations (NASA, NOAA and the U.S. Geological Survey (USGS) have extensive resources to aid scientific users. There is a growing effort to also make data more relevant, useful and usable for decision makers and managers. For example, NASA and USGS provide Landsat data free of charge from multiple websites: LandsatLook Viewer[477], USGS GloVis: The Global Visualization Viewer[478],and USGS Earth Explorer[479]. The USGS also freely offers the Landsat data collection[480], which consists of a global set of high-quality, relatively cloud-free imagery from Landsats 1-5 and 7. The latest satellite in the series, Landsat 9, was launched in September 2021.

Commercially acquired data may also provide a cost-effective means to augment and/or complement the suite of Earth observations acquired by NASA and other U.S. government agencies and those by international partners and agencies. NASA recognizes the potential impact that commercial remote sensing data may have in enabling efficient approaches to advancing Earth System Science and applications development for societal benefit. The scientific community may use commercial datasets that are acquired by NASA for scientific purposes in adherence to vendor-specific terms and conditions.

GENERAL POLICY ON AND FUNDING OF RESEARCH AND SYSTEMATIC OBSERVATION

USGCRP member agencies fund global change research, observations and related activities through support for scientists working in federal agencies, federally supported laboratories and the academic community. Agency budgets for global change research are based on annual appropriations from Congress and are reported yearly in the USGCRP annual report to Congress, *Our Changing Planet*.[481] The reported budget numbers do not reflect agency investments in operations (e.g., NOAA weather satellites) that provide data also used for

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[476] https://www.nap.edu/catalog/24938/thriving-on-our-changing-planet-a-decadal-strategy-for-earth.
[477] http://landsatlook.usgs.gov/.
[478] http://glovis.usgs.gov/.
[479] http://earthexplorer.usgs.gov/.
[480] https://lta.cr.usgs.gov/Tri_Dec_GLOO.
[481] https://downloads.globalchange.gov/ocp/ocp2022/Our-Changing-Planet_FY-2022.pdf.

climate change research. The reported USGCRP Research and Development budget has remained relatively flat from 2009 through 2020, at ~ $2.5 billion per year. The budget in 2021 was approximately $3.3 billion. USGCRP member agencies work together on coordinated calls for proposals on selected topics nationally, and internationally through the Belmont Forum.

Data developed through U.S. federal funding sources is required to be made publicly available nationally and internationally to both the private and public sectors. Major resources for global change data, and tools from multiple agencies - including the Climate Resilience Toolkit.[482]

RESEARCH

When Congress established the USGCRP in 1990, it recognized the need for multi-agency coordination to build the scientific understanding needed to tackle global and climate change, and to use that science to inform responses; they established USGCRP to provide that coordination. USGCRP uses decadal strategic plans and their updates to guide the program and annual updates to Congress, *Our Changing Planet,* to report on progress.

USGCRP's STRATEGIC PLANNING

The USGCRP National Research Plan 2012-2021 and its update in 2017 (both available at globalchange.gov) represented a major shift for the whole-of-government program. They added a major new emphasis on informing decisions and developing a sustained assessment process to the traditional focus on fundamental understanding of the climate system and its interplay with wider global change. Selected outcomes from USGCRP's work in informing decisions and sustained assessments are highlighted in Chapter 6.

USGCRP is now developing its next decadal strategic plan. Intended for release in late 2022, the decadal plan was open for public comment and reviewed by the National Academies of Sciences, Engineering and Medicine (NASEM) Committee to Advise USGCRP. The recently released NASEM report "Global Change Research Gaps and Opportunities, 2022-2031"[483] helped inform the next USGCRP plan and their review of the plan provided many constructive suggestions for USGCRP. The plan was developed by senior career climate officials from the USGCRP member agencies. During plan development, USGCRP solicited

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[482] https://www.data.gov/climate/.
[483] https://www.nap.edu/catalog/26055/global-change-research-needs-and-opportunities-for-2022-2031.

input from a wide swathe of federal agencies with climate-related responsibilities and held public engagement sessions via NASEM.

THE RESEARCH FRAMEWORK

This section highlights advances in climate and global change modeling. These clearly don't stand alone but rather tie closely to observations and process understanding work conducted by USGCRP agencies. Key observational capabilities are discussed in the following section.

MODELING CAPABILITIES

Each year since 2015, USGCRP has hosted a 'Climate Modeling Summit' with representatives from the six major U.S. climate modeling centers with the goal to improve the coordination and communication involving national ambitions for improved climate modeling and prediction capabilities. Adjacent to each annual Summit, USGCRP also organizes a topical workshop that serves as a venue for focused technical discussion on a high-priority modeling topic facing the U.S. and international prediction research communities.

The U.S. climate modeling community participates in the WCRP, e.g., with commitments to provide model ensemble runs as part of all 23 Model Intercomparison Projects (MIPs). These MIPs are used by U.S. research institutions to guide scientific priorities across the U.S. federal agencies, e.g., as a means to more rapidly advance climate science, foster international collaborations, and serve societal needs.

To support the climate prediction community, the U.S. federal agencies have made significant investments in the archiving and analysis of climate model output data, in high performance computing for climate prediction, and linking climate models to impacts models over a variety of human sectors. The Earth System Grid Federation (ESGF) archives model ensemble runs for all climate models world-wide. It occupies a network of international nodes, and investments in its capabilities are provided by the U.S. Department of Energy (DOE), NASA, the European Union, Australia, and other countries. Finally, climate modeling supported by a variety of USGCRP agencies continues to evolve with more sophisticated predictions that combine climate change with impacts across a variety of agricultural, energy, water, and land use sectors, so that stakeholders have actionable information that meets their needs. There is a growing emphasis on Multi-Sector Dynamics modeling.

INTERNATIONAL RESEARCH PROGRAMS AND PARTNERSHIPS

The long-term strength of U.S. global change research—from sustaining Earth observations, to assessing global climate, to preparing for global change—depends on close engagement with international efforts. As part of its mandate under the Global Change Research Act, USGCRP works to improve coordination of U.S. activities with the programs of other nations and international organizations in order to promote international cooperation on global change research and build global change research capacity in developing countries.

The United States is the single largest contributor to intellectual content of Intergovernmental Panel on Climate Change (IPCC) reports, with well over 100 writing team members serving during the Sixth Assessment Report (AR6) cycle, including on the four volumes comprising the AR6, three Special Reports (Special Report on Global Warming of 1.5 degrees Celsius, Special Report on Climate Change and Land, Special Report on the Ocean and Cryosphere in a Changing Climate), and a Task Force on Green House Gases (TFI) Methodology Refinement. The U.S. Government routinely provides comprehensive reviews of the draft reports, involving a process open to the general public, hundreds of targeted reviewers, and convened expert panels to ensure rigor of submitted comments. The USGCRP also provides travel support to facilitate non-Federal U.S. scientist participation in international assessment activities (IPCC, United Nations Environment Program (UNEP), Office of Atmospheric Programs (OAP), Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), and the Arctic Council).

In support of its international mandate, USGCRP currently helps provide core budget support to three international science organizations: Future Earth, which builds interdisciplinary, cross-sectoral partnerships to advance global sustainability science; the SysTem for Analysis, Research, and Training (START), which provides opportunities for research, education, and training to scientists, policymakers, and practitioners in developing countries; and the WCRP, which is the primary international coordination mechanism for climate system research.

The SERVIR program, also described in Chapter 7, is another example of international programming to support research and systematic observation. SERVIR is a joint initiative between NASA and USAID that develops demand-driven services, tools, and training for decision-makers in more than 50 countries. By connecting USAID's development network with NASA's science, geospatial technologies, and extensive satellite data, SERVIR helps strengthen local capacity to integrate science and technology into decision-making. Since 2004, SERVIR has collaborated with leading regional organizations in partner countries to help people and institutions track land use and land use changes, identify and manage climate risks, and prepare for and respond rapidly to hydroclimatic disasters and other hazards. In March 2019, USAID and NASA initiated activities for SERVIR-Amazonia, a five-year effort to provide environmental information that helps people address development challenges and impacts of climate change on lives and livelihoods in the Amazon Basin, home to the world's largest tropical rainforest. SERVIR-Amazonia is one of five SERVIR regional hubs currently operating around the world. It is implemented through a network of local and international partners serving the Amazon region.

Currently, USGCRP is developing a new regional engagement effort, entitled Latin America and the Caribbean Initiative (LACI): Enhancing Capacity for Climate Risk Assessment and Catalyzing Partnerships to Inform Decisions. The vision behind LACI is to provide opportunities for partnerships between the Caribbean, Latin American, and North American countries to enhance capacity for climate risk and vulnerability assessments that would support local and regional decision-making in response to climate change impacts. LACI is a collaborative effort between the USGCRP and the Group on Earth Observations (USGEO) and regional partners, including the AmeriGEO (regional organization of international GEO), and the Inter-American Institute (IAI) for Global Change Research. LACI is grounded in co-design with the following anticipated overarching activities: partnership building and fostering, peer-to-peer learning and training, and data synthesis and analysis. The proposed activities will help participants at all career stages expand their knowledge of assessment practices and protocols while building meaningful relationships across geographic, disciplinary, and institutional borders.

The United States played a leading role in the development of a Belmont Forum international Collaborative Research Action (CRA). The CRA, funded by multiple countries and launched in April 2019, focuses on issues at the intersection of climate, environment, and human health. The CRA is supporting international research teams of natural, health, and social scientists and stakeholders, working together to understand how climate variability and change influence human health and well-being, and to support effective responses. The initiative aims to generate scientific evidence and tools to support policy and decision-making that can enhance health system resilience to climate impacts and provide significant public health benefits.

RESEARCH AND DEVELOPMENT OF MITIGATION AND ADAPTATION APPROACHES, INCLUDING TECHNOLOGIES

Federal agencies are prioritizing research and development investments in mitigation and adaptation solutions to reduce climate pollution in every sector of the economy and increase resilience to the impacts of climate change. Government investments include research, development, demonstration, and deployment to support the scale-up and transition to operations of emerging clean energy and other emissions mitigation enabling technologies, such as utility-scale energy storage and other zero-carbon grid resilience technologies; carbon capture, utilization and storage; clean hydrogen; advanced nuclear power; advanced building heating and cooling technologies, including cold-climate heat pumps and low-GWP refrigerants; clean industrial process heat; rare earth element separations; floating offshore wind; sustainable biofuels/bioproducts; and carbon dioxide removal approaches. Chapters 4 provides information on a number of relevant programs. Other examples of federal agencies pursuing research investments include:

- The U.S. Department of Energy's Office of Energy Efficiency & Renewable Energy (EERE), whose mission is to accelerate the research, development, demonstration, and deployment of technologies and solutions to equitably transition America to net-zero greenhouse gas (GHG) emissions and ensure the clean energy economy benefits all Americans. EERE's strategy includes investments in five priority areas: decarbonizing the electricity sector; decarbonizing transportation across all modes; decarbonizing energy-intensive industries; reducing the carbon footprint of buildings; and decarbonizing the agriculture sector.
- The U.S. Department of Agriculture's Forest Service pursues research to conserve forests, increase carbon sequestration in forest ecosystems, and provide new energy efficient products and technologies for society. Forest Service science investigates the pools and fluxes of carbon in various ecosystems throughout the country and around the world. This work includes understanding the carbon cycle as influenced by forest type and age, but also knowing the impacts of forest management practices over time on carbon sequestration and patterns of carbon emissions. By understanding the dynamics of the carbon cycle, decision-makers can better incorporate carbon sequestration into management objectives.
- The Federal government currently has a suite of capabilities, from *in situ* to space-based capabilities, to track the emissions and uptake of GHGs from point and nonpoint sources. However, those capabilities are distributed across Federal agencies, each with responsibilities for various sectors or Earth systems. As a result, the U.S. government is taking steps to improve coordination of these efforts and plan for future efforts and investments.
- Through the 24 Feed the Future Innovation Labs, the U.S. Agency for International Development (USAID) and the U.S. government support research by more than 70 universities and many partners on developing and scaling up safe and effective technologies that address the current and future challenges posed by a changing climate and the need to feed a growing global population. Research covers areas that range from climate-resilient crop varieties to small-scale irrigation to financial and market innovations that strengthen the resilience of farmers and rural economies.

Climate adaptation and resilience is also a priority for federal research, and agencies are pursuing greater understanding of adaptation approaches. Chapter 6 provides examples of this work; the programs below also illustrate these investments:

- The U.S. Geological Survey National and Regional Climate Adaptation Science Centers (CASCs) is a partnership-driven program that teams scientific researchers with natural and cultural resource managers and local communities to help fish, wildlife, waters, and lands across the country adapt to changing conditions. The CASC network places emphasis on generating actionable science, information and products that address identified science needs and are directly usable in supporting resource management decisions, actions, and plans. Development of actionable science requires scientists to work iteratively with the intended end users of the scientific product, such as resource managers and native communities.
- With global change propelling ecosystems on trajectories toward irreversible ecological transformation, natural resource managers need new approaches to guide decision making. A coalition of scientists from several federal agencies, under the leadership of the National Park Service and the U.S. Geological Survey, developed the Resist-Accept-Direct (RAD) framework, which identifies the options managers have for responding and helps them make informed, purposeful, and strategic choices. In December 2021, scientists from the U.S. Geological Survey National and Regional Climate Adaptation Science Centers, along with other science centers and federal agencies, published a special issue of the journal BioScience, providing an in-depth exposition of the RAD framework and exploring the practical applications of the framework, compatibility of existing tools, social barriers and opportunities, and future science needs.
- The U.S. Army Corps of Engineers Engineer Research and Development Center (ERDC) provides innovative and environmentally sustainable solutions to the nation's water resources challenges. Climate change is putting increasing pressure on water resources, and ERDC's technologies help provide safe and resilient communities and infrastructure. ERDC science and technology help the Army Corps of Engineers manage existing water resources infrastructure sustainably in the face of climate change and other challenges.

SYSTEMATIC OBSERVATIONS

The United States has been a global leader in observing the ocean, atmosphere, land, space, and cryosphere. Along with international partners, observing networks have enabled monitoring of all domains for improved understanding of the integrated Earth system.

The U.S. Earth observation community has been developing new capabilities that leverage federal investments in artificial intelligence, sensor miniaturization, small satellites (smallsats), and private-public partnerships. Recent advances in machine learning have enabled automated image analysis as well as enhanced algorithm capabilities to accelerate the detection of climate change and provide near real time actionable information on evolving climate impacts for decision makers. The combination of sensor miniaturization and the lower costs of launching smallsats into orbit has created an opportunity for several private-public partnerships to design, build, and start to deploy constellations of satellites to fill gaps in Earth observation needs.

U.S. Group on Earth Observations (USGEO) is the interagency coordination mechanism for Federal Agencies' civil Earth observations activities, and for participation in the GEO international voluntary partnership. USGEO is a Subcommittee under the White House National Science and Technology Council's (NSTC) Committee on Environment (CE). Its membership consists of 13 Federal Agencies and components of the Executive Office of the President; the 2019 National Plan for Civil Earth Observations guides this work.[484]

APPLIED USES OF USGCRP AGENCY OBSERVATIONS

There are numerous applications of observations supported by the USGCRP federal agencies. The Observations Interagency Working Group (ObsIWG) produces a Compendium of Federal Earth Observation Activities[485] that is used to support coordination of field campaigns and other observing efforts across agencies. The compendium is also used to identify gaps in the sustained observing networks. The compendium provides data and information useful to scientists, policy makers and decision makers in all areas of climate science to better understand, assess, predict, and respond to global change.

CHALLENGES FOR EARTH OBSERVATIONS

Under the challenges of an Earth stressed by a changing climate, it is essential to monitor the environment to build our understanding of the functioning of the Earth system. Remote sensing and *in situ* systems are critical to collecting long-term, high-quality observations. Aging infrastructure and instrumentation is a concern facing our networks of today and tomorrow. A number of instrument manufacturers have gone out of business during COVID, presenting a real challenge to observing communities. Natural hazards (e.g., volcanic eruptions, wildfires, severe storms) have also impacted field sites in vulnerable coastal and mountainous environments and other regions where climate change is impacting biomes. There are also general challenges attaining high temporal resolution at space-based stations and high spatial resolution data at ground sites. Ensuring a commitment to maintaining and

[484] https://usgeo.gov/uploads/Natl-Plan-for-Civil-Earth-Obs.pdf.
[485] https://www.globalchange.gov/about/iwgs/obsiwg/observation_compendium.

strengthening our observing networks is essential to improve our ability to make appropriate decisions based on high quality observations.

DOCUMENTATION OF U.S. CLIMATE OBSERVATIONS

Long-term data records enable development of indicators of climate and climate change. The Environmental Protection Agency (EPA) produces the Climate Change Indicators in the U.S. report[486] while the USGCRP manages an interagency indicators platform.[487] A Global Climate Dashboard[488] shows the time series for variables focused on climate change, climate variability, and climate projections.

The United States also contributes to work on Essential Climate Variable (ECV) datasets[489]– time series to enable understanding of the evolution of climate. They are also useful to guide mitigation and adaptation measures and help attribute climate events to underlying causes while underpinning climate services. High priority ECVs for future investment include cloud and radiation properties to help improve climate models, Arctic indicators to improve our understanding of highly complex and changing high latitude environments, soil moisture to understand drought and the potential for wildfire, and GHG fluxes. Key time series include GHGs, sea ice, sea level/temperature, ocean heat, and polar ice mass.

Observing capabilities enable a plethora of scientific applications ranging from informing the global stocktaking exercises, improving severe weather forecasts and climate monitoring, and enabling better decision making for navigation, transportation, agriculture, wildfire and smoke forecasts, and resource management, to name a few.

CURRENT SURFACE AND SATELLITE-BASED OBSERVATIONS OF LAND, OCEANS, ATMOSPHERE, AND CRYOSPHERE

Since we cannot observe all variables at all times, the growth of sustained *in situ* observing networks to provide point data, development of satellite networks to view large regions of earth from space, and planning of intensive field campaigns to systematically observe many variables over a short period to improve climate and other models are all essential to obtain a global view of earth's dynamic system. Following is a sampling of current observational networks and efforts leading to improved understanding of each domain.

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[486] https://www.epa.gov/climate-indicators.
[487] https://www.globalchange.gov/indicators.
[488] https://www.climate.gov/.
[489] https://public.wmo.int/en/programmes/global-climate-observing-system/essential-climate-variables.

IN SITU ATMOSPHERIC OBSERVATIONS

- The U.S. Climate Reference Network (USCRN) is a systematic and sustained network or climate monitoring with 114 commissioned stations in the contiguous United States, 21 stations in Alaska (with a plan to eventually have a total of 29), and 2 stations in Hawaii. These stations use high-quality instruments to measure temperature, precipitation, wind speed, soil conditions, and more.
- Ground-based remote sensing aerosol networks in AERONET (AErosol RObotic NETwork) have provided for more than 25 years measurements of aerosol optical, microphysical and radiative properties for aerosol research and characterization). The network is supported by NASA in partnership with the French government and expanded by a range of international collaborators. [490]
- Stations in the Global Climate Observing System (GCOS) Surface Network (GSN), the GCOS Upper Air Network (GUAN), and in the Global Atmosphere Watch (GAW) are distributed geographically as prescribed in the GCOS and GAW network designs. The data (metadata and observations) from these stations are shared according to GCOS and GAW protocols.
- The Southern Hemisphere ADditional OZonesondes provides a consistent dataset from balloon-borne ozonesondes for ground verification of satellite tropospheric ozone measurements at 17 sites across the tropical and subtropical regions of the southern hemisphere.[491]

IN SITU OCEAN OBSERVATIONS

- Argo (is an international program that collects information from the ocean using a fleet of robotic instruments that drift with the ocean currents and move up and down between the surface and a mid-water level.[492]
- The U.S. Integrated Ocean Observing System (IOOS) is a globally linked and nationally coordinated federal and non-federal network of coastal observations and data management, led by NOAA.[493]
- The Ocean Observatories Initiative (OOI) is a science-driven ocean observing network that delivers real-time data from more than 800 instruments to

[490] https://aeronet.gsfc.nasa.gov/; https://www-loa.univ-lille1.fr/photons.
[491] https://tropo.gsfc.nasa.gov/shadoz/.
[492] https://argo.ucsd.edu/.
[493] https://ioos.noaa.gov/.

address critical science questions regarding the world's oceans, supported by the National Science Foundation.[494]

IN SITU TERRESTRIAL OBSERVATIONS

- The National Science Foundation's National Ecological Observatory Network (NEON)) is a continental-scale observation facility designed to collect long-term open access ecological data to better understand how U.S. ecosystems are changing. NEON monitors 81 ecosystems across the United States, including freshwater and terrestrial ecosystems. It has been fully operational since 2019.[495]
- The AmeriFLUX network was established to monitor long-term measurements of carbon dioxide (CO_2), methane, water, and energy exchange from a variety of ecosystems. The system helps define the current global carbon monoxide (CO) budget, enable improved projections of future concentrations of atmospheric CO, and enhance the understanding of carbon fluxes, net ecosystem production, and carbon sequestration in the terrestrial biosphere.[496]

IN SITU CRYOSPHERE OBSERVATIONS

- NASA's Operation IceBridge (OIB), successfully bridged the observing gap of Earth's Polar ice caps between the end of ICESat-1 mission in 2009 and the successful start of ICESat-2 observations in 2019 using a highly specialized fleet of research aircraft and the most sophisticated suite of innovative science instruments ever assembled to characterize annual changes in thickness of sea ice, glaciers, and ice sheets. In addition, IceBridge collected critical data used to predict the response of Earth's Polar ice to climate change and resulting sea-level rise.[497]
- Oceans Melting Greenland was a multi-year (2016-2021) NASA airborne field campaign to understand the role that the ocean plays in melting Greenland's glaciers. From the sky and the sea, OMG gathered *in situ* data about water temperatures and the glaciers all the way around Greenland to get a better

[494] oceanobservatories.org.
[495] https:// www.neonscience.org/.
[496] https://ameriflux.lbl.gov/.
[497] https://icebridge.gsfc.nasa.gov/.

idea of the impact of ocean water on the Greenland ice sheet to better understand global sea level rise.[498]

SATELLITE BASED MEASUREMENTS

- NOAA's National Environmental Satellite Data and Information Service (NESDIS) has geostationary and polar orbiting satellites that continuously monitor the Earth's climate system..[499]
- The NASA Earth Science Division currently has more than twenty-one Earth observing satellites in low Earth orbit. Since 2014, NASA has helped to launch fourteen satellite systems to monitor various parts of the climate system, including: precipitation, atmospheric carbon dioxide, soil moisture, hurricane winds, Earth's surface mass and water changes, ice-cloud-land elevation, forest canopy density, forest fires, sea surface height, surface temperature and plant evaporative stress, carbon dioxide flux estimates, total solar irradiance, lightning, aerosols, and stratospheric ozone.
- NOAA has developed a new program, GeoXO, for the next generation of geostationary Earth observations, while NASA is implementing the Earth System Observatory, a set of complementary Earth-focused missions to provide information about climate change, natural hazards, wildfires, and agricultural processes. NASA is also working with various national and international partners to construct and prepare at least nine new satellites for launch in the next several years. These satellites will observe precipitation intensity & storm structure, hazards and environmental change, land surface, GHGs, hourly air quality for North America, megacity air pollution & human health, plankton & ocean ecosystems, far infrared energy escaping the polar regions, and coastal biogeochemistry for North America.

U.S. INVOLVEMENT IN INTERNATIONAL OBSERVING

The United States works with partners around the world on global climate observations, including through organizations such as the World Meteorological Organization (WMO) to coordinate global climate observations. Many U.S. observing communities work together in contribution to the international climate observing community under the Global Climate Observing System (GCOS). The mission of GCOS is to provide continuous, reliable, comprehensive data and information on the state of the global climate system. GCOS

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[498] https://omg.jpl.nasa.gov/portal/.

[499] https://www.nesdis.noaa.gov/.

consists of the climate-relevant components of existing atmospheric, oceanic and terrestrial observing systems intended to meet the totality of national and international user needs for climate observations. The United States also contributes to Global Atmosphere Watch, which provides information and services on atmospheric composition to the public and to decision-makers relating to: the abundance GHGs, the protective stratospheric ozone layer, and the levels urban air pollution and its impact on human health.

DATA MANAGEMENT AND INFORMATION SYSTEMS

While federally managed Earth observations are typically collected for a specific purpose, these data are often found to be useful in other applications, including use by state, local, and international decision makers and in the private sector. It is therefore essential to manage and preserve observations data so that users can find, evaluate, understand, and utilize them in new and unanticipated ways. Examples of data management systems and guidance include:

- *Common Framework for Earth Observations Data*,[500] a USGEO product that provides guidance to data producers in Federal agencies for improving and standardizing their data-management practices.
- *Earth Observing System Data and Information System*,[501] which includes updated description and statistics from NASA
- *Socioeconomic Data and Applications Center* (SEDAC),[502] which includes updated description and statistics on SEDAC from NASA
- *National Integrated Drought Information System,*[503] a multi-agency partnership that coordinates drought monitoring, forecasting, planning, and information at federal, tribal, state, and local levels across the country.
- *Global Change Information System,*[504] which coordinates and integrates information about changes in the global environment and related societal effects, serves as a key access point to assessments, reports, and tools produced by the USGCRP, and guides users to global change research produced by the 13 USGCRP member agencies.

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[500] https://usgeo.gov/uploads/common_framework_for_earth_observation_data.pdf.
[501] https://earthdata.nasa.gov/eosdis.
[502] https://sedac.ciesin.columbia.edu.
[503] https://www.drought.gov/about.
[504] https://data.globalchange.gov.

- *Data Access Tools for Climate and Health,*[505] the Climate and Health Monitor and Outlook (CHMO) is a multifaceted, experimental, interpretive product intended to improve the utility of seasonal- to-subseasonal information for heat health risk management.
- *U.S. Climate Resilience Toolkit,*[506] a website designed to help people find and use tools, information, and subject matter expertise from across the U.S. government to build climate resilience.
- *Climate.gov*[507] provides science and information to help people make decisions on how to manage climate-related risks and opportunities they face.
- *State of the Climate Report*,[508] NOAA's annual report, based on contributions from scientists around the world, and providing a detailed update on global climate indicators, notable weather events, and other data collected by environmental monitoring stations and instruments located on land, water, ice, and in space.
- U.S. EPA Climate Change Indicators in the United States[509] is a compilation of a key set of indicators related to the causes and effects of climate change by more than 50 data contributors from various government agencies, academic institutions, and other organizations.

[505] https://ephtracking.cdc.gov/Applications/heatTracker/.
[506] https://toolkit.climate.gov/.
[507] https://climate.gov/.
[508] https://www.ncdc.noaa.gov/sotc/.
[509] https://www.epa.gov/climate-indicators.

Chapter 9.
CLIMATE EDUCATION, ENGAGEMENT, WORKFORCE DEVELOPMENT, AND TRAINING

Chapter 9. CLIMATE EDUCATION, ENGAGEMENT, WORKFORCE DEVELOPMENT, AND TRAINING

INTRODUCTION

In 2021 and 2022, across the United States, climate education, engagement, workforce development and training initiatives and programs have surged in quantity and scope. This acceleration is due to the Administration's prioritization of addressing the climate crisis, demonstrated in Executive Orders 13990 "Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis"[510] and 14008 "Tackling the Climate Crisis at Home and Abroad,"[511] in addition to the release of the Intergovernmental Panel on Climate Change (IPCC) 6th Assessment and associated increasing recognition of the importance of education, capacity building and community engagement to advance climate action. A growing number of federal, state, tribal, and local leaders across the United States are implementing programs and curricula intended to educate the public and students about the science of and solutions to climate change.

The Administration's focus on job quality and commitment to ensure that the jobs created from unprecedented investments support workers' rights to organize and level the playing field for collective bargaining is helping to ensure better compensation, more job security, protection of worker rights, and improved health and safety on the job. These measures will work long term to ensure that clean energy opportunities are able to attract and retain a skilled and qualified workforce. In response, workforce development programs in colleges and universities are expanding STEM education for professional careers in clean energy, while trades schools, apprenticeship programs, community colleges, employers, nonprofit training providers are offering education and training to support clean energy deployment.

Effective climate communication and access to information initiatives are empowering many local governments, businesses, community groups, and individuals to take science-based, just, and urgent climate action. Public participation and engagement campaigns are growing in importance as climate strategies to ensure that community goals are met through climate action, in turn increasing trust in, support for, and longevity of solutions. The Administration's focus on climate and environmental justice, demonstrated in executive

[510] https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/20/executive-order-protecting-public-health-and-environment-and-restoring-science-to-tackle-climate-crisis/
[511] https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/27/executive-order-on-tackling-the-climate-crisis-at-home-and-abroad/.

orders 13990 and 14008, works to ensure that climate action and education, engagement, workforce development and training activities address historic harms to marginalized communities and offer opportunity for all, regardless of race, age, gender, socioeconomic status, background, ability, or any other characteristic.[512]

These efforts are increasingly strategically coordinated and networked at different levels from community through the national. However, enhanced coordination and human infrastructure is needed for collective impact. Cities, counties, states, businesses, and cultural institutions around the country have set ambitious clean energy, resilience and climate action goals, but the path to achieving them is challenging. Making the case for climate action continues to be one of the leading challenges that communities face in undertaking ambitious climate action. Effectively engaging communities in climate action and building people's capacity is helping leaders to close the wage and skills gap, eliminate carbon pollution, and build healthier, more equitable, more resilient and regenerative communities.

NATIONAL CONTEXT IN THE UNITED STATES

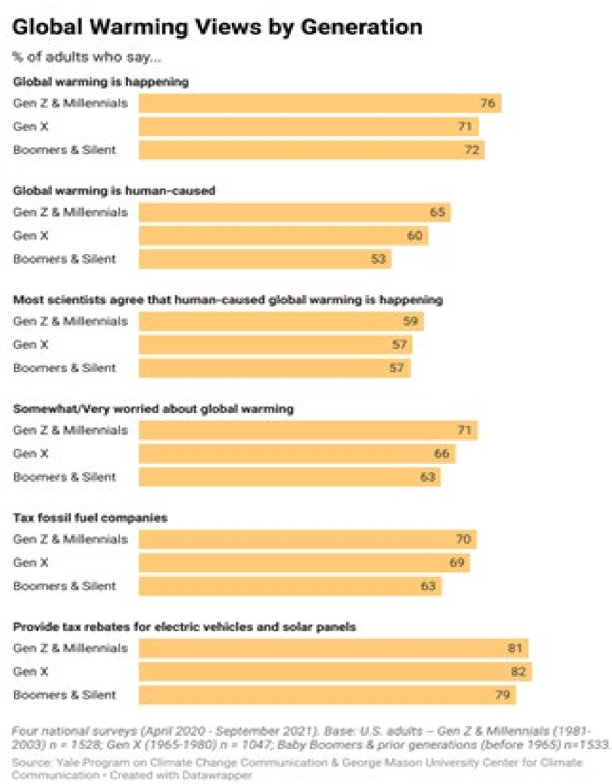
The national context around climate action has shifted dramatically in recent years. Federally, the Biden-Harris Administration s prioritization of tackling the climate crisis has accelerated the development and implementation of a wide range of climate education, training, and outreach programs. Outside the federal government, interest, investment, and effort in these activities have continued to increase as climate impacts worsen and the need for all-of-society climate solutions become clearer. Emerging networks within fields of climate education, workforce development, and outreach and across fields are increasingly coordinating and mobilizing this work on all levels. Some of these programs are detailed below.

Public opinion of climate change and climate action has changed as well, and surveys show that U.S. society could be close to a tipping point on climate action. As of April 2022, the majority of Americans believe that global warming is happening (72 percent), support climate action (66-80 percent, depending on the action),[513] are worried about global warming (64 percent) and find climate change at least somewhat important to them personally (64 percent), though this consensus is extraordinarily poorly understood.[514] This is in part due

[512] https://www.nature.com/articles/s41467-022-32412-y.
[513] *Ibid*.
[514] https://climatecommunication.yale.edu/wp-content/uploads/2022/07/climate-change-american-mind-april-2022.pdf

to the fact that only one third (33 percent) of Americans reported discussing global warming "occasionally" or "often" and only 24 percent of people report hearing friends talk about global warming once a month or more. Fewer than half of Americans think their friends and family take action on global warming (40 percent) or that their friends and family expect them to take action (40 percent). Additionally, a national survey in 2020-2021 from American Society on Aging indicates that people's views on climate issues differ greater when it comes to partisanship and race rather than by age.[515] The continued gulf between high concern and urgency and low perceived action and social pressure is hindering climate action at all levels across the United States. Action to bridge this gap through solutions-focused education, workforce development and training, communication, and engagement are beginning to mobilize the concerned majority and make climate action a social norm.

Figure 9-1 Climate Change Views Differ by Generation across the United States from April 2020 and September 2021[505]



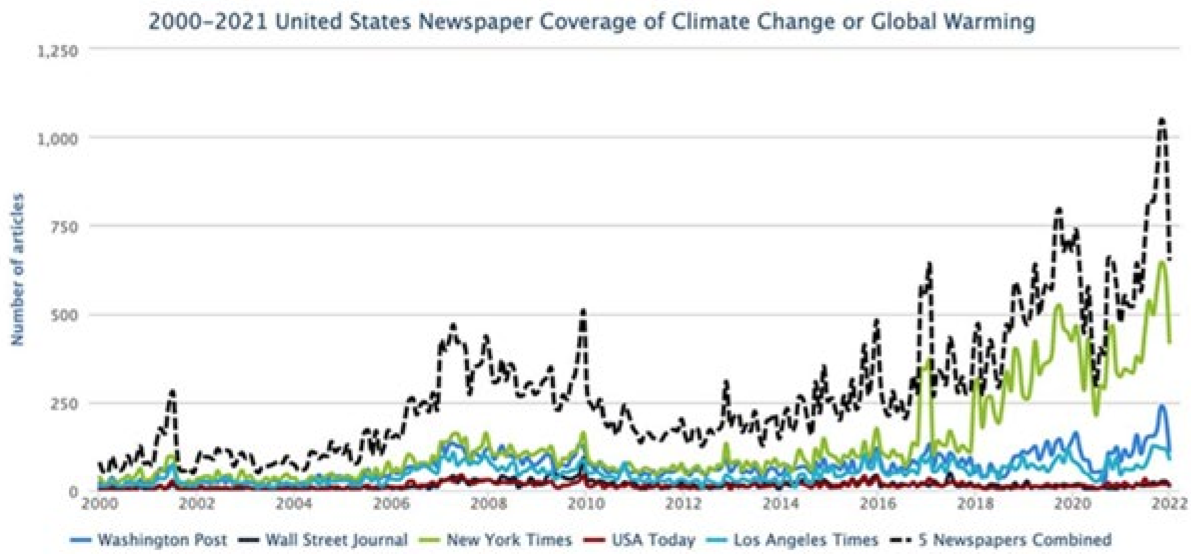
CLIMATE REPORTING AND AWARENESS

American media coverage of climate change increased between 2020 and 2022, with not only more stories told but more news organizations devoting more resources to climate

[515] https://generations.asaging.org/how-do-climate-change-views-differ-generation

topics. Leading newspapers such as the Boston Globe, New York Times, the Washington Post, and others have added or expanded their climate desks and hired climate-specific journalists over the past two years, signaling that climate stories are becoming more important to news consumers.[516] Six of the ten largest newspapers and all of the major cable news networks in the U.S. reported record high numbers of climate stories in 2021.[517]

Figure 9-2: Month-to-Month Newspaper (top) and Television (bottom) Climate News Stories from Major Sources[518]



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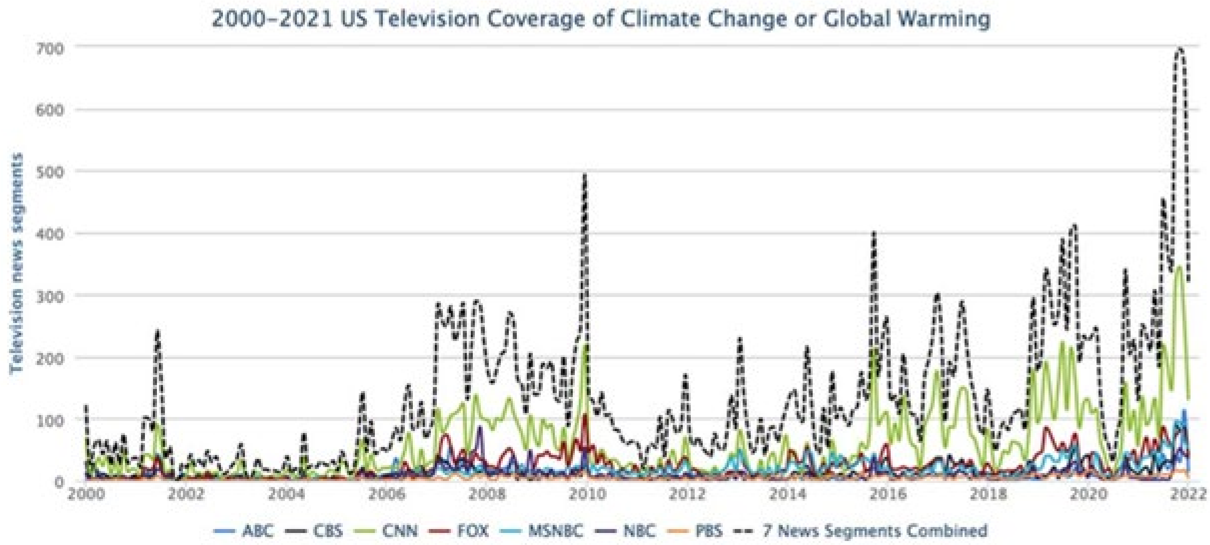
[516] See, for example, https://www.bostonglobe.com/2022/01/20/science/into-red-how-globe-will-cover-climate-change/, https://www.nytimes.com/2022/02/23/climate/nyt-climate-newsletter-somini-sengupta.html, https://www.washingtonpost.com/pr/2022/02/10/post-announces-newsroom-expansion-adding-more-than-70-positions-2022/.

[517] The Center for Science and Technology Policy Research at the University of Colorado has tracked media coverage of climate change since 2000.
https://sciencepolicy.colorado.edu/icecaps/research/media_coverage/summaries/special_issue_2021.html

[518] Newspaper (top figure): Boykoff, M., Daly, M., McNatt, and Nacu-Schmidt, A. (2022). United States Newspaper Coverage of Climate Change or Global Warming, 2000-2022.. d Media and Climate Change Observatory Data Sets. Cooperative Institute for Research in Environmental Sciences, University of Colorado. doi.org/10.25810/jck1-hf50. Television (bottom figure): Boykoff, M., Fifford, L., Nacu-Schmidt, A. and Osborne-Gowey, J. (2022). US Television Coverage of Climate Change or Global Warming, 2004-2022. Media and Climate Change Observatory Data Sets. Cooperative Institute for Research in Environmental Sciences, University of Colorado. doi.org110.25810/c862-Oe81.



UPDATES SINCE NC7

Climate education, training, and outreach efforts continued to mature and expand in the 2 years since the 7th National Communication (NC7). A focus on justice and equity has become the norm across both non-federal and federal climate efforts, which is likely to increase efficacy of climate solutions and begin to ameliorate past environmental and social injustices. This chapter presents a non-exhaustive list of some of the actions at the federal, nonfederal, and community level that are inspiring urgent, effective, sustainable, and just climate action across the United States.

FEDERAL ACTION

FEDERAL CONTEXT

Two executive orders, signed by President Biden in 2021, set the stage for an expansion of climate education, training, empowerment, and justice actions in 2022 and beyond. Executive order 14008,[519] among many other climate actions, established a whole-of-government approach to climate change, ensuring that our investments would support the expansion of good union jobs and that every agency would be tackling the climate crisis in its work. It also created the Justice40 initiative, which sets a goal that 40 percent of benefits from domestic Federal climate investments should go to communities burdened by

[519] https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/27/executive-order-on-tackling-the-climate-crisis-at-home-and-abroad/

environmental injustices. Executive Order 14057[520] mandated that all agencies "build employees' skills and knowledge through engagement, education, and training," again among many other climate policies. These two orders are reflected in many of the actions described in this chapter and are spurring climate education, training, and outreach across the entire government, resulting in a more organized approach to federal action on this issue.

Additional climate education, training, and outreach efforts were created through the passage of the Infrastructure Investment and Jobs Act in November 2021. A sample of programs created through this bill are highlighted below

EDUCATION

SOLAR POWER IN YOUR COMMUNITY GUIDE - DEPARTMENT OF ENERGY[521]

This comprehensive guide to planning, permitting, and installing solar panels for local governments was updated in 2022 to include a chapter on developing local solar workforce development and education programs and a focus on equity in solar policy. The guide includes robust strategies for creating new programs or integrating energy literacy into existing programs at K-12 schools, career and technical education, union apprenticeship programs, higher education, and workforce development agencies. It also includes a chapter on communication and community education to increase solar adoption.

CLIMATE LITERACY AND ENERGY AWARENESS NETWORK – MANY AGENCIES[522]

In 2021 and 2022, the award winning Climate Literacy and Energy Awareness Network (CLEAN) held annual climate resource reviews to actively bridge the accessibility gap in climate and energy education resources. The program is currently funded by the National Oceanic and Atmospheric Administration (NOAA), but has also received funding from the National Science Foundation (NSF), U.S. Department of Energy (DOE) and the National Aeronautics and Space Administration in the past. The CLEAN review team strives to provide a collection of the most accurate and up-to-date information for educators to use and climate curriculum development. Resources must pass a rigorous, multi-step review process to be included in the award-winning CLEAN collection. The result of the review process will be an updated collection of the best available climate resources. This active, yearly review process supports the continuous development of strong climate curriculum and bridges the

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520 https://www.whitehouse.gov/briefing-room/presidential-actions/2021/12/08/executive-order-on-catalyzing-clean-energy-industries-and-jobs-through-federal-sustainability/
521 https://www.energy.gov/eere/solar/local-government-guide-solar-deployment
522 https://cleanet.org/index.html

gap of accessible education, making it easy for anyone to utilize and learn from these cutting-edge climate science resources. The Teaching Climate section of Climate.gov has syndicated the CLEAN collection since 2010.

EMPLOYING PEER MENTORING TO EMPOWER YOUTH TO BECOME 21ST CENTURY ENERGY LEADERS - NSF[523]

This NSF funded project proposes to make use of an existing energy transition/climate change simulation experience, En-ROADS, followed by student energy projects to help learners come to understand the issues involved in energy transition and its environmental justice implications.

CREATE ENERGY NATIONAL CENTER - NSF[524]

This NSF funded project will address the rapidly changing energy landscape to develop and promote exemplary programs in support of the education of a skilled technical workforce for the American energy sector. The CREATE National Energy Center proposes to become the preeminent source of faculty professional development and instructional materials for energy educators, increase the visibility of energy careers and broaden participation of groups historically underrepresented in these careers, and build academic, industry, and international partnerships to advance energy technician education. The CREATE Center will empower two-year college faculty and academic programs to champion new energy technologies to ensure American competitiveness in this fast-changing sector.

CULTURE OVER CARBON: UNDERSTANDING THE IMPACT OF MUSEUMS' ENERGY USE – INSTITUTE OF MUSEUM AND LIBRARY SERVICES[525]

Culture Over Carbon is a groundbreaking research project funded by a National Leadership grant (2021 – 2023) from the Institute of Museum and Library Services (IMLS). It will improve the museum field's understanding of energy use by examining data from five types of museums, and zoos and aquariums, gardens, and historic sites. The project will establish an energy carbon footprint for the museum sector and create "roadmaps" to help these cultural sector institutions use energy more efficiently. The research will consider how GHG emissions vary by an institution's geographic location, that energy sources differ by state and municipality, and that regulations vary as well. This project will help participating institutions understand their specific energy use, while also building the cultural sector's broad understanding of its current energy practices and helping it to plan for future expected changes in energy availability, policies, and regulations. The grant was awarded to the New England Museum Association (NEMA). NEMA leads the project in partnership with

523 https://www.nsf.gov/awardsearch/showAward?AWD_ID=2147839
524 https://www.nsf.gov/awardsearch/showAward?AWD_ID=2201631
525 https://ecprs.org/engagement/culture-over-carbon/

Environment & Culture Partners (ECP) and the nonprofit energy consultants New Buildings Institute (NBI).

TRAINING AND WORKFORCE DEVELOPMENT

BETTER BUILDINGS WORKFORCE ACCELERATOR - DEPARTMENT OF ENERGY[526]

The Better Buildings Workforce Accelerator and Workforce Development Portal provide resources to provide upskilling opportunities for incumbent workers and guide people towards careers in energy efficiency. These programs were founded to address challenges facing the building workforce: a lack of interest in the field, underrepresentation of women and Black Americans, varying quality of building science programs, lack of continuing education for energy efficiency, lagging efficiency upgrades for multifamily houses, and the need to retrofit millions of structures to be more energy efficient. The accelerator has a two-fold mission of training the existing building workforce on energy efficiency and developing interest in energy efficiency careers. They offer education and training programs for architects, building managers, construction workers, and real estate agents as well as building science curricula for K-12 and post-secondary schools and on-the-job training programs.

UNITED STATES GEOLOGICAL SURVEY NATIONAL AND REGIONAL CLIMATE ADAPTATION SCIENCE CENTERS (CASCS)[527]

The USGS National and Regional Climate Adaptation Science Centers (CASCs) are partnership-driven programs that team scientists with natural and cultural resource managers and local communities to help fish, wildlife, water, land, and people adapt to a changing climate. The CASC network has supported over 200 students and early-career scientists and managers through 10+ fellowship and training programs. Participants conduct groundbreaking research on climate change impacts and adaptation, develop skills in science communication and partner engagement, and build networks of peers and mentors to support future career development. CASCs have also developed trainings across their networks and are supporting other bureaus within the Department of the Interior in integrating climate adaptation into various aspects of their climate training.

INTERAGENCY WORKING GROUP ON COAL AND POWER PLANT COMMUNITIES AND ECONOMIC REVITALIZATION - MANY AGENCIES[528]

This Working Group, established in 2021, helps identify and mobilize over $200 billion in federal funding opportunities that can be used to reduce pollution, support new industries,

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526 https://betterbuildingssolutioncenter.energy.gov/workforce
527 https://www.usgs.gov/programs/climate-adaptation-science-centers
528 https://energycommunities.gov/

and create good-paying jobs in coal and fossil fuel communities to revitalize their economies and provide new income for the post-fossil fuel future. Working Group members include the Office of Management and Budget/Domestic Policy Council, Department of Energy, Department of Treasury, Department of the Interior, Department of Agriculture, Department of Commerce, Department of Labor, Department of Health and Human Services, Department of Transportation, Department of Transportation, Environmental Protection Agency, and the Appalachian Regional Commission.

FEDERAL EMPLOYEE CLIMATE TRAINING - ALL OF GOVERNMENT

Executive Order 14057[529] required that agencies "build employees' skills and knowledge through engagement, education, and training". All agencies are now developing climate training programs for their employees, with the NOAA coordinating many of the trainings. The modules will cover the basics of climate science, communication strategies, and broad and agency-specific solutions. This set of trainings is the first step in creating a climate-literate federal workforce that will be better able to address climate impacts in all areas of government work.

COMMUNICATION

DESIGN AND DISCOVERY FORUM: CLIMATE SCIENCE, CHILDREN, AND THE MEDIA - NATIONAL SCIENCE FOUNDATION[530]

This convening brought together media, education, and climate professionals to discuss communication and education around climate topics for children aged 5-11, with a particular focus on inspiring the next generation of scientists and engaging historically underserved communities in the creation and communication of climate resources. The goal of the forum was to create an ongoing dialogue between media and climate scientists on how to engage, empower, and inspire young children to engage with scientifically accurate, hopeful, solutions-oriented climate action.

CLIMATE.GOV 3.0 - NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION[531]

Climate.gov s third iteration launched in October 2021 and is designed to make accessing the United States most up to date climate information, stories, and data more accessible, understandable, and easy. The website includes redesigned News and Features, Maps and Data, Teaching Climate educational resources, and Climate Resilience Toolkit pages that integrate state of the art data and visualizations with action-oriented solutions and educational information. The redesigned Climate.gov integrates artificial intelligence to

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[529] https://www.whitehouse.gov/briefing-room/presidential-actions/2021/12/08/executive-order-on-catalyzing-clean-energy-industries-and-jobs-through-federal-sustainability/

[530] https://nsf.gov/events/event_summ.jsp?cntn_id=304151&org=NSF

[531] https://www.climate.gov/whats-new

improve the accessibility of accurate and timely climate information. The upgrades to this flagship website, including search tools enhanced by artificial intelligence and a suite of user experience and accessibility improvements, will better connect Americans to climate explainers, data dashboards, and classroom-ready teaching resources.

PUBLIC ACCESS TO INFORMATION

5TH NATIONAL CLIMATE ASSESSMENT - U.S. GLOBAL CLIMATE RESEARCH PROGRAM[532]

The U.S. Global Climate Research Program is currently developing the fifth National Climate Assessment. This comprehensive scientific, economic, and social review of climate impacts and projections across all regions of the U.S. is published every four years. It is written to be accessible to the general public, useful for decision-makers, scientifically rigorous, and responsive to the needs of the communities who will use it. Hundreds of climate experts are currently working to create the Assessment in consultation with communities and stakeholders across the 10 regions and over 15 topic areas included in the report.

RULES TO ENHANCE AND STANDARDIZE CLIMATE-RELATED DISCLOSURES FOR INVESTORS - SECURITIES AND EXCHANGE COMMISSION[533]

While not yet finalized as of the publication of this report, the Securities and Exchange Commission has proposed a rule change that would require companies to publicly disclose climate-related risks to their business, finances, and operations. This rule change would also mandate disclosure of GHG emissions. This rules change would provide the public with comparable, clear, and consistent climate and economic information upon which they can make sound and sustainable financial decisions.

OPPORTUNITIES FOR EXPANDING AND IMPROVING CLIMATE INFORMATION AND SERVICES FOR THE PUBLIC - MULTIPLE AGENCIES[534]

These reports lay out a comprehensive roadmap for the federal government to further increase open-access delivery of climate tools and services. The White House Office of Science & Technology Policy (OSTP), NOAA, and the Federal Emergency Management Agency (FEMA) led a report on holistically expanding and improving climate information and services for the public. A second report, developed by the member agencies of the Federal Geographic

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532 https://www.globalchange.gov/nca5

533 https://www.sec.gov/news/press-release/2022-46

534 https://downloads.globalchange.gov/reports/eo-14008-211-d-report.pdf, https://www.fgdc.gov/resources/key-publications/2021-climate-mapping-report

Data Committee, focuses on opportunities to enhance geospatial data and mapping tools to inform climate planning.

SOCIAL SCIENCE SUPPORT - NATIONAL SCIENCE FOUNDATION[535]

The National Science Foundation (NSF) will leverage its Societal Experts Action Network (SEAN) to support the work of National Climate Task Force's Interagency Working Groups on Drought, Flood, Coastal, Extreme Heat, and Wildfire Resilience. The SEAN consists of experts in the social, behavioral, and economic sciences who develop evidence-based recommendations to support decision-makers at all levels of government.

ENGAGEMENT

U.S. DEPARTMENT OF THE INTERIOR - TRIBAL CLIMATE LISTENING SESSIONS[536]

The Department invited representatives of federally recognized Tribes to participate in three upcoming virtual listening sessions focused on climate change and Tribal Nations and two upcoming virtual listening sessions focused on Bureau of Indian Affairs (BIA) discretionary grants for Tribes. The Department also invites Tribal youth to the first scheduled climate listening session, which is focused on Tribal youth and climate. Climate change, equity, and environmental justice are among this Administration's top priorities. The Department would like to ensure that its efforts and the initiatives it develops to meet these priorities and to effectively administer discretionary grants programs are shaped and designed based on feedback and information received from across Indian Country and Alaska Native Villages.

URBAN HEAT CAMPAIGNS - NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION[537]

The Urban Heat Campaigns have expanded in the past two years, with 14 communities mapped in 2022 to bring the total to 69 communities mapped since 2017. The program engages local community members to participate in heat mapping campaigns of their communities, using sensors mounted on cars and bikes. This year, the campaign will also include two international communities in Brazil and Sierra Leone. Additionally, 2022 will be the first year that air quality readings will be taken to better understand the localized impact of air pollution in select cities. The data will be used by federal agencies, community groups, and local government planning agencies to find urban heat islands and pollution-burdened

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[535] https://www.nationalacademies.org/our-work/societal-experts-action-network

[536] https://www.federalregister.gov/documents/2021/10/06/2021-21804/tribal-listening-sessions-on-climate-change-and-discretionary-grants

[537] https://www.noaa.gov/news-release/noaa-and-communities-to-map-heat-inequities-in-14-us-cities-and-counties

neighborhoods and better direct adaptation and mitigation efforts to begin rectifying inequitable climate vulnerabilities across the surveyed cities.

CLIMATE AND EQUITY ROUNDTABLES - NOAA[538]

NOAA gathered input directly from local stakeholders, by hosting a series of Climate and Equity Roundtables to receive recommendations on how to make improvements to its policies, products, and services to better meet the needs of underserved communities. The roundtable in Detroit, Michigan focused on neighborhood flooding and other roundtables will focus on heat resilience in Arizona and Nevada, coastal inundation in Louisiana, equitable climate resilience in the Pacific Islands, flooding and resilience in Mississippi River communities, coastal flood risk in Connecticut, and climate risks in Alaska conducted with the Alaska Native Tribal Health Consortium.

NETWORKS

CLIMATE ENGAGEMENT AND CAPACITY-BUILDING SCOPING WORKING GROUP (CEC-SWG) - MULTIPLE AGENCIES

The CEC scoping working group, formed in the summer of 2022, coordinates federal programs working on climate education, training and workforce development, communication, public access to information, and engagement. This group is designed to expand synergies between programs working in this area; share best practices, learnings, and challenges between agencies; and provide a space for collaboration on cross-agency efforts such as climate training for all government employees, inventorying all relevant programs and the writing of the National Communication. Agency participants include the National Oceanic and Atmospheric Administration, Environmental Protection Agency, Smithsonian Institution, National Science Foundation, National Aeronautics and Space Administration, Department of the Interior/National Park Service, Department of Energy, Department of Education, Department of Labor, Department of Health and Human Services, Department of Homeland Security, U.S. Department of Agriculture/U.S. Forest Service, U.S. Global Change Research Program, U.S. Group on Earth Observations, AmeriCorps, Institute of Museum and Library Services.

2022 FEDERAL ENGAGEMENT AND CAPACITY-BUILDING INVENTORY RESULTS

The 2022 Federal Engagement and Capacity-building Inventory builds on the initial inventory conducted in 2021. This preliminary analysis included only program language in the

[538] https://www.noaa.gov/regional-collaboration-network/noaas-climate-and-equity-roundtables

President's Budget request, passed bills, or on Department websites; program directors and members of the CEC-SWG validate and add to these results. This inventory shows a 70-program increase in total existing programs and a 30-program reduction in total proposed programs. This year's inventory results of existing and proposed programs are summarized in Table 9-1 and Figure 9-2, below.

Table 9-1: Existing and Proposed Education, Engagement, Workforce Development and Training Programs-Related Programs (FY 2022)

	Total Existing	Education	Training	Communication	Public Access	Engagement	Total Proposed	Education	Training	Communication	Public Access	Engagement
Department of Agriculture	21	18	9	12	19	10	1	1	0	0	0	1
Department of Commerce	41	23	23	13	21	24	2	1	1	0	0	1
Department of Education	1	1	1	1	1	1	0	0	0	0	0	0
Department of Energy	36	12	29	5	7	13	4	2	2	1	1	1
Department of Health and Human Services	5	0	2	2	3	1	1	0	1	0	0	0
Department of Homeland Security	9	5	4	4	4	5	3	2	3	0	0	0
Department of Labor	2	0	2	0	0	0	2	0	2	0	0	0
Department of the Interior	25	5	15	3	7	12	13	0	7	3	8	9
Department of Transportation	9	1	6	0	1	2	1	0	0	0	0	1
Department of Veterans Affairs	1	1	1	0	0	0	0	0	0	0	0	0
AmeriCorps	3	2	3	0	0	3	0	0	0	0	0	0
Environmental Protection Agency	43	14	12	4	19	20	4	1	4	1	1	2
Institute of Library and Museum Services	2	2	1	0	1	1	0	0	0	0	0	0

National Aeronautics and Space Administration	22	7	6	2	10	9	1	0	0	0	1	1
National Endowment for the Humanities	2	1	1	0	2	1	0	0	0	0	0	0
National Science Foundation	6	2	5	0	1	2	0	0	0	0	0	0
Smithsonian Institution	31	24	8	6	16	8	8	2	4	2	5	4
U.S. Global Change Research Program (USGCRP)*	9	1	5	5	5	4	0	0	0	0	0	0
TOTALS	**268**	**119**	**133**	**57**	**117**	**116**	**40**	**9**	**24**	**7**	**16**	**20**

In 2021, President Biden forged consensus and signed the Bipartisan Infrastructure Law – a historic investment in America that will change people's lives for the better and get America moving again.[539] In 2022, the president signed the Inflation Reduction Act[540] and the Creating Helpful Incentives to Produce Semiconductors (CHIPS) and Science Act,[541] motivating more climate action across the government. These acts added 25 new, fully-funded programs to the Inventory. These programs are detailed in the following tables.

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[539] https://www.whitehouse.gov/build/

[540] https://www.whitehouse.gov/briefing-room/statements-releases/2022/08/15/by-the-numbers-the-inflation-reduction-act/

[541] https://www.whitehouse.gov/briefing-room/statements-releases/2022/08/09/fact-sheet-chips-and-science-act-will-lower-costs-create-jobs-strengthen-supply-chains-and-counter-china/

Table 9-2: Education, Engagement, Workforce Development and Training Programs Across Federal Departments and Agencies that are funded by President Biden's Bipartisan Infrastructure Law.

Department/ Agency	Program Name	Bipartisan Infrastructure Law Description	Climate Education, Engagement, and Workforce Development Element
Department of Energy	Building, Training, And Assessment Centers	To provide grants to institutions of higher education to establish building training and assessment centers to educate and train building technicians and engineers on implementing modern building technologies.	Education
Department of Energy	Solar Improvement Research & Development	To fund research, development, demonstration, and commercialization activities to improve solar energy technologies.	Training and Workforce Development
Department of Energy	Wind Energy Technology Program	To fund research, development, demonstration, and commercialization activities to improve wind energy technologies.	Education, Training and Workforce Development
Department of Transportation	Public Transportation Technical Assistance and Workforce Development	Provides funding to support workforce development and transition, including in relation to zero-emission fleet conversion, and other technical assistance to support transit providers in enhancing safe, efficient, equitable and climate-friendly public transportation. Additionally, the program supports the development of standards for the public transportation industry.	Education, Training and Workforce Development
Department of the Interior	Tribal Climate Resilience - Adaptation Planning	Tribal Climate Adaptation programs provides support for climate resilient planning to help sustain Tribal ecosystems and natural and cultural resources, economies, infrastructure, human health, and safety.	Training and Workforce Development, Engagement

Department/ Agency	Program Name	Bipartisan Infrastructure Law Description	Climate Education, Engagement, and Workforce Development Element
Department of Commerce	Coastal Zone Management	National Oceanic and Atmospheric Administration's Office for Coastal Management will implement these funds through Coastal Zone Management competitive and noncompetitive grants with the purpose of restoring and protecting coastal ecosystems through direct investment by coastal states and territories in ecologically significant habitats.	Engagement
Department of Homeland Security	Building Resilient Infrastructure and Communities (Robert T Stafford Act Section 203(i))	The Building Resilient Infrastructure and Communities program makes federal funds available to states, U.S territories, federally recognized Tribal governments, and local communities for hazard mitigation activities.	Training and Workforce Development, Engagement
Department of Transportation	Port Infrastructure Development Program Grants	Grants to invest in the modernization and expansion of U.S. ports to remove bottlenecks, ensure long-term competitiveness, resilience, and sustainability while reducing impacts to the environment and neighboring communities.	Training and Workforce Development
Department of Transportation	Low or No Emission (Bus) Grants	Provides funding to state and local governments for the purchase or lease of zero-emission and low-emission transit buses, including acquisition, construction, and leasing of required supporting facilitates. 5 percent of the funding for zero emission buses within this program will also support workforce development training so transit operators and mechanics can learn how to maintain and operate zero emission vehicles.	Training and Workforce Development

Table 9-3: Education, Engagement, Workforce Development and Training Programs Across Federal Departments and Agencies that are funded by the Inflation Reduction Act.

Department/ Agency	Program Name	Inflation Reduction Act (IRA) Description	Climate Education, Engagement, and Workforce Development Element
Department of Commerce	Investing in Coastal Communities and Climate Resilience	To provide for the conservation, restoration, and protection of coastal and marine habitats, resources, Pacific salmon and other marine fisheries, to enable coastal communities to prepare for extreme storms and other changing climate conditions, and for projects that support natural resources that sustain coastal and marine resource dependent communities, marine fishery and marine mammal stock assessments, and for related administrative expenses.	Training and Workforce Development
Department of Energy	State-based Home Energy Efficiency Contractor Training Grants	To carry out a program to provide financial assistance to States to develop and implement a State program which shall provide training and education to contractors involved in the installation of home energy efficiency and electrification improvements.	Education, Training Workforce Development
Department of Energy	Latest Building Energy Code	For grants to assist States, and units of local government that have authority to adopt building codes… to implement a plan for the jurisdiction to achieve full compliance with any building energy code in new and renovated residential or commercial buildings, as applicable, which plan shall include active training and enforcement programs and measurement of the rate of compliance each year.	Training and Workforce Development

Department/ Agency	Program Name	Inflation Reduction Act (IRA) Description	Climate Education, Engagement, and Workforce Development Element
Department of Energy	Zero Energy Code	For grants to assist States, and units of local government that have authority to adopt building codes … to implement a plan for the jurisdiction to achieve full compliance with any building energy code in new and renovated residential and commercial buildings, which plan shall include active training and enforcement programs and measurement of the rate of compliance each year.	Training and Workforce Development
Department of Transportation or other agency	Clean Heavy-Duty Vehicles	For the incremental costs of replacing an eligible vehicle that is not a zero-emission vehicle with a zero-emission vehicle, as determined by the Administrator based on the market value of the vehicles; purchasing, installing, operating, and maintaining infrastructure needed to charge, fuel, or maintain zero-emission vehicles; workforce development and training to support the maintenance, charging, fueling, and operation of zero-emission vehicles; and planning and technical activities to support the adoption and deployment of zero-emission vehicles.	Training and Workforce Development
Department of the Interior	Tribal Climate Resilience	For Tribal climate resilience and adaptation programs. The investment enables climate preparedness and resilience across all Indian Affairs programs and for all Federally-recognized Tribal Nations and Alaska Native villages through technical and financial assistance, access to scientific resources and educational opportunities.	Education, Communication

Department/ Agency	Program Name	Inflation Reduction Act (IRA) Description	Climate Education, Engagement, and Workforce Development Element
Environmental Protection Agency	Low Emissions Electricity Program	For consumer-related education and partnerships with respect to reductions in GHG emissions that result from domestic electricity generation and use; For education, technical assistance, and partnerships within low-income and disadvantaged communities with respect to reductions in GHG emissions that result from domestic electricity generation and use; For industry-related outreach, technical assistance, and partnerships with respect to reductions in GHG emissions that result from domestic electricity generation and use; For outreach and technical assistance to, and partnerships with, State, Tribal, and local governments with respect to reductions in GHG emissions that result from domestic electricity generation and use;	Education, Communication
Environmental Protection Agency	Environmental and Climate Justice Block Grants	For community-led air and other pollution monitoring, prevention, and remediation, and investments in low- and zero-emission and resilient technologies and related infrastructure and workforce development that help reduce GHG emissions and other air pollutants; mitigating climate and health risks from urban heat islands, extreme heat, wood heater emissions, and wildfire events; climate resiliency and adaptation; reducing indoor toxics and indoor air pollution; or facilitating engagement of disadvantaged communities in State and Federal advisory groups, workshops, rulemakings, and other public processes.	Training and Workforce Development, Engagement

Department/ Agency	Program Name	Inflation Reduction Act (IRA) Description	Climate Education, Engagement, and Workforce Development Element
Council on Environmental Quality	Environmental and Climate Data Collection	To support data collection efforts relating to— disproportionate negative environmental harms and climate impacts; and cumulative impacts of pollution and temperature rise; to establish, expand, and maintain efforts to track disproportionate burdens and cumulative impacts and provide academic and workforce support for analytics and informatics infrastructure and data collection systems; and to support efforts to ensure that any mapping or screening tool is accessible to community-based organizations and community members.	Access to information
Environmental Protection Agency	Greenhouse Gas Corporate Reporting	To support enhanced standardization and transparency of corporate climate action commitments and plans to reduce GHG emissions; enhanced transparency regarding progress toward meeting such commitments and implementing such plans; and progress toward meeting such commitments and implementing such plans.	Access to information
Environmental Protection Agency	Environmental Product Declaration Assistance	To develop and carry out a program to support the development, enhanced standardization and transparency, and reporting criteria for environmental product declarations that include measurements of the embodied GHG emissions of the material or product associated with all relevant stages of production, use, and disposal, and conform with international standards, for construction materials and products.	Access to information
Environmental Protection Agency	Low-Embodied Carbon Labeling for Construction Materials	To identify and label construction materials and products that have substantially lower levels of embodied GHG emissions associated with all relevant stages of production, use, and disposal, as compared to estimated industry averages of similar materials or products.	Access to information

Table 9-4: Education, Engagement, Workforce Development and Training Programs Across Federal Departments and Agencies that are funded by the Creating Helpful Incentives to Produce Semiconductors (CHIPS) and Science Act.

Department/ Agency	Program Name	Creating Helpful Incentives to Produce Semiconductors (CHIPS) and Science Description	Climate Education, Engagement, and Workforce Development Element
Department of Energy	Clean energy technology university prize competition	Authorizes a prize competition for university students to develop a business model for furthering the commercial application of an innovative clean energy technology to encourage student interest in clean energy technology development in diverse regions of the U.S.	Training and Workforce Development
Department of Energy	Low-emissions steel manufacturing research program	Authorizes a Department of Energy research, development, demonstration, and commercial application program of advanced tools, technologies, and methods for low-emissions steel manufacturing, focusing on several key technology areas, including heat generation, carbon capture, smart manufacturing, resource efficiency, alternative materials, and high-performance computing. It also directs the Secretary to support an initiative for the demonstration of low-emissions steel manufacturing in collaboration with industry partners, institutions of higher education, and the National Laboratories, and to consider leveraging the resources of the Manufacturing USA Institutes.	Public Access to Information

Department/ Agency	Program Name	Creating Helpful Incentives to Produce Semiconductors (CHIPS) and Science Description	Climate Education, Engagement, and Workforce Development Element
Department of Energy	Department of Energy research, development, and demonstration activities	Authorizes appropriations for building technologies, sustainable transportation, advanced manufacturing, industrial emissions reduction technology, advanced materials, and renewable power research, development, and demonstration within the Office of Energy Efficiency and Renewable Energy. It also authorizes appropriations for grid modernization research, development and demonstration within the Office of Electricity. Authorizes appropriations for advanced materials research, development, and demonstration within the Office of Nuclear Energy. Authorizes appropriations for clean industrial technologies, alternative fuels, and carbon removal research, development, and demonstration within the Office of Fossil Energy and Carbon Management.	Public Access to Information
National Institute of Standards and Technology	Greenhouse gas measurement research	Authorizes and expands NIST's GHG measurement program, including support for testbeds and a Center for Greenhouse Gas Measurements, Standards, and Information.	Public Access to Information

SAMPLE NON-FEDERAL CLIMATE EDUCATION, ENGAGEMENT, WORKFORCE DEVELOPMENT AND TRAINING INITIATIVES BETWEEN 2020-2022

NON-FEDERAL SPOTLIGHT

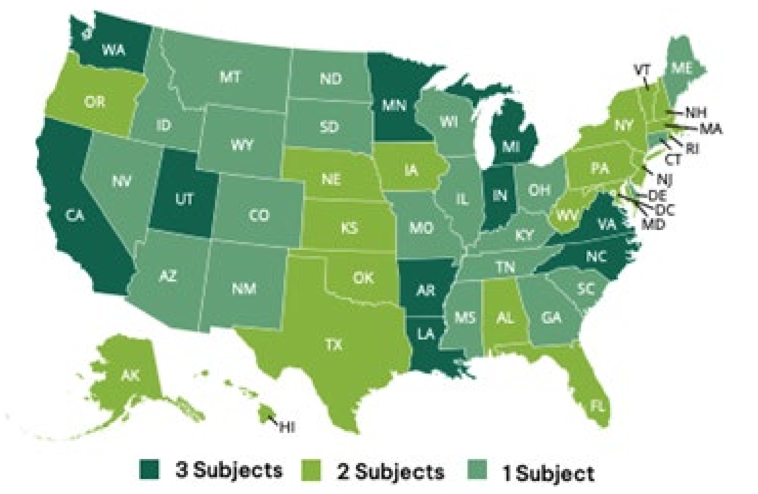
To achieve the long-term transformations to get to 2050 net-zero emissions, the United States will need to bring all its greatest strengths to bear, including innovation, creativity, and diversity. Already, many nongovernmental organizations are acting ambitiously to address climate change within their own operations or support the overall transition of the U.S. economy. Even more broad-based engagement on research, education, and implementation through our universities, cultural institutions, investors, businesses, and other nongovernmental organizations will be required to reach our 2050 goal.[542] These non-federal spotlights highlight numerous examples of education, engagement, workforce development and training initiatives working to support these social transformations.

EDUCATION

Mapping the Landscape of K–12 Climate Change Education Policy in the U.S. - NAAEE and MECCE[543]

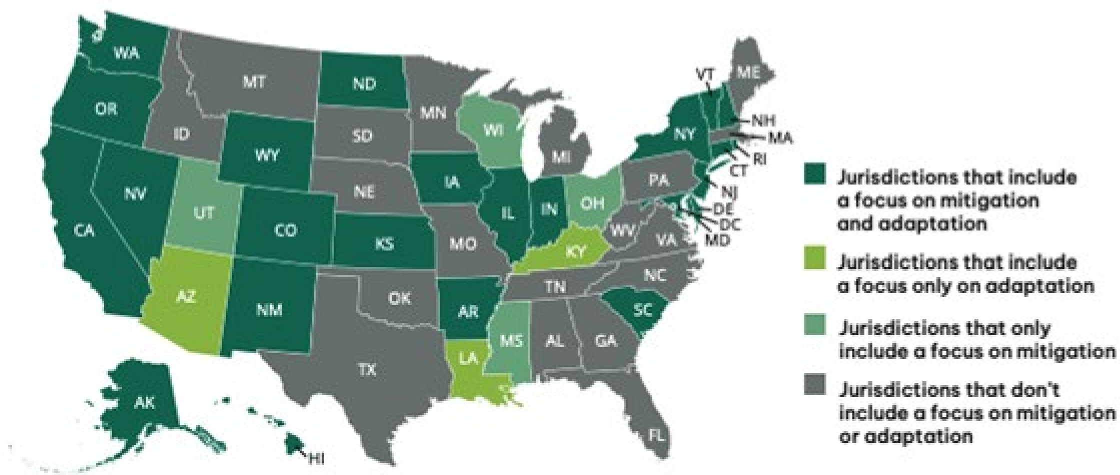
North American Association for Environmental Education (NAAEE) and Monitoring and Evaluating Climate Communication and Education Project (MECCE) released in June 2022 the findings of a comprehensive analysis of K–12 Climate Change Education Policy in the United States. The study builds on prior climate change education research and underscores the importance of including climate change in education policy in all areas of institutional activity to further climate change action through education.

Figure 9-3 : Number of Subjects with Climate Change Content in State Standards and Curriculum Frameworks by State[544]



542 https://www.whitehouse.gov/wp-content/uploads/2021/10/US-Long-Term-Strategy.pdf
543 https://naaee.org/eepro/resources/mapping-landscape
544 *Ibid*.

Figure 9-4: Inclusion of Adaptation and/or Mitigation Climate Change Content within State Standards or Curriculum Frameworks[545]



TURN IT AROUND! MOBILIZING YOUTH VISIONS AND VOICES TO REIMAGINE CLIMATE FUTURES - ARIZONA STATE UNIVERSITY, UNESCO FUTURES OF EDUCATION INITIATIVE, THE ARTISTS' LITERACIES INSTITUTE, AND THE OPEN SOCIETY FOUNDATION[546]

The Turn it Around! Flashcards for Education Futures: a learning tool for adults, made by youth, to reimagine the approach to education, and people's relationship with nature and the living world during this time of climate crisis. "Turn it Around! An Education Guide to Climate Futures" is an unconventional policy report, which was inspired by youth voices and visions of education futures mobilized as a part of the "Turn it Around!" initiative. It is designed to set in motion a series of intergenerational, decolonial, methodological, and pedagogical 'turns' necessary to transform education and culture toward more sustainable and ecologically just futures.

FRANKENTHALER CLIMATE INITIATIVE[547]

The Frankenthaler Climate Initiative funds energy efficiency and clean energy generation projects in the following categories: scoping grants help museums understand the climate and energy mitigation opportunities at their facilities, technical assistance grants support the specification and budgeting of an identified efficiency project to allow for procurement and

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545 *Ibid*.

546 https://turnitaroundcards.org/

547 http://www.frankenthalerclimateinitiative.org/

financing, and implementation grants provide partial seed funding for fully specified projects.

The Helen Frankenthaler Foundation awarded grants to 79 visual arts institutions in its inaugural cycle in 2021. Institutions of all sizes that have visual arts as a key part of their mission and programming are encouraged to apply next cycle in Spring 2023. This includes collecting and non-collecting institutions as well as visual arts schools.

EMERGING SUB-NATIONAL CLIMATE EDUCATION INITIATIVES AND NETWORKS

Across the United States, states, counties, and cities are increasingly developing strategies to accelerate local action on climate change through education systemically. Such initiatives have increased significantly in 2021 and 2022 and range from the Aspen Institutes K12 Climate Action Commission, Los Angeles Unified School District's School Board resolution Transforming Teaching Of Climate Change, California funding of the Climate Change and Environmental Justice Program, New Jersey's Climate Change Education Standards and Resources, Washington State's ClimeTime initiative to support climate change education professional development for all school districts, Presidio Graduate School's Climate Change Education for All online program teacher professional development equips educators, the non-partisan youth-adult led Education Climate Action resolution campaign by Schools for Climate Action, and UndauntedK12's K-12 climate solutions center for school district leaders.

EDUCATION SECTOR DECARBONIZATION

Education systems across the United States are decarbonizing as part of communities' climate actions. These systems are often committed to principles of equity, justice, and inclusion; transitioning to 100 percent clean energy can help advance these goals by saving money that can be invested into under-resourced schools and helping to address climate change, which disproportionately impacts low-income communities and communities of color. Examples include the Maryland's Prince George's County Board of Education Climate Change Action Plan, Oregon's Portland Public Schools Climate Crisis Response, Climate Justice and Sustainable Practices Policy, and the Massachusetts' Arlington request for proposals for Electrification and Air Quality Master Plan for the school district. Additionally, the New Buildings Institute has released the Decarbonization Roadmap Guide written for those interested in healthy, efficient, carbon neutral school design, construction and operation.

WORKFORCE DEVELOPMENT AND TRAINING

GREEN WORKFORCE TRAINING PROGRAM - SOLAR ONE[548]

Solar One's Green Workforce Training Program (GWF), educates both the entry level and incumbent workforce in energy efficiency, green building operations and maintenance, and renewable energy. Since its inception in 2009, the program has successfully trained over 4,000 individuals in a wide array of hard-skills training courses and industry recognized certifications. The GWF team works closely with established New York and New Jersey workforce agencies and our trainee demographics include criminal justice system-involved individuals, disconnected youth, veterans, individuals struggling with addiction, people experiencing homelessness, and residents of public housing.

CALIFORNIA CLIMATE CORPS[549]

Climate Corps is an award-winning fellowship program in California that provides professional development opportunities for emerging leaders through implementation of sustainability and resiliency projects with local governments, nonprofits, and for-profit businesses. Host organizations receive the support of qualified, passionate, dedicated Fellows, who gain real-world expertise in sustainability project implementation. Climate Corps simultaneously addresses climate and sustainability projects and cultivates the next generation of environmental leaders. Since 2010, Climate Corps has worked with over 200 partners and 800 Fellows on 1,000 high-impact projects and in the 2021-2022 program cycle, it has worked with over 65 partners and 85 Fellows on 150 high-impact projects. The California Climate Corps program is a national model many other states are exploring to replicate to support their states climate actions.

NEZ PERCE TRIBE'S PLANS FOR VIRTUAL POWER PLANT - NIMIIPUU ENERGY[550]

The Nez Perce Tribe in Idaho is inviting other tribes to take part in a Native-led Virtual Power Plant (VPP). Nimiipuu Energy is a tribally owned energy company working toward eliminating the Tribe's energy purchased from outside sources; by producing all of the energy they consume. Their plan is to install a variety of energy projects that will total 500+ Megawatts by 2027. In 2022, Nimiipuu Energy announced plans to create a virtual renewable power plant with Tribes across the region to provide enough power to remove the four Snake River hydroelectric dams, which obstruct culturally significant fish migrations and endanger local ecosystems. Additionally, projects are also beginning on residential homes located on the

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548 https://www.solar1.org/.

549 https://www.climatecorps.org/.

550 http://www.nimiipuu.energy/.

Nez Perce Reservation. Nez Perce Energy and the Department of Energy are working to create culturally appropriate Workforce Training and Development for Tribal members in all facets of renewable energy education.

GRID ALTERNATIVES[551]

GRID Alternatives is working across the United States and internationally to build community-powered solutions to advance economic and environmental justice through renewable energy. Through installing renewable energy systems they are driving economic growth and environmental benefits in communities most impacted by underemployment, pollution and climate change. GRID Alternatives is a national leader in helping economic and environmental justice communities nationwide get clean, affordable renewable energy, transportation, and jobs. In 2021, GRID Alternatives installed 3,439 solar systems, including 109 installations on Tribal lands, and 604 EV charging stations, providing almost hands-on 20,000 training hours in renewable energy installation.

COMMUNICATION

HOW WE RESPOND - AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE (AAAS)[552]

In 2021, AAAS expanded the program to develop the Engaging Communities in Climate Conversations module that guides scientists through the fundamentals of engaging in conversations about climate change, with a focus on impacts and solutions.

THE CLIMATE CONNECTIONS PODCAST - YALE CLIMATE CONNECTIONS[553]

Yale Climate Connections is a nonpartisan, multimedia climate news service providing a daily radio program and original reporting, commentary, and analysis. The radio program is broadcast several times a day on more than 680 public, university, community, and alternative radio frequencies nationwide, and internationally on several English-language stations. The radio program receives more than a million listens each week.

SPECIALS ON CLIMATE CHANGE AND SUSTAINABILITY - PUBLIC BROADCASTING SERVICE (PBS)[554]

Beginning in April 2022, Earth Month, and continuing through the fall, PBS will premiere programs that explore the lasting impacts of climate change on the natural world on PBS,

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[551] https://gridalternatives.org/.
[552] https://howwerespond.aaas.org.
[553] https://yaleclimateconnections.org/the-climate-connections-podcast/.
[554] https://www.pbs.org/about/about-pbs/blogs/news/pbs-announces-new-programming-in-honor-of-earth-month-2022/.

PBS.org and the PBS Video app. PBS, with more than 330 member stations, offers all Americans the opportunity to explore new ideas and new worlds through television and digital content.

PUBLIC ACCESS TO INFORMATION

AMERICA IS ALL IN[555]

America Is All In is the most expansive coalition of leaders ever assembled in support of climate action in the United States. It mobilizes thousands of U.S. cities, states, tribal nations, businesses, and schools, as well as faith, health, and cultural institutions. The coalition champions a whole-of-society mobilization to deliver the transformational change that science demands, with the goal of a healthy, prosperous, equitable, and sustainable future. America Is All In reports provide leaders and communities with critical information on the All-In Climate Strategy for Faster, More Durable Emissions Reductions.

ENGAGEMENT

WHITE HOUSE ENVIRONMENTAL JUSTICE ADVISORY COUNCIL[556]

Through President Biden's Executive Order 14008, titled Tackling the Climate Crisis at Home and Abroad[557] the White House Environmental Justice Advisory Council (WHEJAC) is being established to advise the Chair of the Council of Environmental Quality (CEQ) and the newly established White House Environmental Justice Interagency Council (IAC) to increase the Federal Government's efforts to address environmental injustice. The WHEJAC's efforts will include a broad range of strategic, scientific, technological, regulatory, community engagement, and economic issues related to environmental justice. WHEJAC Final Recommendations: Justice40, Climate and Economic Justice Screening Tool and Executive Order 12898 Revisions.[558]

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[555] https://www.americaisallin.com.

[556] https://www.whitehouse.gov/environmentaljustice/white-house-environmental-justice-advisory-council/.

[557] https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/27/executive-order-on-tackling-the-climate-crisis-at-home-and-abroad/.

[558] https://www.epa.gov/environmentaljustice/white-house-environmental-justice-advisory-council-final-recommendations.

NETWORKS

HBCU CLIMATE CHANGE CONSORTIUM[559]

The Consortium was conceived to help raise awareness about the disproportionate impact of climate change on marginalized communities to develop Historically Black Colleges and Universities (HBCU) students leaders, scientists and advocates on issues related to environmental and climate justice policies, community resilience, adaptation and other major climate change topics—especially in vulnerable communities in the southern United States where the vast majority of HBCUs are located and where more billion-dollar disasters occur than the rest of the country combined. The Consortium has supported hundreds of HBCU faculty, students and leaders from climate-vulnerable communities participate in a number of important domestic and international gatherings including most recently at the Eighth Annual Historically Black Colleges and Universities (HBCU) Climate Change Conference April 13 - 16, 2022[560]. The conference addressed issues related to climate justice, adaptation, community resilience, global climate issues, and other major climate change topics (i.e. transportation, energy sources, carbon emissions, green jobs/green economy, just transition, and community economic development).

CLIMATE LITERACY AND ENERGY AWARENESS NETWORK (CLEAN)[561]

The Climate Literacy and Energy Awareness Network (CLEAN) is a growing community-based informal network of scientists, educators, policymakers, community leaders, students, and citizens who are engaged in fostering climate and energy literacy in the United States and abroad. CLEAN provides a forum for organizations, agencies, and individuals to collaborate towards more robust climate education. Members share ideas, coordinate efforts, promote policy reform, develop learning resources, and support integration of climate literacy into formal and informal education venues. Initiatives of CLEAN feature accurate, peer-reviewed scientific information, engaging learning experiences, and multiple formal and informal pathways to reach broad and diverse audiences. The virtual Accelerating Climate Capacity, Engagement, and Leadership Summit (ACCELS)[562] is being convened by the CLEAN Network. For the first time, climate and energy literacy leaders will come together to share and learn, and to explore collaborations for 2023.

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[559] https://www.dscej.org/our-work/hbcu-climate-change-consortium.

[560] https://www.dscej.org/events/eighth-annual-hbcu-climate-change-conference.

[561] https://cleanet.org/index.html.

[562] https://www.eventbrite.com/e/accelerating-climate-capacity-engagement-and-leadership-summit-accels-registration-355224846077.

U.S. ACE COALITION[563]

U.S. ACE Coalition represents professionals and organizations representing 21 states, Puerto Rico, and Washington, DC working on Action for Climate Empowerment (ACE) in the U.S. They work in and across education, training, public awareness, public access to information, public engagement, and international collaboration. The U.S. ACE Coalition's goal is to catalyze the American public to take rapid, just, community-based climate action. The Coalition was established by non-federal organizations that participated in the creation of the ACE National Strategy Framework for the United States[564].

NATIONAL EXTENSION CLIMATE INITIATIVE[565]

The National Extension Climate Initiative serves to link climate change-related education and research across Extension program areas and associations in the United States. They hold a variety of monthly meetings designed to offer the latest information about climate change science, research, and communication for Extension educators and to offer a safe space to share ideas, obstacles, and solutions to advance climate change outreach in Extension. On April 19-21, 2021, the virtual forum, Climate Change in Extension: Elevating and Amplifying Action[566], brought together Extension faculty, staff, federal representatives, administrators, interested partners and constituents to address the question: What can/should the Cooperative Extension System do to advance climate change programming?

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[563] https://www.usacecoalition.org
[564] https://drive.google.com/file/d/11FoDIGUtoqx6ejcfKly21xrgm32tf6IQ/view
[565] https://nationalextensionclimateinitiative.net/
[566] https://nationalextensionclimateinitiative.net/events/

U.S. CLIMATE AMBITION REPORT

Annex 1.

FIFTH BIENNIAL REPORT (BR5)

Annex 1. FIFTH BIENNIAL REPORT (BR5)

The Fifth Biennial Report is submitted as an annex to the Eighth National Communication of the United States.

BR5 Chapter 1: SUMMARY OF GREENHOUSE GAS EMISSIONS AND REMOVALS

Please see Chapter 3 of the attached 8th National Communication of the United States, which incorporates biennial report-related requirements regarding greenhouse gas emissions and removals.

BR5 Chapter 2: DESCRIPTION OF ECONOMY-WIDE TARGET

Nationally Determined Contribution

In April 2021 the United States communicated its nationally determined contribution (NDC) under the Paris Agreement: to achieve an economy-wide target of reducing its net greenhouse gas emissions by 50-52 percent below 2005 levels in 2030. The NDC is absolute and economy-wide, covering all sectors and gases. Like the 2020 target, it will be accounted for using a net-net accounting approach using estimates of emissions and removals as reported the most recent Inventory of U.S. Greenhouse Gas Emissions and Sinks. Net emissions in the 2030 target year will be compared against net emissions in the 2005 base year to calculate the percentage emissions reductions achieved. Please see the Information for Clarity, Transparency, and Understanding accompanying the NDC communication for full details; this document can be found on the NDC Registry.[1]

2020 Quantified Economy-Wide Emission Reduction Target

In 2010 the United States a target of achieving economy-wide emissions reductions in the range of 17 percent below 2005 levels in 2020 (Table A1-1).[2] The United States reports on progress towards this target using its annual Inventory of U.S. Greenhouse Gas Emissions and Sinks,[3] which provides information on all sectors and gases covered in our economy-wide emissions target. This inventory-based accounting approach means that the U.S. target covers the full scope of emissions and removals under the UNFCCC inventory reporting guidelines, and the relevant data and methodologies are published in the annual Inventory report.

There have been no changes in the domestic institutional arrangements since the last BR for monitoring, reporting, archiving of information and evaluation of the United States' progress towards the economy-wide emission reduction target.

[1] https://unfccc.int/sites/default/files/NDC/2022-06/United%20States%20NDC%20April%2021%202021%20Final.pdf.

[2] https://unfccc.int/files/meetings/cop_15/copenhagen_accord/application/pdf/unitedstatescphaccord_app.1.pdf.

[3] https://www.epa.gov/system/files/documents/2022-04/us-ghg-inventory-2022-main-text.pdf.

As reported in Chapter 3 of this Biennial Report, the **United States has exceeded its quantified economy-wide emission reduction target for 2020**. Further details on the achievement of this target are provided in the following chapter.

Table A1-1: Key parameters for the U.S. 2020 quantified economy-wide emissions reduction target

Parameter	Information
Base Year	2005
Target Year	2020
Emissions Reduction Target	In the range of 17% below 2005 levels
Gases Covered	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, and NF_3
Global Warming Potential	100-year values from the IPCC Fourth Assessment Report (IPCC 2007)
Sectors Covered	All IPCC sector sources and sinks, as measured by the full annual inventory (i.e., energy, transport, industrial processes, agriculture, LULUCF, and waste)
Accounting for Land Use, Land-Use Change, and Forestry (LULUCF)	Emissions and removals from the LULUCF sector are accounted using a net-net approach and a 2005 base year, including a production approach to account for harvested wood products. No specific accounting approaches have been applied to address the impact of natural disturbances on emissions and removals; the emissions and removals used in accounting are the same as reported for 2020 in our annual inventory report.
Use of international market-based mechanisms	International market-based mechanisms were not used in meeting the 2020 quantified economy-wide emissions reduction target.
Other	The United States has applied a net-net accounting approach to determine whether it has achieved its 2020 target. Net emissions in the target year are compared against net emissions in the base year to calculate the percentage emissions reductions achieved.

- The United States was fully committed to reducing emissions in the range of 17 percent below 2005 levels in 2020. We did not ascribe a specific margin to the range on one side or the other. The range recognized the important effect of external factors in determining emissions in a single year. The range was not a conditional commitment, and there are no underlying assumptions.

- The Inventory of U.S. Greenhouse Gas Emissions and Sinks coverage of sectors and use of global warming potential values is consistent with the UNFCCC inventory reporting guidelines for Annex I Parties. Values are those reported in the most recent report.
- CH_4 = methane; CO_2 = carbon dioxide; HFCs = hydrofluorocarbons; IPCC = Intergovernmental Panel on Climate Change; N_2O = nitrous oxide; NF_3 = nitrogen trifluoride; PFCs = perfluorocarbons; SF_6 = sulfur hexafluoride.

BR5 Chapter 3: 2020 QUANTIFIED ECONOMY-WIDE EMISSION REDUCTION TARGET

Achievement of the 2020 quantified economy-wide emission reduction target

As noted in Chapter 2 of this Biennial Report, the United States 2020 quantified economy-wide emissions reduction target was to reduce emissions in the range of 17 percent below 2005 levels.[4] The United States uses a net-net accounting approach, using estimates of emissions and removals reported in the most recent Inventory of U.S. Greenhouse Gas Emissions and Sinks.[5]

The United States achieved, and exceeded, its 2020 quantified economy-wide emissions reduction target. Net greenhouse gas emissions in 2020 were 21 percent below 2005 levels.

Table A1-2: Achievement of the 2020 Target

2020 quantified economy-wide emissions reduction target	2005 Net Emissions (MMT CO_2e)	2020 Net Emissions (MMT CO_2e)	% Emissions reduction in 2020 compared to 2005	2020 quantified economy-wide emissions reduction target achieved?
In the range of 17% below 2005 levels in 2020	6645.0	5222.4	21.4% below 2005 levels in 2020	Yes

Note: Net emissions as reported in the annual greenhouse gas inventory submitted April 14, 2022.[6]

Net greenhouse gas emissions decreased 10.6 percent from 2019 to 2020, with gross emissions (i.e., before factoring in removals by carbon sinks) decreasing by 9.0 percent during this same time. This decline in emissions is the result of a combination of many

[4] https://unfccc.int/files/meetings/cop_15/copenhagen_accord/application/pdf/unitedstatescphaccord_app.1.pdf.

[5] https://www.epa.gov/system/files/documents/2022-04/us-ghg-inventory-2022-main-text.pdf.

[6] https://www.epa.gov/system/files/documents/2022-04/us-ghg-inventory-2022-main-text.pdf.

factors, including the impact of the coronavirus (COVID-19) pandemic on economic activity and travel in 2020, as well as long-term trends in population, economic growth, energy markets, technological changes including energy efficiency, and the carbon intensity of energy fuel choices.

Carbon dioxide (CO_2) emissions from fossil fuel combustion decreased 10.5 percent from 2019 to 2020. This reflects a 13.3 percent decrease in transportation sector emissions resulting from reduced travel due to the COVID-19 pandemic. It also includes a 10.4 percent decrease in emissions in the electric power sector. This decrease in electric power sector emissions was due to a decrease in electricity demand of about 2.5 percent from 2019 to 2020, as well as the continued shift from coal to less carbon intensive natural gas and renewables. The decline in gross emissions also reflects an overall downward trend in emissions due to shifts towards a greater share of clean and renewable energy, the displacement of coal by less carbon-intensive natural gas, greater energy efficiency, and a shift towards a service economy, among other long-term factors. The policies and measures reported in Chapter 4 of the National Communication attached to this report, and in previous reports, have played a significant role in fostering these trends.

Progress Towards the 2030 Target

The United States will also apply a net-net accounting approach for its 2030 NDC, using net greenhouse gas emission estimates reported in the most recent Inventory of U.S. Greenhouse Gas Emissions and Sinks to assess progress towards the U.S. 2030 NDC.

Mitigation Actions and Their Effects

As discussed in previous chapters, the United States has made continual progress in implementing policies and measures that have led to emissions reductions. This progress is reflected in the achievement of our 2020 target. A key portion of this mitigation progress can be attributed to, in part, by market transformations and energy use changes driven by both federal and nonfederal policy and measures, primarily across the electricity and transportation sectors. The policies and measure put in place since our 2020 goal was established helped modify long-term trends by accelerating the deployment of clean infrastructure, avoiding the lock-in of fossil fuel infrastructure, speeding the turnover of fossil fuel vehicle and appliance stock, influencing land use decisions and agricultural production practices, and shifting investment and behaviors toward a clean energy, low emissions future.

Chapter 4 of the National Communication describes the federal and nonfederal policies that contributed to the achievement of our 2020 target, and progress in reducing emissions in the ensuing years. Annex 2 includes a detailed list of relevant policy and measures.

There have not been significant changes since the previous report to the domestic institutional arrangements for domestic compliance, monitoring, reporting, archiving of information and evaluation of progress towards U.S. emissions reduction targets. Chapter 3 of the attached National Communication, and the Inventory of U.S. Greenhouse Gas Emissions and Sinks,[7] describe these in detail.

The United States supports partners around the world in setting ambitious climate targets, and implementing these in a manner that benefits communities and economies as well as the climate. These efforts are critical in the race to set the world on a global trajectory to net-zero emissions by 2050. These efforts include programs to develop economic development paradigms that are consistent with ambitious global climate action, and measures to enhance the resilience of communities and economies in response to changes in global climate, trade patterns, and consumer preferences. This holistic, country-driven approach to supporting development efforts, including to capture the positive effects arising from the implementation of mitigation policies, programs and actions and enhance resilience against any negative impacts is at the heart of assistance provided by USAID and other U.S. technical agencies.

Estimates of Emission Reductions and Removals from Land Use, Land-Use Change and Forestry Activities

The annual Inventory of U.S. Greenhouse Gas Emissions and Sinks[8] includes data on gross greenhouse gas emissions excluding emissions and removals from the LULUCF sector; emissions and removals from the LULUCF sector; and total GHG emissions, including emissions and removals from the LULUCF sector, from 1990 onward. This includes estimates of emissions and removals for the 2005 base year and 2020 target year. A summary of this information on emissions and removals is found in Chapter 3 of the attached 8th National Communication. In 2020, removals from forests, trees in urban areas, agricultural soils,

[7] https://www.epa.gov/system/files/documents/2022-04/us-ghg-inventory-2022-main-text.pdf.
[8] https://www.epa.gov/system/files/documents/2022-04/us-ghg-inventory-2022-main-text.pdf.

landfilled yard trimmings and food scraps, and coastal wetlands were equivalent to 812.2 MMT CO_2e, or 13.6 percent of total economy-wide GHG emissions.

Use of Units from Market-Based Mechanisms

International market-based mechanisms were not used in meeting the 2020 quantified economy-wide emissions reduction target.

BR 5 Chapter 4: PROJECTIONS

Please see Chapter 5 of the attached 8th National Communication, which incorporates biennial report-related requirements regarding projections of greenhouse gas emissions.

BR 5 Chapter 5: SUPPORTING THE GLOBAL COMMUNITY: CLIMATE FINANCE, TECHNOLOGY TRANSFER, AND CAPACITY BUILDING

Please see Chapter 7 of the attached 8th National Communication, which incorporates biennial report-related requirements regarding supporting the global community with regard to finance, technology transfer, and capacity building.

U.S. CLIMATE AMBITION REPORT

Annex 2.

SUMMARY TABLE OF POLICIES AND MEASURES

Annex 2. SUMMARY TABLE OF POLICIES AND MEASURES

This table provides information on key federal policies and measures, including several longstanding federal efforts that were reported in previous National Communications. For entries with quantified estimates of mitigation impacts, explanations of the estimation methodologies are provided in Annex 3. This table does not present a comprehensive account of every policy and measure that supports U.S. climate goals, but rather a selection of significant actions underway. Key provisions of the Inflation Reduction Act are described in Chapter 4, but not presented in this table, given the law's recent enactment.

Throughout this table, an asterisk (*) next to a policy/measure name is used to indicate that it is included at least partially in the "With Measures" projection presented in Chapter 5, referred to there as the "2021 Policy Baseline." Only policies/measures adopted and implemented as of November 2021 are included in that projection. To determine which of the policies/measures presented here are captured by the "With Measures" projection, an evaluation was made to determine whether the policy/measure is either explicitly modeled in the projection (direction or indirectly) or has its effect indirectly captured through broader modeling parameters that impact projected GHG emissions. Some of these policies/measures have been recently expanded or strengthened after the November 2021 analysis cutoff date, meaning their impacts are not fully accounted for in the "With Measures" projection.

Table A-2-1: Summary Table of Policies and Measures

Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Implementation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO2e) in 2030
Transport								
National Program for Light-Duty Vehicle GHG Emissions and Fuel Efficiency Standards*	Reduce GHG emissions from the light-duty vehicle sector	Establishes fuel efficiency and GHG emission standards for new light-duty vehicles (LDVs) produced for sale in the U.S.	CO2, CH4, N2O, HFCs	Implemented and Ongoing	Regulatory	2012 (model year)	Environmental Protection Agency, Department of Transportation	271,000
National Program for Heavy-Duty Vehicle GHG Emissions and Fuel Efficiency Standards*	Reduce GHG emissions from the heavy-duty vehicle sector	Establishes fuel efficiency and GHG emission standards for work trucks, buses, and other heavy-duty vehicles (HDVs)	CO2, CH4, N2O	Implemented and Ongoing	Regulatory	2011	Environmental Protection Agency, Department of Transportation	148,000
Renewable Fuel Standard*	Increase use of renewable transportation fuels	Increases the share of renewable fuels used in transportation via implementation of the Renewable Fuel Standard Program	CO2	Implemented and Ongoing	Regulatory	2011	Environmental Protection Agency	n/a
Control of Air Pollution from Airplanes and Airplane Engines: GHG Emission Standards and Test Procedures*	Reduce GHG emissions from certain classes of aircraft	Establishes greenhouse gas emission standards for airplanes used in commercial aviation and for large business jets. This action aligns U.S. standards with the international CO_2 emissions standards set by the International Civil Aviation Organization (ICAO).	CO2	Implemented and Ongoing	Regulatory	2021	Environmental Protection Agency, Federal Aviation Administration	n/a

Annex 2. SUMMARY TABLE OF POLICIES AND MEASURES

Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Implementation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO2e) in 2030
SmartWay Transport Partnership*	Reduce GHG emissions from movement of goods	Promotes collaboration with businesses and other stakeholders to decrease climate-related and other emissions from movement of goods	CO2	Implemented and Ongoing	Voluntary	2004	Environmental Protection Agency	12,000
National Clean Diesel Campaign*	Reduce diesel emissions	Reduces diesel emissions through the implementation of proven emission control technologies	CO2	Implemented and Ongoing	Voluntary	2008	Environmental Protection Agency	n/a
Light-Duty Vehicle Fuel Economy and Environment Label*	Provide information to vehicle buyers	Provides comparable information on new LDVs' fuel economy, energy use, fuel costs, and environmental impacts	CO2	Implemented and Ongoing	Regulatory	2011	Environmental Protection Agency, Department of Transportation, Department of Energy	n/a
Federal Fleet Program*	Reduce GHG emissions from the federal vehicle fleet	Requires federal agencies to acquire low greenhouse gas emitting (light-duty and medium-duty passenger) vehicles	CO2	Implemented and Ongoing	Regulatory	2010	Environmental Protection Agency	n/a
EPA Ports Initiative*	Reduce GHG emissions from ports	Program to reduce emissions from ports and other goods movement hubs through use of community engagement, data and analysis, funding, and information sharing	CO2, CH4, N2O	Implemented and Ongoing	Voluntary	2016	Environmental Protection Agency	n/a
Anti-Idling Programs*	Reduce GHG emissions from commercial motor vehicles	Decreased fuel consumption and greenhouse gas emissions due to reduced wait times and engine idling at the U.S.-Canada border and at U.S. inspection stations.	CO2, CH4, N2O, HFCs	Implemented and Ongoing	Economic	2011-2015	Department of Transportation	n/a
Maritime Environmental and Technical Assistance Program*	Reduce GHG emissions from the maritime sector	Supports technology and innovation projects within the maritime sector to provide needed (and often lacking) information on applications to reduce and mitigate environmental impacts related to air and water quality.	CO2, CH4, N2O	Implemented and Ongoing	Information	2010	Department of Transportation	n/a

Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Implementation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO2e) in 2030
On-Road GHG Assessment Tools*	Support State and local strategies to reduce GHG emissions from the transportation sector	Supports and encourages State and local governments to estimate future GHG emissions from the on-road portion of the transportation sector and find strategies to mitigate these effects.	CO2, CH4, N2O	Implemented and Ongoing	Information	2011	Department of Transportation	n/a
Alternative Fuel Corridors Program*	Establish a national network of alternative fuel corridors	Designates Alternative Fuel Corridors in collaboration with State and local partners for electric, hydrogen, natural gas and propane. Publishes corridor maps, information and technical guidance and supports mapping tools in cooperation with the Department of Energy.	CO2, CH4, N2O	Implemented and Ongoing	Voluntary Agreement	2016	Department of Transportation	n/a
Continuous Lower Energy, Emissions and Noise Program*	Reduce GHG emissions from the aviation sector	The Continuous Lower Energy, Emissions and Noise (CLEEN) Program is the FAA's principal environmental effort to accelerate the development of new aircraft and engine technologies.	CO2, CH4, N2O	Implemented and Ongoing	Economic	2010	Department of Transportation	n/a
Carbon Offsetting and Reduction Scheme for International Aviation*	Reduce GHG emissions from the aviation sector	Supports the monitoring, reporting, and verification of CO_2 emissions from international flights pursuant to Annex 16, Volume IV – Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), of the Chicago Convention.	CO2, CH4, N2O	Implemented and Ongoing	Voluntary	2019	Department of Transportation	n/a
Next Generation Air Transportation System*	Reduce GHG emissions from the aviation sector	Achieves more efficient aircraft operations and reduced GHG emissions through airspace, operational, and infrastructure improvements	CO2, CH4, N2O	Implemented and Ongoing	Economic	2004	Department of Transportation	n/a
Federal Transit, Highway, and Railway Programs*	Reduce GHG emissions from the transit, highway, and railway sectors	Helps public transportation providers, railways, and other key stakeholders to implement strategies that reduce GHGs.	CO2, CH4, N2O	Implemented and Ongoing	Economic	1991-2015	Department of Transportation	n/a

Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Implementation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO2e) in 2030
Transit GHG Assessment Tools*	Assist transit agencies with estimating the GHG emissions from transit projects.	The tool provides a resource to generate coarse but informative estimates of GHG emissions using limited project information and can be used for a broad range of transit projects.	CO2, CH4, N2O	Implemented and Ongoing	Voluntary	2017	Department of Transportation	n/a
Low and No-Emission Component Assessment Program*	Reduce GHG and regulated emissions from transit buses.	Supports research for the testing, evaluation, and analysis of low or no emission components intended for use in "LoNo" transit buses to provide public transportation.	CO2, CH4, N2O	Implemented and Ongoing	Voluntary	2017	Department of Transportation	n/a
Bus Testing Program*	Reduce GHG and regulated emissions from transit buses.	Provides information on transit bus GHG and regulated emissions to support FTA-funded transit operators in selecting cleaner and more efficient bus models for their fleets.	CO2, CH4, N2O	Implemented and Ongoing	Regulatory	1989	Department of Transportation	n/a
Decarbonization MOU and Blueprint	Coordinate cross-agency approach to decarbonizing the transportation sector.	On September 15, 2022, the Departments of Transportation, Energy, and Housing and Urban Development and the Environmental Protection Agency signed a Memorandum of Understanding to coordinate an “all-of-government” approach to decarbonizing the transportation sector.	CO2, CH4, N2O, HFCs	Adopted	Voluntary	2022	Department of Transportation, Department of Energy, Environmental Protection Agency, Department of Housing and Urban Development	n/a
Carbon Reduction Program	Provide funding to states and localities to reduce transportation emissions from on-road highway sources.	Funded by the Bipartisan Infrastructure Law, this program provides $6.4 billion in formula funding for states and localities over five years for a wide range of projects designed to reduce transportation emissions from on-road highway sources.	CO2, CH4, N2O	Adopted	Economic	2022	Department of Transportation	n/a

Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Implementation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO2e) in 2030
National Electric Vehicle Infrastructure Program	Provide funding to states to build out an EV charging network.	The National Electric Vehicle Infrastructure formula program (NEVI) provides nearly $5 billion for states to begin to build out a nationwide EV charging network, with a particular focus on the Interstate Highway System.	CO2, CH4, N2O	Adopted	Economic	2022	Department of Transportation, Department of Energy	n/a
Charging and fueling infrastructure discretionary	Provide funding for electric vehicle charging infrastructure.	This discretionary grant program is further divided into two $1.25 billion programs that can help provide EV charging where people live and work: a Corridor Charging Grant Program for charging and fueling infrastructure on Alternative Fuel Corridors, and a Community Charging Grant Program for charging and fueling infrastructure in communities.	CO2, CH4, N2O	Adopted	Economic	2022	Department of Transportation	n/a
Port Infrastructure Development Program (PIDP)*	Encourage seaports to adopt zero-emissions equipment and conduct decarbonization planning.	Under the Bipartisan Infrastructure Law, PIDP was expanded to allow for funding for electric vehicle charging or hydrogen refueling infrastructure for drayage and medium- or heavy-duty trucks and locomotives that service the port and related grid upgrades. This grant program will provide $2.25 billion over five years to improve port facilities, including projects that will reduce or eliminate toxic air pollutants and greenhouse gas emissions. The Bipartisan Infrastructure Law overall doubles the level of investment in port infrastructure and waterways, helping strengthen our supply chain and reduce pollution.	CO2, CH4, N2O	Implemented and Ongoing	Economic	2019	Department of Transportation	n/a
Congestion Mitigation and Air Quality (CMAQ) Improvement Program*	Encourage the purchase of low- and zero-emissions medium- and heavy-duty vehicles	Under the Bipartisan Infrastructure Law, CMAQ was expanded to allow for the funding of the purchase of medium- or heavy-duty zero emission vehicles and related charging equipment.	CO2, CH4, N2O	Implemented and Ongoing	Economic	1991	Department of Transportation	n/a

Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Implementation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO2e) in 2030
The Surface Transportation Block Grant (STBG) Program*	Provide funding for a wide variety of surface transportation applications, including low- and zero-emissions options	STBG was expanded to include eligibility for electric vehicle charging infrastructure and vehicle-to-grid infrastructure.	CO2, CH4, N2O	Implemented and Ongoing	Economic	2016	Department of Transportation	n/a
Federal Transit Administration (FTA) Low and No Emission Bus Programs*	Encourage the adoption of zero- and low-emission transit buses	The Bipartisan Infrastructure Law expands this competitive program which provides funding to state and local governmental authorities for the purchase or lease of zero-emission and low-emission transit buses as well as acquisition, construction, and leasing of required supporting facilities.	CO2, CH4, N2O	Implemented and Ongoing	Economic	2016	Department of Transportation	n/a
FTA Buses + Bus Facilities Competitive Program*	Improve existing bus-related facilities, including actions to reduce emissions	This program provides competitive funding to states and direct recipients to replace, rehabilitate, and purchase buses and related equipment and to construct bus-related facilities including technological changes or innovations to modify low or no emission vehicles or facilities.	CO2, CH4, N2O	Implemented and Ongoing	Economic	2016	Department of Transportation	n/a
Capital Investment Grants (CIG) Program*	Provide funding for capital investments in transit systems	The Bipartisan Infrastructure Law guarantees $8 billion, and authorizes $15 billion more in future appropriations, to invest in new high-capacity transit projects communities choose to build, providing more people with clean, convenient, and reliable transit service.	CO2, CH4, N2O	Implemented and Ongoing	Economic	2016	Department of Transportation	n/a
Electric or Low Emitting Ferry Pilot Program	Encourage the adoption of low- and zero-emission passenger ferries	This Bipartisan Infrastructure Law competitive grant program will support the transition of passenger ferries to low or zero emission technologies.	CO2, CH4, N2O	Adopted	Economic	2022	Department of Transportation	n/a

Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Implementation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO2e) in 2030
Railroad Rehabilitation and Improvement Financing (RRIF)*	Provide funding for rail improvements, including for transit-oriented development	The Bipartisan Infrastructure Law expands eligibility for transit-oriented development in the Railroad Rehabilitation and Improvement Financing (RRIF) loans.	CO2, CH4, N2O	Implemented and Ongoing	Economic	2009	Department of Transportation	n/a
TIFIA 49 for Transit	Provide financing for transit-oriented development	The Transportation Infrastructure Finance and Innovation Act (TIFIA) program will begin offering low-cost and flexible financing for transit and Transit-oriented Development (TOD) projects at the maximum level authorized under law. This new initiative, "TIFIA 49," authorizes borrowing up to 49% of eligible project costs, helping more projects get off the ground. With few exceptions, TIFIA loans have historically been capped at 33% of eligible project costs.	CO2, CH4, N2O	Adopted	Economic	2022	Department of Transportation	n/a
Transit Oriented Development Pilot	Encourage comprehensive transit-oriented development planning	The Pilot Program for TOD Planning provides funding to local communities to integrate land use and transportation planning with a new fixed guideway or core capacity transit capital investment. Comprehensive planning funded through the program must examine ways to improve economic development and ridership, foster multimodal connectivity and accessibility, improve transit access for pedestrian and bicycle traffic, engage the private sector, identify infrastructure needs, and enable mixed-use development near transit stations.	CO2, CH4, N2O, HFCs	Adopted	Economic	2022	Department of Transportation	n/a

Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Impleme ntation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO2e) in 2030
Safe Streets for All	Improve the safety of zero-emissions active transportation options	DOT's new Safe Streets and Roads for All program will provide $5 billion over 5 years directly to local and tribal governments to support their efforts to advance "vision zero" plans and other improvements to reduce crashes and fatalities, especially for cyclists and pedestrians. By making our roadways safer, this program will encourage people to choose active modes of transportation, reducing emissions.	CO2, CH4, N2O, HFCs	Adopted	Economic	2022	Department of Transportation	n/a
Transportation Alternatives Program*	Encourage zero-emissions active transportation options	The Bipartisan Infrastructure Law provides formula funding for the Transportation Alternatives Program, which supports pedestrian and bike infrastructure, recreational trails, safe routes to school and more, giving more people the option to choose clean active transportation options.	CO2, CH4, N2O, HFCs	Implemented and Ongoing	Economic	2016	Department of Transportation	n/a
U.S. Aviation Climate Action Plan	Establish a roadmap for net-zero aviation sector emissions	This Plan, launched at UNFCCC COP-26 in Glasgow in 2021, establishes a national goal of net-zero carbon emissions for U.S. aviation by 2050.	CO2, CH4, N2O	Implemented and Ongoing	Voluntary	2021	Department of Transportation, Department of Energy, Department of Agriculture	n/a
Sustainable Aviation Fuel "Grand Challenge" and Roadmap	Set targets for sustainable aviation fuel and create a roadmap for achieving them	DOT, the Department of Energy, and the Department of Agriculture launched the SAF Grand Challenge in 2021, and in September 2022 rolled out a Roadmap to meet the Challenge's goals of 3 billion gallons of sustainable aviation fuel by 2030 and 35 billion gallons by 2050.	CO2, CH4, N2O	Implemented and Ongoing	Voluntary	2022	Department of Transportation, Department of Energy, Department of Agriculture	n/a

Annex 2. SUMMARY TABLE OF POLICIES AND MEASURES

Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Implementation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO2e) in 2030
Federal Aviation Administration (FAA) Terminal Program	Provide grants for airports to increase energy efficiency in terminals	This discretionary grant program funded by the Bipartisan Infrastructure Law will provide $5 billion over five years for airport terminal development and other landside projects. This discretionary grant program will support projects that increase energy efficiency through upgrading environmental systems, upgrading plant facilities, and achieving LEED standards.	CO2, CH4, N2O	Adopted	Economic	2022	Department of Transportation	n/a
Federal Aviation Administration (FAA) ASCENT Program*	Conduct research on zero- and low-carbon aviation fuels	This university-led Center of Excellence on sustainable aviation fuels and environment undertakes cutting edge research to advance new technologies, reduce environmental impacts, and develop sustainable fuels.	CO2, CH4, N2O	Implemented and Ongoing	Information	2013	Department of Transportation	n/a
Rebuilding American Infrastructure with Sustainability and Equity (RAISE) Grants*	Provide funding for large surface transportation projects that contribute to emissions reductions	RAISE grants support surface transportation projects of local and/or regional significance that can improve the sustainability of our transportation system.	CO2, CH4, N2O	Implemented and Ongoing	Economic	2021	Department of Transportation	n/a
Higher Biofuels Infrastructure Incentive Program*	To increase the sales and use of higher blends of ethanol and biodiesel	Provides grants for biofuel distribution at blender platforms down to the retail pump level. Increases available access to biofuels.	CO2	Implemented and Ongoing	Economic	2020	Department of Agriculture	1,325
State and Alternative Fuel Provider Fleet Program*	Require fleets to purchase alternative fuel vehicles	Requires covered fleets either to acquire alternative fuel vehicles as a percentage of their annual LDV acquisitions or to employ other petroleum-reduction methods.	CO2	Implemented and Ongoing	Regulatory	1992	Department of Energy	n/a

Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Implementation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO2e) in 2030
Vehicle Technology Deployment (Clean Cities)*	Support the use of alternative fuel vehicles and other petroleum-reducing vehicle technologies	Provides technical assistance, consumer information, industry coordination, tools, knowledge-sharing, and cost-shared funding for local/regional projects that mitigate GHG emissions and reduce reliance on petroleum in the transportation sector.	CO2, CH4, NO2	Implemented and Ongoing	Economic	1993	Department of Energy	8,328
Biofuels Demonstration Facilities*	Demonstrate biorefineries to produce sustainable aviation fuel to de-risk industrial buildout	By 2030, build and operate 4-5 demonstration-scale integrated biorefineries with a focus on sustainable aviation fuels capable of >50% reduction in GHG emissions relative to petroleum.	CO2, CH4, N2O	Implemented and Ongoing	Research	2021	Department of Energy	n/a
Advanced Technology Vehicle Manufacturing Loan Program*	Provide loans to advanced vehicle technology manufacturers	Provides direct loans to qualifying U.S. advanced technology vehicles or component and engineering integration projects.	CO2	Implemented and Ongoing	Economic	2008	Department of Energy	367,000
Energy: Supply								
Onshore Renewable Energy Development Program*	Encourage renewable energy development onshore	Provides opportunities for and encourages use of federal public lands for the development of wind, solar, and geothermal energy.	CO2	Implemented and Ongoing	Economic	Around 1980	Department of the Interior	8,300
Offshore Renewable Energy Program*	Encourage renewable energy development offshore	Advances a sustainable Outer Continental Shelf renewable energy future through site planning and environmentally responsible operations and energy generation.	CO2	Implemented and Ongoing	Economic	2009	Department of the Interior	n/a

Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Implementation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO2e) in 2030
Waste Prevention, Production Subject to Royalties, and Resource Conservation	Reduce the waste of natural gas from venting, flaring, and leaks during oil and gas production activities on Federal and Indian leases	The rule would describe the reasonable steps that operators of Federal and Indian oil and gas leases must take to avoid the waste of natural gas and ensure that, when Federal or Indian gas is wasted, the public and Indian mineral owners are compensated through royalty payments.	CH4	Under Development	Regulatory	TBD Regulations under development	Department of the Interior	n/a
Offshore Fugitive Emissions*	Reduce fugitive emissions from offshore oil and gas facilities	Perform fugitive emission monitoring of offshore oil and gas facilities utilizing portable infrared cameras during risk-based air quality compliance inspections. The program helps identify fugitive sources and facilitate quick remediation.	CH4	Implemented and Ongoing	Regulatory	2010	Department of the Interior	n/a
Orphaned Well Program*	Reduce or eliminate fugitive emissions from orphaned onshore well sites	The Orphaned Well Program is led by the Bureau of Land Management (BLM) and the Office of Environmental Policy and Compliance. The program will inventory, assess, plug, and restore orphaned well sites through fugitive emissions monitoring at orphaned well sites, prioritization of sites for plugging and closure, and grants to State and Tribal agencies for well plugging and clean-up. The program began in 1976 and received significant new funding from the Bipartisan Infrastructure Law to carry out these activities.	CH4, CO2	Implemented and Ongoing	Regulatory, Economic	1976	Department of the Interior	n/a
Offshore Carbon Sequestration Program	Allow for the storage of carbon dioxide in the U.S. outer continental shelf (OCS) sub-seabed	The Bipartisan Infrastructure Law amended the OCSLA to authorize DOI to grant leases, easements, or rights-of-way on the OCS for activities that "provide for, support, or are directly related to the injection of a carbon dioxide stream into sub-seabed geologic formations for the purpose of long-term carbon sequestration."	CO2	Under Development	Regulatory	TBD Regulations under development	Department of the Interior	n/a

Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Implementation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO2e) in 2030
Onshore Carbon Sequestration Policy	Allow for the subsurface storage of carbon dioxide on public lands.	The Department of the Interior issued a policy enabling the use public lands for site characterization, transportation, injection, capture, and geologic sequestration of carbon dioxide. This includes authorizing rights-of-way and the use of pore space managed by the BLM when surface facilities, including injection wells, are on private or state-owned lands or lands managed by another Federal agency. BLM is engaging in outreach and rulemaking.	CO2	Under Development	Regulatory	TBD Regulations under development	Department of the Interior	n/a
Abandoned Mine Land Reclamation Program*	Reclaim abandoned mine lands.	The Abandoned Mine Land (AML) Reclamation Program run by the Office of Surface Mining Reclamation and Enforcement addresses the hazards and environmental degradation posed by legacy coal mines. The Bipartisan Infrastructure Law invests an additional $11 billion in reclaiming these sites. States with unreclaimed mines on the list of EPA's Methane Coal Mine Opportunities Database are encouraged to prioritize the reclamation of such sites in a manner that eliminates methane emissions to the greatest extent possible.	CO2	Implemented and Ongoing	Regulatory, Economic	1977	Department of the Interior	n/a
Civil Nuclear Credit Program*	Preserve the continued operation of U.S. nuclear reactors	The Bipartisan Infrastructure Law creates a $6 billion program to allocate credits to owners or operators of certified U.S. nuclear reactors that would otherwise stop operations due to economic factors.	CO2	Adopted	Economic	2022	Department of Energy	n/a

Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Impleme ntation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO2e) in 2030
Enhanced Geothermal Systems Demonstration Projects*	Support the development and deployment of enhanced geothermal systems through demonstration project funding	Demonstration projects facilitate technology validation and deployment, reduce cost, and improve performance by aiding industry along the learning curve toward technological readiness.	CO2	Implemented and Ongoing	Research	2009	Department of Energy	n/a
Offshore Wind Demonstration Projects*	Support the development and deployment of offshore wind energy systems through demonstration project funding	Designed to reduce the cost of offshore wind energy through the development and deployment of innovative technologies, in order to develop offshore wind systems ready for commercial operation in U.S. waters. The demonstrations will help address key challenges associated with installing full-scale offshore wind turbines, connecting offshore turbines to the power grid, and navigating new permitting and approval processes.	CO2	Implemented and Ongoing	Economic	2012	Department of Energy	n/a
Hydroelectric Production Incentive program*	Support the expansion of hydropower energy development at existing dams through an incentive payment procedure	In 2014 and 2015, Congress appropriated funds for Hydroelectric Production Incentives under Section 242 of the Energy Policy Act of 2005. Qualified hydroelectric facilities–existing powered or non-powered dams and conduits that added a new turbine or other hydroelectric generating device–may receive up to 1.8 cents per kilowatt hour, indexed for inflation (approximately 2.3 cents per kilowatt hour today) with maximum payments of $750,000 per year for hydroelectric energy generated by the facility during the incentive period.	CO2	Implemented and Ongoing	Economic	2005	Department of Energy	n/a

Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Implementation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO2e) in 2030
Clean Hydrogen Electrolysis Program	Reduce cost of clean hydrogen production	The Bipartisan Infrastructure Law provides support for research, development, demonstration, and deployment of clean hydrogen production using electrolyzers for commercialization.	CO_2, CH_4, NO_2	Adopted	Research	2022	Department of Energy	n/a
Regional Clean Hydrogen Hubs	Stimulate clean hydrogen market lift-off by demonstrating performance at scale	The Bipartisan Infrastructure Law provides support for regional clean hydrogen hubs, a network of clean hydrogen producers, potential off-takers, and supporting infrastructure	CO_2, CH_4, NO_2	Adopted	Economic	2022	Department of Energy	n/a
Interconnection Information Exchange (i2X)	Facilitate integration of renewable resources into the power grid	Funded by the Bipartisan Infrastructure Law, i2X is a new program aiming to develop innovative solutions to enable faster, simpler, and fairer interconnection of solar energy, wind energy, and energy storage, while enhancing the reliability and resilience of our nation's distribution and transmission grid networks	CO_2, CH_4	Adopted	Information	2022	Department of Energy	n/a
TESTBED*	Demonstrate concentrating solar-thermal power systems for next-generation heat applications	This project is working to develop, build, and operate a supercritical carbon dioxide (sCO_2) power cycle integrated with thermal energy storage, heated by a concentrated solar thermal energy supplied by a newly built heliostat field. This plant will operate as a demonstration of a sCO_2 power cycle, integrated with thermal energy storage (TES), at a turbine inlet temperature of 600°C to be able to use conventional stainless steel alloys widely available today. This project will generate real operational data of a TES-driven sCO_2 power cycle, to enable commercial adoption of this novel technology.	CO_2, CH_4	Implemented and Ongoing	Research	2020	Department of Energy	n/a

Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Impleme ntation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO2e) in 2030
National Community Solar Partnership*	Connect Americans to low-cost community solar options	Community solar allows community members of all types to access the meaningful benefits of renewable energy, including reduced energy costs, increased resilience, ownership, and wealth building. DOE's community solar target is to power 5 million homes and provide 20% savings on a subscriber's energy bills, up from 10% on average today, by 2025.	CO2, CH4	Implemented and Ongoing	Information	2019	Department of Energy	n/a
Cyber and All-Hazards Resilience for Energy Systems in Transition*	Enable the secure and resilient development, deployment, and operation of emissions-reducing energy technologies (RDD&D)	Preparedness, RDD&D, and response activities to enhance the cybersecurity and all-hazards resilience of emissions-reducing energy technologies (e.g., distributed energy resources) and enable their secure and resilient integration into existing energy systems.	CO2	Implemented and Ongoing	Other	2018	Department of Energy	n/a
Clean Energy Cybersecurity Accelerator*	Catalyze the development of new cybersecurity solutions for emissions-reducing energy technologies	Brings together federal partners, the energy sector, and technology innovators to work jointly to develop and deploy renewable, modern, and secure grid technologies that are cost competitive – ensuring cybersecurity is built into renewable technologies and architectures.	CO2	Implemented and Ongoing	Research	2021	Department of Energy, National Renewable Energy Laboratory	n/a
Microgrid R&D*	Conduct R&D for the use of microgrids in the integration and operational optimization of distributed energy resources	Provides $8-10 million annually to DOE national labs for conducting applied R&D on microgrids increase the resilience, reliability, and decentralization of electricity delivery infrastructure.	CO2	Implemented and Ongoing	Research	2017	Department of Energy	n/a

Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Implementation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO2e) in 2030
Power Electronics*	Conduct R&D on SF6 alternatives for use as a gaseous dielectric in high-voltage circuit breakers and gas-insulated substations.	Conducts basic materials research in advanced conductors for transmission cables; applied materials research to address converter component limitations for high-voltage, high-power applications; and research and development into solid-state power substations converter building blocks that can be used in power flow controllers, solid-state transformers, and solid-state circuit breakers, all of which can help reduce the need for SF6-filled equipment.	SF6	Implemented and Ongoing	Research	2016	Department of Energy	n/a
Energy Storage Demonstration	Deploy new energy storage systems to reduce technology risk and prove out new solutions.	Supports and provides a pathway for demonstration and deployment of novel, mature storage technologies, including large scale commercial development and deployment of long cycle life, lithium-grid scale batteries and their components.	CO2	Adopted	Economic	2022	Department of Energy	n/a
Biological and Environmental Research*	Enable development of biofuels, bioproducts, and enhanced carbon storage	Foundational research enabling the development of sustainable cellulosic biofuels and bioproducts, stabilization and enhanced storage of carbon in terrestrial ecosystems, and broader understanding of related environmental processes.	CO2	Implemented and Ongoing	Research	2007	Department of Energy	n/a
Basic Energy Sciences Research*	Enable development of clean energy technologies	Basic chemical and materials sciences research to enable clean hydrogen production, fuels from sunlight, long-term energy storage, etc.	CO2	Implemented and Ongoing	Research	2010	Department of Energy	n/a
Fusion Energy Sciences Research*	Enable fusion energy, which could replace other central station electrical power sources which produce carbon.	Develop a fundamental scientific understanding of matter at very high temperatures and densities. This is accomplished through the study of plasmas, the fourth state of matter, and how it interacts with its surroundings.	CO2	Implemented and Ongoing	Research	1977	Department of Energy	n/a

Annex 2. SUMMARY TABLE OF POLICIES AND MEASURES

Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Implementation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO2e) in 2030
Advanced Reactor Demonstration Program*	Demonstrate technology capable of decarbonizing the electricity sector and industrial process heat	Supports the design, development, licensing, construction and operation of two advanced nuclear reactor projects, resulting in the introduction of clean, resilient baseload power generation to the domestic power portfolio.	CO2	Implemented and Ongoing	Research	2020	Department of Energy	n/a
Energy Storage Demonstration Projects and Pilot Grants*	Improve the performance, security, and reliability of energy storage technologies, including in rural areas.	Energy storage system demonstration projects, including second-life applications of electric vehicle batteries as aggregated energy storage installations to provide services to the electric grid.	CO2, CH4, N2O	Implemented and Ongoing	Research	2020	Department of Energy	n/a
Long Duration Demonstration Initiative and Joint Program*	Develop long-duration energy storage technologies.	Demonstration projects focused on the development of long-duration energy storage technologies.	CO2, CH4, N2O	Implemented and Ongoing	Research	2020	Department of Energy	n/a
Implementation of the PIPES Act*	Reduce methane emissions from pipelines.	Several rulemakings and an advisory are complete or underway as required by the PIPES Act of 2020 to reduce methane emissions from pipelines.	CH4	Implemented and Ongoing	Regulatory	2021	Department of Transportation	n/a
EPA Green Power Partnership*	Reduce GHG emissions through green power purchases and use	Encourages and supports U.S. organizations to voluntarily purchase green power to reduce the air pollution and health impacts associated with the use of electricity.	CO2	Implemented and Ongoing	Voluntary	2001	Environmental Protection Agency	68,000
EPA Combined Heat & Power Partnership*	Reduce GHG emissions by encouraging energy efficiency	Encourages industry to engage and collaborate through EPA's Partner network. The Partnership serves as a resource center for assessing the environmental impact of thermal and electrical energy use through CHP project development.	CO2	Implemented and Ongoing	Voluntary	2001	Environmental Protection Agency	n/a

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Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Impleme ntation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO2e) in 2030
RE-Powering America's Land Initiative*	Promote renewable energy on formerly contaminated lands	Encourages development of renewable energy on current and formerly contaminated lands, landfills, and mine sites by identifying contaminated lands that might be suitable for renewable energy development and providing technical assistance to communities	CO_2	Implemented and Ongoing	Economic	2006	Environmental Protection Agency	n/a
Natural Gas STAR Program & Methane Challenge*	Reduce GHG emissions from oil and natural gas companies	Works with oil and natural gas companies to promote proven, cost-effective technologies and practices that improve operational efficiency and reduce methane emissions	CH_4	Implemented and Ongoing	Voluntary	1993 / 2016	Environmental Protection Agency	6,430
Coalbed Methane Outreach Program*	Reduce GHG emissions from coal mining	Voluntary program with the goal of reducing methane emissions from coal mining activities	CH_4	Implemented and Ongoing	Voluntary	1994	Environmental Protection Agency	5,160
Federal Air Standards for Oil and Natural Gas Sector*	Reduce volatile organic compound emissions from oil and natural gas sectors	The new source performance standards control volatile organic compound emissions from various sources, substantially reducing methane emissions as a co-benefit	CH_4	Implemented and Ongoing	Regulatory	2012	Environmental Protection Agency	11,000
Electric Loan Program*	To provide financial support to modernize and expand rural electricity infrastructure	Provides loans to finance electricity infrastructure to ensure reliable and affordable electricity to rural communities	CO_2, N_2O	Implemented and Ongoing	Economic	1936	Department of Agriculture	2,745
Rural Energy for America Program (REAP)*	To stimulate adoption of energy efficiency measures and renewable energy systems.	Provides grants and loan guarantees to various rural residents, agricultural producers, and rural businesses for energy efficiency and renewable energy systems.	CO_2, CH_4	Implemented and Ongoing	Economic	2008	Department of Agriculture	339

Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Implementation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO2e) in 2030
Biorefinery, Renewable Chemical, and Biobased Product Manufacturing Assistance Program*	To assist in the development, construction and retrofitting of new and emerging technologies	Provides loan guarantees for using renewable biomass to make advanced biofuels, renewable chemicals and biobased products.	CO_2, CH_4	Implemented and Ongoing	Economic	2010	Department of Agriculture	735
Advanced Biofuel Payment Program*	To increase the production of advanced biofuels	Incentive payments are made for advanced biofuel produced. Includes cellulosic biofuels, biogas, wood pellets.	CO_2, CH_4	Implemented and Ongoing	Economic	2009	Department of Agriculture	3,614
Guaranteed Underwriting Program (313A)*	To provide loans or refinancing bonds related to utility infrastructure projects	Provides loan funds to eligible lending institutions to relend to rural electric cooperatives.	CO_2, N_2O	Implemented and Ongoing	Economic	2002	Department of Agriculture	n/a
Energy: Residential and Commercial End-Use								
Better Buildings Initiative*	Accelerate the adoption of best practices and proven solutions for reducing energy use, carbon emissions, water use, and waste generation in buildings throughout the U.S.	Partners working with DOE in the Better Buildings Initiative set ambitious goals and contribute real-world energy, carbon, water, and waste solutions to accelerate our future toward a clean energy economy.	CO_2	Implemented and Ongoing	Voluntary	2011	Department of Energy	37,000

Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Implementation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO2e) in 2030
Appliance, Equipment, and Lighting Energy Efficiency Standards*	Establish minimum energy conservation requirements	Establish minimum energy conservation standards for more than 60 categories of appliances, equipment, and lighting.	CO2	Implemented and Ongoing	Regulatory	1987	Department of Energy	251,600 to 273,600
Home Performance with ENERGY STAR*	Encourage energy-efficiency improvements in existing homes	Provides homeowners with resources to identify trusted contractors for high-quality, comprehensive energy audits and residential retrofits.	CO2	Implemented and Ongoing	Voluntary	2002	Department of Energy	61,900
Zero Energy Ready Homes (ZERH)*	Encourages above code energy energy-efficiency in new homes	Homes that meet high performance energy efficiency criteria established by DOE may use the Zero Energy Ready Homes label for sales and marketing so that consumers can easily find homes and home builders that build to high performance energy efficient homes.	CO2, CH4, HFCs	Implemented and Ongoing	Voluntary	2013	Department of Energy	n/a
Building Energy Codes Program*	Support energy-efficient building codes	Provides technical assistance supporting cost-effective building energy codes, including model code advancement, as well as state and local code implementation.	CO2	Implemented and Ongoing	Regulatory, Voluntary	1992	Department of Energy	39,800
Manufactured Homes Regulatory Program*	Support the development of more-efficient manufactured homes.	Establish minimum energy conservation standards for manufactured homes.	CO2	Implemented and Ongoing	Regulatory	2007	Department of Energy	770
Federal Building Rulemakings (Codes and Clean Energy)*	Support the development of more efficient Federal buildings with clean energy uses.	Establish minimum building code standards for Federal buildings along with clean energy standards.	CO2	Implemented and Ongoing	Regulatory	1992	Department of Energy	146

Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Implementation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO2e) in 2030
Geothermal Heating and Cooling Demonstration Projects*	Improve the efficiency and reduce installation costs for geothermal heat pumps	Advance RD&D activities aimed at improving the operational efficiency of geothermal heat pumps by up to 50% by 2030 and lower the cost of ground heat exchangers by up to 30% by 2050.	CO2	Implemented and Ongoing	Research	2021	Department of Energy	n/a
Initiative for Better Energy, Emissions, and Equity (E3 Initiative)*	Transform the heating and cooling marketplace, making affordable, clean and efficient solutions easily available across America.	The E3 Initiative focuses on advancing the research, development, and national deployment of clean heating and cooling systems that include heat pumps, advanced water heaters, low-to-no global warming potential refrigerants, and smarter HVAC diagnostic tools in residential and commercial buildings.	CO2, CH4, N2O, HFCs	Implemented and Ongoing	Voluntary	2021	Department of Energy	n/a
Advanced Building Construction (ABC) Initiative*	Integrate energy-efficiency solutions into highly productive U.S. construction practices for new buildings and retrofits.	The U.S. Department of Energy's Advanced Building Construction (ABC) Initiative integrates energy-efficiency solutions into highly productive U.S. construction practices for new buildings and retrofits.	CO2, CH4, N2O, HFCs	Implemented and Ongoing	Economic	2020	Department of Energy	n/a
Non-Profits Program	Improve the efficiency of non-profit buildings	The Bipartisan Infrastructure Law provides competitive grants and other strategic initiatives to enable non-profit organizations to reduce their energy use and carbon emissions while freeing up funds to serve their mission and communities.	CO2, CH4, N2O, HFCs	Adopted	Economic	2023	Department of Energy	n/a
Energy Efficiency Revolving Loan Fund Capitalization Grant Program	Increase the energy efficiency of existing building stock	The Bipartisan Infrastructure Law establishes the Energy Efficiency Revolving Loan Fund Capitalization Grant program for states to conduct commercial and residential energy audits/retrofits.	CO2, CH4, N2O, HFCs, PFCs	Implemented and Ongoing	Economic	2022	Department of Energy	n/a

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Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Implementation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO2e) in 2030
Building, Training, and Assessment Centers	Increase uptake of energy conserving technologies in residential and commercial buildings	The Bipartisan Infrastructure Law establishes a grant program for institutions of higher education to establish building training and assessment centers to educate and train building technicians and engineers on implementing modern building technologies.	CO2, CH4, N2O, HFCs, PFCs	Adopted	Education	2022	Department of Energy	n/a
Connected Communities program*	Remake buildings into a clean and flexible energy resources.	The Connected Communities program works to remake buildings into a clean and flexible energy resources by combining energy efficiency and demand flexibility with smart technologies and communications to inexpensively deliver greater affordability, comfort, productivity, and performance to America's homes and buildings.	CO2, CH4, N2O, HFCs	Implemented and Ongoing	Economic	2019	Department of Energy	n/a
Weatherization Assistance Program (WAP)*	Fund weatherization services for low-income households	Provides funding and technical support to states, U.S. territories, and tribes, which in turn work with a network of about 700 local agencies to provide trained crews to perform residential weatherization services for income-eligible households.	CO2, CH4, N2O	Implemented and Ongoing	Economic	1977	Department of Energy	1,700
Public Schools Program	Improve energy performance, health, and safety of public k-12 schools	The Bipartisan Infrastructure Law provides competitive grants for energy improvements at public school facilities and other strategic initiatives to prioritize schools with high needs, facilitate substantial additional investment, build enduring capacity in local educational agencies, and scale promising partnership models to improve the energy performance and health outcomes in our nation's schools equitably and efficiently.	CO2, CH4, N2O, HFCs	Adopted	Economic	2022	Department of Energy	n/a
ENERGY STAR Products*	Reduce GHG emissions through energy-efficient products	Products that earn the ENERGY STAR label are independently certified to meet strict standards for energy efficiency set by the EPA.	CO2	Implemented and Ongoing	Voluntary	1992	Environmental Protection Agency	266,000

Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Implementation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO2e) in 2030
ENERGY STAR Commercial Buildings*	Reduce GHG emissions from U.S. commercial building operations	ENERGY STAR tools and resources help businesses determine the most cost-effective approach to managing energy use in their buildings —enabling the private sector to save energy, increase profits, and boost competitiveness.	CO2	Implemented and Ongoing	Voluntary	1995	Environmental Protection Agency	141,000
ENERGY STAR Residential New Construction*	Reduce GHG emissions through energy-efficient new homes and apartments	Promotes improvement in energy performance in residential buildings beyond the labeling of products	CO2	Implemented and Ongoing	Voluntary	1995	Environmental Protection Agency	6,700
Energy: Industrial End-Use								
Better Plants (part of Better Buildings Initiative)*	Reduce energy consumption, carbon emissions, water consumption, and waste in the manufacturing sector	Industrial partners working with DOE in the Better Plants program set ambitious goals and contribute real-world energy, carbon, water, and waste solutions to accelerate our future toward a clean energy economy.	All	Implemented and Ongoing	Voluntary	2011	Department of Energy	67,000
Industrial Assessment Centers (IACs)*	Encourage energy efficiency in industrial plants	Provide energy assessments to small and medium sized manufacturers and make energy efficiency, carbon reduction, water efficiency, and waste reduction recommendations.	CO2, CH4, N2O, HFCs	Implemented and Ongoing	Economic	1976	Department of Energy	n/a
Superior Energy Performance/ISO 50001*	Reduce energy consumption in the manufacturing sector	Encourages the implementation of strategic energy management systems that align to the ISO 50001 standard. Provides guidance, tools and protocols to facilitate energy efficiency savings and improved energy performance	CO2, CH4, N2O, HFCs	Implemented and Ongoing	Voluntary	2011	Department of Energy	n/a

Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Implementation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO2e) in 2030
Combined Heat and Power (CHP) Deployment Program*	Reduce energy consumption from large energy users.	Provide screening assessments for combined heat and power systems to identify cost-effective CHP opportunities	CO2	Implemented and Ongoing	Economic	2004	Department of Energy	5,100
ENERGY STAR for Industry*	Reduce GHG emissions from U.S. manufacturing	Partners with manufacturers to reduce CO_2 emissions, develop long-term decarbonization strategies, and provide performance measurement tools.	CO2	Implemented and Ongoing	Voluntary	2000	Environmental Protection Agency	43,000
Industrial Processes and Product Use								
Industrial Decarbonization RD&D*	Reduce GHG emissions from the industrial sector.	A multi-year RD&D program on sector-specific and crosscutting decarbonization technologies to increase energy efficiency and reduce GHG emissions in the U.S. industrial sector.	CO2, CH4, N2O, HFCs	Implemented and Ongoing	Research	2021	Department of Energy	n/a
CO2 Utilization*	CO2 utilization technologies that have the potential to develop additional markets for CO_2 based-products.	Partners with industry, Labs and academia for CO_2 conversion to fuels, organic and inorganic chemicals, food and feeds, construction materials, energy storage, wastewater treatment, and others	CO2	Implemented and Ongoing	Research, Economic	2015	Department of Energy	n/a
Industrial Emissions Demonstration Projects	Reduce emissions associated with heavy industry	Carry out demonstration programs on industrial emissions.	CO2, CH4, N2O	Adopted	Research	2022	Department of Energy	n/a
Advanced Manufacturing Research	Enable decarbonization of industrial manufacturing processes	Basic chemical and materials sciences research to enable decarbonization of industrial manufacturing processes	CO2	Implemented and Ongoing	Research	2022	Department of Energy	n/a

Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Implementation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO_2e) in 2030
Carbon Capture Program*	Pre- and post-combustion capture RDD&D on transformational gas separation technologies that can help achieve decarbonization goals.	Partner with National Laboratories, Universities and Industry on RDD&D to be applied to a wide variety of sources such as power plants, cement and steel facilities, refineries, petrochemical facilities, and other sources. Research, development, demonstration, and deployment (RDD&D) is focused on adapting technologies or making them robust enough to capture greater than 95% of the CO_2 emissions from these wide variety of sources including FEED studies for power and industrial facilities	CO_2	Implemented and Ongoing	Research, Economic	2002	Department of Energy	n/a
The American Innovation and Manufacturing Act (AIM Act)*	Phase down HFC production and consumption; maximize reclamation and minimize releases of HFCs and their substitutes; facilitate sector-based transitions to next-generation technologies	Establishes phasedown of HFC production and consumption through allowance allocations; establishes regulations to reduce HFC emissions and increase reclamation of existing substances; establishes restrictions on subsectors to effect transition to alternatives	HFCs	Implemented and Ongoing	Regulatory	2022	Environmental Protection Agency	107,951
Significant New Alternatives Policy Program*	Transition away from ozone-depleting chemicals	Facilitates smooth transition away from ozone-depleting chemicals in industrial and consumer sectors	HFCs, PFCs, SF_6	Implemented and Ongoing	Regulatory	1990	Environmental Protection Agency	469,294
GreenChill Advanced Refrigeration Partnership*	Reduce ozone-depleting and GHG emissions from supermarkets	Reduces ozone-depleting and GHG refrigerant emissions from supermarkets through data collection, benchmarking, collaboration, and information sharing on technologies and practices to reduce emissions	HFCs	Implemented and Ongoing	Voluntary	2007	Environmental Protection Agency	18,829

Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Implementation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO_2e) in 2030
Responsible Appliance Disposal Program*	Reduces emissions from end-of-life appliances	Reduces emissions of refrigerant and foam-blowing agents from end-of-life appliances	HFCs	Implemented and Ongoing	Voluntary	2006	Environmental Protection Agency	249
Voluntary Code of Practice for the Reduction of Emissions of HFC and PFC Fire Protection Agents*	Reduces GHG emissions from fire protection agents	Minimizes non-fire emissions of HFCs and PFCs used as fire-suppression alternatives, and protects people and property from the threat of fire using proven, effective products and systems	HFCs, PFCs	Implemented and Ongoing	Voluntary	2002	Environmental Protection Agency	n/a
SF6 Emission Reduction Partnership for Electric Power Systems*	Reduce GHG emissions from electricity transmission and distribution	Collaborative effort between EPA and the electric power industry to identify, recommend, and implement cost-effective solutions to reduce SF6 emissions	SF6	Implemented and Ongoing	Voluntary	1999	Environmental Protection Agency	1,090
Forestry/LULUCF								
Forest Legacy Program (FLP)*	To encourage the protection of privately owned forest lands through conservation easements or land purchases	Provides grants to states for fee purchase or conservation easements for high value forests from private landowners.	CO2	Implemented and Ongoing	Economic	1991	Department of Agriculture—Forest Service	n/a

Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Implementation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO2e) in 2030
Collaborative Forest Landscape Restoration Program*	To encourage the collaborative, science-based ecosystem restoration of priority forest landscapes.	The purpose of the Collaborative Forest Landscape Restoration Program (CFLRP) is to encourage the collaborative, science-based ecosystem restoration of priority forest landscapes.	CO2	Implemented and Ongoing	Economic	2009	Department of Agriculture—Forest Service	n/a
Forest Health*	To maintain, enhance, and restore healthy forest conditions.	Provides technical and financial assistance to prevent, suppress, and control outbreaks of forest insect, disease, and invasives threatening forest resources.	CO2	Implemented and Ongoing	Economic	1978	Department of Agriculture—Forest Service	n/a
Community Forest Program (CFP)*	To establish community forests that provide community benefits.	Provides grants to match funds with municipal, tribal, or NGO partners for fee purchase of forests to benefit communities.	CO2	Implemented and Ongoing	Economic	2013	Department of Agriculture—Forest Service	n/a
Forest Stewardship Program (FSP)*	To enhance and sustain multiple forest resources and contribute to healthy and resilient landscapes.	Partners with state forestry agencies, cooperative extension, and conservation districts to connect private landowners with the resources needed to manage forests and woodlands and develop stewardship plans.	CO2	Implemented and Ongoing	Economic	1991	Department of Agriculture—Forest Service	n/a
Great American Outdoors Act (GAOA) (Legacy Restoration Fund and Land and Water Conservation Fund)*	To increase investments in recreation infrastructure, public lands access, and land and water conservation.	GAOA provides permanent full funding for the Land and Water Conservation Fund (LWCF) and establishes a new National Parks and Public Land Legacy Restoration Fund (LRF) to address the deferred maintenance backlog for 5 federal agencies over the next 5 years.	CO2	Implemented and Ongoing	Economic	2020	Department of Agriculture—Forest Service	n/a

Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Impleme ntation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO2e) in 2030
Joint Chiefs' Landscape Restoration Partnership*	To collaborate with agricultural producers and forest landowners to invest in conservation and restoration at large, landscape scale.	USDA's Forest Service and Natural Resources Conservation Service are working together to improve the health of forests where public forests and grasslands connect to privately owned lands: restoring landscapes, reducing wildfire threats to communities and landowners, protecting water quality and enhancing wildlife habitat.	CO_2	Implemented and Ongoing	Economic	2014	Department of Agriculture—Forest Service	n/a
Landscape Scale Restoration (LSR)*	To promote collaborative, science-based restoration of priority forest landscapes.	Provides grants to further multiple jurisdiction priorities identified in State Forest Action Plans.	CO_2	Implemented and Ongoing	Economic	2009	Department of Agriculture—Forest Service	n/a
Sustainable Forestry and African American Land Retention Program (SFLR)*	To address declining African-American rural land holdings, under-participation in sustainable forest management, and heirs' property issues.	Partners with local, state, and other federal agencies to provide resources to assist landowners in local needs, estate planning, and sustainable forestry across Region 8.	CO_2	Implemented and Ongoing	Economic	2013	Department of Agriculture—Forest Service	n/a
Urban and Community Forestry (UCF) Program*	To ensure a resilient and equitable tree canopy where more than 84 percent of Americans live.	Provides financial and technical assistance to state and local agencies to improve understanding and management of urban tree cover and communities and manage the Challenge Cost Share Grant.	CO_2	Implemented and Ongoing	Economic	2013	Department of Agriculture—Forest Service	n/a

Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Implementation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO2e) in 2030
Wood Innovations Program*	To expand and create markets for wood products and wood energy that support long-term, sustainable management of forest lands.	Provides technical assistance and funding to foster the introduction and expansion of wood uses in the economy, including expanding the use of wood energy and the use of advanced wood products, such as incorporation of byproducts of ecosystem restoration projects in long-lived products.	CO_2	Implemented and Ongoing	Economic	2015	Department of Agriculture—Forest Service	n/a
Forest ecosystem restoration and hazardous fuels reduction programs*	To restore resilient, healthy forest conditions and reduce the risk of wildfire.	Restores the health of the nation's forests, woodlands, and rangelands.	CO_2	Implemented and Ongoing	Economic	2003	Department of Agriculture—Forest Service	n/a
Healthy Forest Reserve Program*	To restore, enhance and protect forestland resources on private lands.	Helps landowners restore, enhance and protect forestland resources on private lands through easements and financial assistance. Through HRFP, landowners promote the recovery of endangered or threatened species, improve plant and animal biodiversity and enhance carbon sequestration.	CO_2	Implemented and Ongoing	Economic	2003	Department of Agriculture	n/a
Agriculture								
Conservation Reserve Program (CRP)*	To remove environmentally sensitive land from agricultural production and plant species that will improve environmental health and quality.	In exchange for a yearly rental payment, farmers enrolled in the program agree to remove environmentally sensitive land from agricultural production and plant species that will improve environmental health and quality. Contracts for land enrolled in CRP are 10-15 years in length. The long-term goal of the program is to re-establish valuable land cover to help improve water quality, prevent soil erosion, and reduce loss of wildlife habitat.	CO_2, N_2O	Implemented and Ongoing	Economic	1985	Department of Agriculture	19,470

Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Implementation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO2e) in 2030
Environmental Quality Incentives Program (EQIP)*	To work with agricultural producers to plan and implement conservation practices on working lands that deliver cleaner air and water, healthier soil and better wildlife habitat.	Provides financial and technical assistance to agricultural producers and non-industrial forest managers to address natural resource concerns and deliver environmental benefits.	CO2, N2O, CH4	Implemented and Ongoing	Economic	1996	Department of Agriculture	10,180
Conservation Stewardship Program (CStP)*	To work with agricultural producers to enhance existing conservation efforts and strengthen production operations on working lands.	Helps agricultural producers maintain and improve their existing conservation systems and adopt additional conservation activities to address priority resource concerns and deliver environmental benefits.	CO2, N2O, CH4	Implemented and Ongoing	Economic	2014	Department of Agriculture	17,740
Agricultural Conservation Easement Program (ACEP)*	To protect croplands and grasslands on working farms and ranches by limiting non-agricultural uses of the land through conservation easements.	Provides financial and technical assistance to help conserve working agricultural lands and wetlands and their related benefits. The Agricultural Land Easements component helps Indian tribes, state and local governments and non-governmental organizations protect working agricultural lands and limit non-agricultural uses of the land. The Wetlands Reserve Easements component helps to restore, protect and enhance enrolled wetlands and adjacent lands. Over 5 million acres enrolled.	CO2, N2O, CH4	Implemented and Ongoing	Economic	1990	Department of Agriculture	n/a

Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Implementation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO2e) in 2030
Regional Conservation Partnership Program (RCPP)*	To promote conservation partnerships that expand USDA's ability to address on farm, watershed, and regional natural resource concerns.	Promotes coordination of USDA conservation activities with partners that offer value-added contributions to expand our collective ability to address on-farm, watershed, and regional natural resource concerns. Seeks to co-invest with partners to implement projects that demonstrate innovative solutions to conservation challenges and provide measurable improvements and outcomes tied to the resource concerns they seek to address.	CO2, N2O, CH4	Implemented and Ongoing	Economic	2014	Department of Agriculture	n/a
Conservation Innovation Grants (CIG)*	To support the development of new tools, approaches, practices, and technologies to further natural resource conservation on private lands.	Supports the development of new tools, approaches, practices, and technologies to further natural resource conservation on private lands. Through creative problem solving and innovation, CIG partners work to address our nation's water quality, air quality, soil health and wildlife habitat challenges, all while improving agricultural operations.	CO2, N2O, CH4	Implemented and Ongoing	Economic	2003	Department of Agriculture	n/a
Conservation Technical Assistance Program (CTA)*	To conserve, maintain and restore the natural resources on working lands.	Provides our nation's farmers, ranchers and forestland owners with the knowledge and tools they need to conserve, maintain and restore the natural resources on their lands and improve the health of their operations for the future	CO2, N2O, CH4	Implemented and Ongoing	Economic	1935	Department of Agriculture	53,950
USDA Climate Hubs*	Communicate research and facilitate learning on land management practices for resilience and reduce emissions from working lands	Support foresters, farmers, ranchers, and rural communities with science-based, region-specific information and technologies that enable climate-informed decision-making and provide assistance to implement those decisions.	CO2, N2O, CH4	Implemented and Ongoing	Information	2014	Department of Agriculture	n/a

Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Implementation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO2e) in 2030
AgSTAR*	Reduce GHG emissions using biogas recovery	Encourages the use of methane recovery technologies at confined animal feeding operations that manage manure as liquids or slurries	CH4	Implemented and Ongoing	Voluntary	1994	Environmental Protection Agency	10,770
Waste								
Standards for New Sources and Emission Guidelines for Existing Sources–Landfills*	Reduce GHG emissions at landfills	Requires owner and operators of new landfills to capture and control emissions from landfills including methane and requires states to develop rules updating requirements for existing and fills to capture and control emissions from landfills including methane	CH4	Implemented and Ongoing	Regulatory	2016	Environmental Protection Agency	283,700
Landfill Methane Outreach Program*	Reduce GHG emissions at landfills	Reduces GHG emissions at landfills by supporting the recovery and use of landfill gas for energy	CH4	Implemented and Ongoing	Voluntary	1994	Environmental Protection Agency	18,270
Community Technical Assistance for Wastewater and Wet Waste*	Enable municipalities to effectively manage wastewater and wet waste	Provide technical assistance from the National Laboratories to municipalities to enable them to effectively deploy fuel generation technologies as a part of waste treatment	CO2, CH4	Implemented and Ongoing	Information	2019	Department of Energy	n/a
Cross-Cutting								

Annex 2. SUMMARY TABLE OF POLICIES AND MEASURES

Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Implementation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO2e) in 2030
Executive Order 14057: Catalyzing Clean Energy Industries and Jobs through Federal Sustainability	Lead by example, catalyze private sector investment, and expand the economy and American industry by transforming how we build, buy, and manage electricity, vehicles, buildings, and other operations to be clean and sustainable.	In December, 2021 the President signed Executive Order 14057 which directs the Federal government to achieve five ambitious goals to reduce emissions across Federal operations: 100 percent carbon pollution-free electricity by 2030, at least half of which will be locally supplied clean energy to meet 24/7 demand; 100 percent zero-emission vehicle acquisitions by 2035, including 100 percent zero-emission light-duty vehicle acquisitions by 2027; Net-zero emissions from Federal procurement no later than 2050, including a Buy Clean policy to promote use of construction materials with lower embodied emissions; A net-zero emissions building portfolio by 2045, including a 50 percent emissions reduction by 2032; and Net-zero emissions from overall federal operations by 2050, including a 65 percent emissions reduction by 2030.	All	Implemented and Ongoing	Regulatory	2021	Office of the Federal Chief Sustainability Officer, multiple agencies	33,000
Federal Buy Clean Initiative	Mainstream the availability and utilization of low-embodied carbon construction materials.	The Federal Government is prioritizing the use of lower-carbon construction materials in Federal procurement and Federally funded projects.	CO2	Adopted	Voluntary	2022	Office of the Federal Chief Sustainability Officer, multiple agencies	n/a
State Energy Program (SEP)*	Fund energy efficiency and renewable energy state programs	Provides funding to state energy offices to reduce market barriers to the cost-effective adoption of renewable energy and energy efficiency technologies.	CO2	Implemented and Ongoing	Economic	1977	Department of Energy	n/a

Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Implementation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO2e) in 2030
Energy Futures Grants	Deploy clean energy technology at the local level	Incubate novel approaches to clean energy technology deployment, prioritizing investments that meet energy needs at the local level, and are inclusive in elevating impoverished and disenfranchised communities, and/or communities that have been marginalized or overburdened.	CO2	Adopted	Economic	2021	Department of Energy	n/a
Energy Efficiency and Conservation Block Grant (EECBG) Program	Reduce fossil fuel emissions, reduce total energy use, and improve energy efficiency in local governments, states, and Indian Tribes	The Bipartisan Infrastructure Law provides new funding for the EECBG Program, which provides Federal grants to states, local governments, and Indian tribes to assist eligible entities in implementing strategies to reduce fossil fuel emissions, to reduce total energy use, and to improve energy efficiency	CO2	Adopted	Economic	2022	Department of Energy	n/a
Local Government Energy Program (LGEP)	Support clean energy programs for local governments that create good paying jobs	Provide competitive awards, on-site capacity, peer exchanges, and technical assistance to support the development and deployment of transformative clean energy programs that create good paying jobs working with qualifying local governments and tribal nations, with a focus on energy communities and disadvantaged or small-to-medium jurisdictions.	CO2	Adopted	Economic	2022	Department of Energy	n/a
Regional Direct Air Capture Hubs	Test, validate, and improve large-scale carbon dioxide removal technologies	Conducts RDD&D on direct air capture, including the development of regional hubs, defined as a network of direct air capture projects, potential off-takers, and supporting infrastructure.	CO2	Adopted	Research	2022	Department of Energy	n/a
Direct Air Capture Technologies Prize Competitions	Support development and deployment of direct air capture technologies.	Prize competition for precommercial carbon dioxide capture from dilute media and commercial applications of direct air capture technologies.	CO2	Adopted	Research	2022	Department of Energy	n/a

Annex 2. SUMMARY TABLE OF POLICIES AND MEASURES

Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Implementation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO2e) in 2030
Carbon Dioxide Removal Program*	Remove carbon dioxide from the atmosphere	The Carbon Dioxide Removal (CDR) Program partners with industry, national laboratories, academia, and environmental justice communities to advance a diverse set of CDR approaches to facilitate gigatonne-scale carbon dioxide removal by mid-century. It emphasizes rigorous analysis of life cycle impacts and has a deep commitment to justice. The program invests in CDR technologies, such as direct air capture and direct ocean capture with durable storage; biomass with carbon removal and storage; and mineralization concepts to remove legacy emissions and address emissions from hard-to-abate sectors.	CO2	Implemented and Ongoing	Research, Economic	2020	Department of Energy	n/a
Section 1703/1705 Loan Guarantee Program*	Mitigate risks related to innovative advanced technology investments	Using these lending authorities, the DOE Loan Programs Office mitigates the financing risks associated with innovative and, in the case of the Section 1705 Program, some commercial energy projects	CO2	Implemented and Ongoing	Economic	2009	Department of Energy	110,800
Clean Energy Demonstration Program on Current and Former Mine Land	Demonstrate technical and economic clean energy projects on former mine land	The Bipartisan Infrastructure Law provides funding for demonstration projects on current or former mine land for solar, microgrids, geothermal, direct air capture, fossil-fueled electricity generation with CCUS, or energy storage.	CO2	Adopted	Economic, Research	2022	Department of Energy	n/a
Carbon Capture Demonstration Projects Program	Improve the efficiency, effectiveness, costs, and performance of carbon capture technologies.	The Bipartisan Infrastructure Law provides funding for demonstration projects in carbon capture technologies on coal and natural gas use, including in manufacturing and industrial facilities.	CO2	Adopted	Economic, Research	2022	Department of Energy	n/a

Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Implementation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO2e) in 2030
Carbon Storage Program*	Address the performance challenges of operating and monitoring commercial scale CO2 storage sites.	Partner with National Laboratories, Universities and Industry to ensure verifiable information to economically and safely assess and monitor long-term storage of CO2 at commercial volumes and timeframes and ensure the viability of geologic carbon storage as an effective CO2 emission reduction solution that can be widely implemented.	CO2	Implemented and Ongoing	Research, Economic	2002	Department of Energy	n/a
National Park Service Programs	Promote climate mitigation and sustainable practices at national parks.	Supports efforts to mitigate the effects of climate change and integrate sustainable practices. The NPS Green Parks Plan and EV Roadmap will provide implementation instructions for EO 14057.	CO2	Implemented and Ongoing	Economic, Voluntary, Educational	2022	Department of Interior / National Park Service	n/a
Mandatory Greenhouse Gas Reporting Program*	Collect annual, accurate and timely GHG emissions data at the facility level	Requires reporting of GHG emissions from 41 U.S. industry groups that, in general, emit 25,000 metric tons or more of CO2e per year. The reporting program covers 85–90% of total U.S. emissions from more than 8,100 facilities	All	Implemented and Ongoing	Regulatory	2009	Environmental Protection Agency	n/a
Center for Corporate Climate Leadership*	Support organization-wide GHG measurement and management	Serves as a resource center for organizations interested in GHG measurement and management, to reduce the business risks and environmental impacts associated with climate change.	All	Implemented and Ongoing	Information	2012	Environmental Protection Agency	n/a
Sustainable Materials Management and Circular Economy*	Encourage sustainable materials management	Provides a systemic approach to reduce the use of materials and their associated environmental impacts over their entire lifecycle	All	Implemented and Ongoing	Voluntary	2009	Environmental Protection Agency	n/a
Rural Energy Savings Program (RESP)*	To stimulate adoption of durable, cost-effective energy efficiency measures.	Provides loan funds to eligible energy providers to relend to its customers for energy efficiency measures and customer owned renewable systems	CO2, N2O	Implemented and Ongoing	Economic	2016	U.S. Department of Agriculture	n/a

Name of Policy or Program	Objective of Policy or Program	Brief Description	Affected Gases	Status	Type of Instrument	Implementation Start Year	Implementing Entities	Estimate of Mitigation Impact (kt CO2e) in 2030
High Energy Cost Grants (HECG)*	To lower energy costs for eligible families and individuals.	Provides grants to eligible organizations to provide energy assistance in rural, low income, high energy cost communities	CO2, N2O	Implemented and Ongoing	Economic	2000	USDA	n/a

U.S. CLIMATE AMBITION REPORT

Annex 3.

METHODOLOGY FOR QUANTIFIED POLICIES AND MEASURES

Annex 3. METHODOLOGY FOR QUANTIFIED POLICIES AND MEASURES

This Annex provides explanations of the methodologies used to develop the estimated mitigation impacts that are presented for several key policies and measures in Annex 2. These quantified estimates for mitigation impacts in 2030 are currently available for a subset of policies and measures implemented by several federal agencies. The agencies vary in their approach to estimating greenhouse gas mitigation impacts, but each methodology description conforms to a template that was provided to the agencies to organize the data in a way that helps provide clarity and transparency to international and domestic communities.

ANNEX 3. CONTENTS

Light-Duty Vehicle GHG Emissions Standards

Sector: Energy Supply

Agency Name: U.S. Environmental Protection Agency

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
   a. In what year did the program start?

A: Beginning in model year 2012, the U.S. Environmental Protection Agency (EPA) has promulgated standards under the Clean Air Act requiring manufacturers producing passenger cars and light trucks for sale in the United States to meet greenhouse gas (GHG) emissions standard, which increase in stringency, generally year over year. EPA established the first round of standards in 2010 for model years (MYs) 2012-2016; in 2012 EPA established standards for MYs 2017-2025. EPA took action in 2020 to reduce the stringency of standards for MYs 2021-2026, and in 2021 EPA again revised the standards for MYs 2023-2026 to increase stringency, essentially restoring the standards to levels similar to those established under the 2012 rule, with a slight increase in stringency for MY2026.

   b. If emissions were calculated using a year other than the start year as the “zero” point for reductions, what was that year?

A: 2016

2. Emissions:
   a. Which gases are measured?

A: The EPA estimates include the extent to which the standards impact carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4) emissions, and hydrofluorocarbon (HFC) emissions from vehicular air conditioners.

   b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: The estimates are based on the GWP values from AR4.

   c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: For the effects of light-duty vehicle standards during the reported calendar years, the EPA used the Optimization Model for reducing Emissions of Greenhouse gases from Automobiles (OMEGA) model and industry supplied GHG compliance data (direct emissions) to estimate the extent to which GHG emission standards reduce CO_2, N_2O and CH_4 emissions, and HFC emissions from vehicular air conditioners.

3. Information quality:
   a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: Federal data sources supporting the EPA light-duty GHG emissions standards can be found in the Regulatory Impact Analysis supporting the MY 2012-2016, 2017-2025 and 2023-2026 rules, available at:

Regulatory Impact Analysis (PDF)(474 pp, 5.75 MB, EPA-420-R-10-009, April 2010)

Regulatory Impact Analysis (PDF)(555 pp, 8.83 MB, EPA-420-R-12-016, August 2012)

Regulatory Impact Analysis: Revised 2023 and Later Model Year Light Duty Vehicle GHG Emissions Standards (PDF) (EPA-420-R-21-028, December 2021).

Federal estimates using the EPA OMEGA models, with inputs supporting the rulemaking, are available at https://www.epa.gov/regulations-emissions-vehicles-and-engines/optimization-model-reducing-emissions-greenhouse-gases

b. What approaches are used to ensure data quality, if any?

A: EPA's OMEGA model underwent peer review and was open to public notice and comment through both the MY 2012-2016 and 2017-2025 light-duty GHG rulemaking processes. (https://www.epa.gov/regulations-emissions-vehicles-and-engines/optimization-model-reducing-emissions-greenhouse-gases)

Additional elements your agency may wish to include if available/applicable

1. Changes since NC7/BR3-4
   a. What changes to the methodology occurred?

A: Revisions were made to the methodology so that the estimates provided are consistent with the 2030 GHG reductions reported in EPA's 2012 rulemaking that set standards for MY 2017-2025 vehicles (see 77 FR 62892, October 15, 2012, Table III-62).

   b. If applicable, do these changes increase or decrease historic values or projections?

A: Increase

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: Most

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: The methodology accounts for the potential that the standards could lead to increased highway travel (i.e., through the "rebound" effect), as well as for potential increases and decreases in energy use and GHG emissions from various "upstream" processes (e.g., petroleum refining, electricity generation). The methodology does not account for the lifecycle effects of the different technologies that manufacturers use to comply with the standards (in part due to the difficulty of determining with certainty what technologies manufacturers will choose to meet the standards because the standards are performance-based rather than design mandates). It should be noted that the estimates are based on assumptions about the mix of passenger cars and light trucks in the vehicle fleet, and actual emissions reductions will vary based on the actual vehicles sold.

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: The methodology used avoids potential double counting of the Department of Transportation corporate average fuel economy (CAFE) standards and fuel efficiency programs, and the EPA GHG emissions standards.

Heavy-Duty Vehicle GHG Emissions Standards

Sector: Transport

Agency Name: U.S. Environmental Protection Agency

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
   a. In what year did the program start?

A: In 2007, the U.S. Congress passed the Energy Independence and Security Act (EISA), directing the Department of Transportation (DOT) to establish fuel efficiency standards for medium- and heavy-duty on-highway vehicles for sale in the United States. In 2011, DOT established fuel efficiency standards, which were voluntary beginning in model year (MY) 2014 and mandatory beginning in MY 2016. EPA has promulgated related GHG emissions standards, which are mandatory beginning in model year 2014.

In 2016, DOT established a second phase (Phase 2) of the fuel efficiency standards for medium and heavy-duty highway vehicles in coordination with EPA-proposed related GHG emissions standards. The rule included efficiency standards for trailers beginning in MY 2018, but those standards were stayed by a D.C. Circuit Court decision on November 12, 2021. The rule also includes efficiency standards for engines and vehicles in MY 2021-27.

   b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

A: 2013 for the medium- and heavy-duty vehicle fuel efficiency and GHG emissions programs.

2. Emissions:
   a. Which gases are measured?

A: The estimates include the extent to which the standards impact CO2, N2O and CH4 emissions, and HFC emissions from vehicular air conditioners.

   b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: AR4 GWP values are used.

   c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: For the effects of medium- and heavy-duty vehicle standards for model years 2014 and beyond during the reported calendar years, the EPA Greenhouse Gas Emissions Model (GEM) and EPA Motor Vehicle Emission Simulator (MOVES) were used to estimate the extent to which combined fuel economy and GHG emission standards reduce CO2, N2O and CH4 emissions, and HFC emissions from vehicular air conditioners.

3. Information quality:
   a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: Federal estimates are used in the EPA MOVES model, as detailed at *http://www.epa.gov/otaq/models/99/moves-cwp.htm*

b. What approaches are used to ensure data quality, if any?

A: The underlying data and algorithms in EPA's MOVES model have undergone formal peer review, following EPA's peer review policies and procedures (https://cfpub.epa.gov/si/index.cfm). In addition, the MOVES Review Work Group under the Mobile Sources Technical Review Subcommittee (MSTRS) provided input throughout model development and reviewed major model updates (https://www.epa.gov/moves/moves-model-review-work-group).

EPA's Greenhouse Gas Emissions Model was subject to peer review and the notice and comment process of the Medium- and Heavy-Duty Greenhouse Gas and Fuel Efficiency Standards rulemaking (https://www.epa.gov/regulations-emissions-vehicles-and-engines/greenhouse-gas-emissions-model-gem-medium-and-heavy-duty).

Additional elements your agency may wish to include if available/applicable

1. Changes since NC7/BR3-4
   a. What changes to the methodology occurred?

A: Emission reduction estimates were revised so that the estimates are consistent with EPA GHG emissions standards for model year 2014 and subsequent model years, and for the DOT Phase 2 fuel efficiency standards.

   b. If applicable, do these changes increase or decrease historic values or projections?

A: Increase

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: All

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: The methodology accounts for the potential that the standards could lead to increased highway travel (i.e., through the "rebound" effect), as well as for potential increases and decreases in energy use and GHG emissions from various "upstream" processes (e.g., petroleum refining, electricity generation). The methodology does not account for the lifecycle effects of the different technologies that manufacturers use to comply with the standards (in part due to the difficulty of determining with certainty what technologies manufacturers will choose to meet the standards because the standards are performance-based rather than design mandates).

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: The methodology used avoids potential double counting of the DOT corporate average fuel economy (CAFE) standards and fuel efficiency programs and the EPA GHG emissions standards. The method avoids double-counting by using EPA's estimates of the future impacts of the medium- and heavy-duty vehicle standards for model years 2014 and beyond, which include estimates of the impact of DOT's standards.

SmartWay

Sector: Transport

Agency Name: U.S. Environmental Protection Agency

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
    a. In what year did the program start?

A:2004

    b. If emissions were calculated using a year other than the start year as the “zero” point for reductions, what was that year?

A: Start year

2. Emissions:
    a. Which gases are measured?

A: CO_2

    b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: N/A

    c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: Partners report fuel use and activity into reporting tools which calculate tons of CO_2 emitted.

3. Information quality:
    a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: Partners self-report using EPA developed reporting tools. The tools can be found at https://www.epa.gov/smartway/resource-pages-current-smartway-partners-and-affiliates

    b. What approaches are used to ensure data quality, if any?

A: SmartWay uses a four-pronged approach to provide data quality:

- *Designing its data collection tools to be easily understandable by the partners filling them out, with a large number of automated quality checks.*
- *Design of its database for optimal Partner Account Manager review and another set of automated quality checks.*
- *Stringent manual review of partner data by its Partner Account Managers (PAMs).*
- *Rigorous data quality review, an audit system, and an adaptive feedback and design loop post PAM review.*

Additional elements your agency may wish to include if available/applicable

1. Changes since NC7/BR3-4
    a. What changes to the methodology occurred?

A: No change.

b. If applicable, do these changes increase or decrease historic values or projections?

A: N/A

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: Most; the impacts do not reflect actions taken by shippers to reduce weight or miles.

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: No.

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: SmartWay provided a technical basis for the heavy duty (HD) GHG regulation for MY 2014 and newer HD trucks. Because the rule applies to new engines and vehicles only, SmartWay will continue to generate CO_2 *reductions from the legacy fleet, carrier operational strategies, and from vehicles and equipment not covered by the rule. The methodology compares SmartWay emissions to a modeled baseline from the MOVES model. As a result, the effects of the GHG regulation are built into the counterfactual.*

Higher Biofuels Infrastructure Incentive Program

Sector: Transport

Agency Name: U.S. Department of Agriculture

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
   a. In what year did the program start?

A: 2020

   b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

N/A

2. Emissions:
   a. Which gases are measured?

A: CO2

   b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: N/A

   c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: This program is still in the process of implementing a strategy for data collection and reporting. As a proxy for a 2030 mitigation impact, reported here is a projected annual estimate for the program once it is fully implemented. Assumes 1 Billion gallons B20; .5 Billion gallons E15. Biofuel and fossil fuel changes are accounted in a gasoline basis.

3. Information quality:
   a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: The HBIIP mitigation impact reported is a projected annual estimate for the program once it is fully implemented. When up and running, this will be self-reported.

   b. What approaches are used to ensure data quality, if any?

A: Environmental assessment required for obligations and loan specialists verify authenticity of estimated energy savings/production. After data entry, outlier checks are also performed.

Additional elements your agency may wish to include if available/applicable

1. Changes since NC7/BR3-4
   a. What changes to the methodology occurred?

A: N/A

   b. If applicable, do these changes increase or decrease historic values or projections?

A: N/A

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: Unknown.

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: No.

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: Unknown.

Vehicle Technology Deployment (Clean Cities Coalition Network)

Sector: Transport

Agency Name: U.S. Department of Energy

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
   a. In what year did the program start?

A: 1993

   b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

A:

2. Emissions:
   a. Which gases are measured?

A: CO2, CH4, N2O

   b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: 30 for CH4, 265 for N2O

   c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: Fuel quantity reported directly by stakeholders and emissions factors from the GREET model are used. Estimates of annual VMT and fuel economy used if fuel quantity not known.

3. Information quality:
   a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: Clean Cities stakeholders report to their coalition directors, who enter it into our online reporting tool.

   b. What approaches are used to ensure data quality, if any?

A: Data checks by coalition directors, regional managers, NREL, and headquarters in that sequence.

Additional elements your agency may wish to include if available/applicable

1. Changes since NC7/BR3-4
   a. What changes to the methodology occurred?

A: none

   b. If applicable, do these changes increase or decrease historic values or projections?

A: NA

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: All

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: A small portion is derived from estimates of the impact that Clean Cities outreach events have on private drivers.

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: We adjust for overlap with the Federal Fleet and State and Fuel Provider programs.

Advanced Technology Vehicle Manufacturing (ATVM) Program

Sector: Transport

Agency Name: U.S. Department of Energy

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
   a. In what year did the program start?

A: The Advanced Technology Vehicle Manufacturing (ATVM) Program was authorized under section 136 of the Energy Independence and Security Act of 2007. The ATVM Program was implemented under an interim rule issued on November 12, 2008.

   b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

A: The ATVM Program, per the legislation compares against a 2005 baseline.

2. Emissions:
   a. Which gases are measured?

A: CO2

   b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: N/A

   c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: The impacts are measured using emissions factors based on gasoline displaced by the improvement in fuel economy of vehicles produced as compared to the 2005 fuel economy baseline for the vehicle type. Calculation Details: Annual Avoided CO2 is calculated from the projects actual (2011, 2013) or projected (2015, 2020) annual petroleum displaced in gallons, multiplied by the EIA Fuel Emission factor of 19.54 lbs CO2/gallon for gasoline (Source: U.S. Environmental Protection Agency, http://www.eia.doe.gov/oiaf/1605/excel/Fuel%20Emission%20Factors.xls). Using the conversion factor where a metric ton (tonne) is equal to 2,204 lbs, the calculation is:

$$Annual\ CO_2\ Emissions\ Avoided = Project's\ Annual\ Petroleum\ Savings * \left[\frac{(19.54 lbs\ CO_2/gallon\ of\ gasoline)}{(2{,}204 lbs\ CO_2/tonne)}\right]$$

Annual Gasoline Displaced

Use the Annual average vehicle miles driven of 12,000 miles. Use the difference of a 2005 vehicle fuel economy baseline (legislation required this baseline) and the model year fuel economy of the vehicles that have been or will be produced from the ATVM program in miles per gallon. Use the actual or planned annual production of those vehicles. The calculation for conventional vehicles is:

$$Annual\ Petroleum\ Displaced = Production\ Volume * \left[\left(\frac{12{,}000}{Baseline\ Fuel\ Economy(mpg)}\right) - \left(\frac{12{,}000}{ATV\ Fuel\ Economy(mpg)}\right)\right]$$

The calculation for EV's and Alternative Fuel vehicles is:

$$Annual\ Petroleum\ Displaced = Production\ Volume * \left(\frac{12{,}000}{Baseline\ Fuel\ Economy}\right)$$

3. Information quality:
   a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: Industry Reports and Federal emissions factors are used.

   b. What approaches are used to ensure data quality, if any?

A: Site visits and periodic conference calls between the borrower and LPO to verify and validate facilities are operating in accordance with the Projects' reporting.

Additional elements your agency may wish to include if available/applicable

1. Changes since NC7/BR3-4
   a. What changes to the methodology occurred?

A: ATVM scope was expanded to include medium and heavy duty vehicles, aircrafts, maritime vessels, trains, and hyperloops. LPO is developing guidelines to implement these new transportation methods. Therefore, the calculation methodology is primarily based on light duty projections.

   b. If applicable, do these changes increase or decrease historic values or projections?

A: It's not yet feasible to determine the impact the expanded scope will have on projections.

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: The measures include incremental mitigation projections from added loan authority (~$40B) to existing program.

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: No

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: Yes, any PAM listed in CAR Chapter 4, Table 4-2 that reduces GHG emissions from light-duty vehicles could potentially double count emissions reductions from this PAM. No, this methodology does not adjust for potential double counting.

Onshore Renewable Energy Development Program

Sector: Energy Supply

Agency Name: U.S. Department of Interior

Key parameters for policy and measures greenhouse gas (GHG) benefits methodology documentation for BR5

1. Timeframe:
   a. In what year did the program start?

A: Approximately 1980

   b. If emissions were calculated using a year other than the start year as the “zero” point for reductions, what was that year?

A: Wind/Geothermal avoided emissions were calculated beginning in 1995; Solar in 2011.

2. Emissions:
   a. Which gases are measured?

A: The Bureau of Land Management (BLM) estimated avoided emissions from purchased electrical consumption for CO2 only.

   b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: N/A

   c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: Avoided emissions are calculated by multiplying the energy output from the renewable energy systems by an emission factor for CO2 representative of electricity produced in the United States. The source of the emission factor is the 2012 Federal Energy Management Program Green House Gas Report Template, Tab 1.7, CO2 emission factor for Purchased Electricity, unspecified Subregion, Cell J9.

3. Information quality:
   a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: The energy outputs for the renewable energy systems were based on industry design capacity as reported by the individual project developers and adjusted for actual energy output using a standard capacity factor for each technology. Calculations of mitigated impacts were verified internally by the Bureau of Land Management (BLM).

   b. What approaches are used to ensure data quality, if any?

A: The industry design capacity is specified in the developer’s land use authorization and verified by BLM inspectors, once the systems are installed.

Additional elements your agency may wish to include if available/applicable

1. Changes since NC7/BR3-4
   a. What changes to the methodology occurred?

A: NA

b. If applicable, do these changes increase or decrease historic values or projections?

A: NA

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: These estimates of avoided GHG emissions reflect all of the renewable energy projects authorized by BLM on public lands and connected actions, projects that required BLM approval of the use of public lands as part of the completion of locating facilities on non-federal property.

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: No

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: Some of the renewable projects developed on public lands have received DOE loan guarantees (Section 1703/1705 Loan Guarantee Program). BLM estimates do not adjust for double counting if any. All projects qualify for the Tax Provision policy, but this policy does not quantitatively account for GHG impacts.

Green Power Partnership

Sector: Energy Supply

Agency Name: U.S. Environmental Protection Agency

Key parameters for policy and measures GHG benefits methodology documentation for BR5

4. Timeframe:
    a. In what year did the program start?

A: 2001

   b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

A: Emissions were calculated using the start year

5. Emissions:
    a. Which gases are measured?

A: CO_2

   b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: N/A

   c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: EPA calculates indirect greenhouse gas impacts by applying a national, marginal carbon emissions factor to total annual green power purchases (kWh) reported by program partners. Partners' annual purchases reflect eligible green power generated during the reporting period. Energy savings goals for 2030 were estimated by applying adjusted growth rates to program savings based on an informed examination of the opportunity for reductions from green power.

6. Information quality:
    a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: The Green Power Partnership (GPP) relies on self-reporting by GPP partners of green power use and uses EPA's most recent version of the Avoided Emissions and Generation Tool (AVERT) for emission factors.

   b. What approaches are used to ensure data quality, if any?

A: EPA receives annual reports from GPP partners, verifying annual green power purchases and/or onsite generation. Internally, EPA and its contractor, ERG, verify data entry into its customer relationship management database, which includes dashboards to review data quality.

Additional elements your agency may wish to include if available/applicable

5. Changes since NC7/BR3-4
    a. What changes to the methodology occurred?

A: None

b. If applicable, do these changes increase or decrease historic values or projections?

A: N/A

6. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: All

7. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: No.

8. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: GPP's actions to encourage voluntary purchases of green power are unique compared to other federal policies which may be used to fund or otherwise encourage the construction of new green power projects. For example, the Onshore Renewable Energy Development Program projects are often financed by long-term offtake agreements from the various state-based compliance markets in the U.S. rather than the voluntary markets.

Natural Gas STAR Program/Methane Challenge

Sector: Energy Supply

Agency Name: U.S. Environmental Protection Agency

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
   a. In what year did the program start?

A: The Natural Gas STAR Program is comprised of two partnerships: the Natural Gas STAR Partnership ("NGS Partnership") began in 1993. The Methane Challenge Partnership ("MC Partnership") began in 2016.

   b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

A: N/A

2. Emissions:
   a. Which gases are measured?

A: CH_4

   b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: IPCC 4th Fourth Assessment Report (AR4)

   c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: The Natural Gas STAR Program, for both the NGS and MC Partnerships, calculates its annual emission reductions achieved based on 100% of the emissions reductions reported to the Program by program partners, who submit methane emission reduction data to EPA annually. These data are used to determine Program emission reduction totals and measure the overall effectiveness of the Natural Gas STAR Program.

For the NGS Partnership, Partner companies have the option of using default calculation methodologies or company-specific methodologies, which must be documented on their annual reports.

The reporting protocol for the MC Partnership is more rigorous and detailed. Partner companies must use the calculation methodologies provided in the Program's "Methane Challenge Technical Documents"; these methodologies are consistent with those used for reporting to US EPA's Greenhouse Gas Reporting Program (GHGRP). If a GHGRP method is not available for an emission source, Partners use emission factors developed for the Inventory of U.S. Greenhouse Gas Emissions and Sinks.

For 2030 impacts, EPA used a marginal abatement cost (MAC) curve analysis to estimate program impacts (United States Environmental Protection Agency. 2019. Non-CO_2 Emission Projections and Mitigation Summary Report:2015-2050. EPA-430-R-19-010). Because the Natural Gas STAR Partnership and Reporting ended in 2022, the 2030 projection only includes data associated with the Methane Challenge Partnership.

3. Information quality:
   a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: Program Partner Company submitted annual reports.

   b. What approaches are used to ensure data quality, if any?

A: For the NGS Partnership, each Annual Report is reviewed using several basic checks to assess whether reductions data appear reasonable (given previously reported data trends) and non-regulatory in nature.

For the MC Partnership, each Annual Report is reviewed using dozens of detailed data checks to assess whether emission and reduction values were estimated correctly and that actions are non-regulatory in nature.

For both Partnerships, any inconsistencies are resolved through direct correspondence with the appropriate partner company. As appropriate, these data are omitted or adjusted prior to their inclusion in the Natural Gas STAR Program annual totals.

<u>Additional elements your agency may wish to include if available/applicable</u>

1. Changes since NC7/BR3-4
   a. What changes to the methodology occurred?

A: Because the Natural Gas STAR Partnership and Reporting ended in 2022, the 2030 projection only includes data associated with the Methane Challenge Partnership.

   b. If applicable, do these changes increase or decrease historic values or projections?

A: No changes

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: The impacts reflect all of the activities reported to the Natural Gas STAR Program by partner companies.

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: No.

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: Natural Gas STAR is the only federal voluntary program that tracks GHG emission reductions from the oil and gas industry. There are Federal regulations under the Clean Air Act (New Source Performance Standards for the Oil and Natural Gas Sector) that control volatile organic compound emissions from various sources, with methane emission reductions as a co-benefit. To avoid potential double counting, EPA's methods for calculating annual achievements and for projecting future impacts of these partnership programs account for the impacts due to regulatory efforts.

Coalbed Methane Outreach Program

Sector: Energy Supply

Agency Name: U.S. Environmental Protection Agency

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
    a. In what year did the program start?

A: 1994

    b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

A: N/A

2. Emissions:
    a. Which gases are measured?

A: CH_4

    b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: IPCC 4th Fourth Assessment Report (AR4)

    c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: The Coalbed Methane Outreach Program (CMOP) annually measures accomplishments using a metric of emissions reductions achieved from coal mine methane recovery projects in the U.S. The Program uses a tiered system applied to total emission reductions from active underground and abandoned mines. Weightings of 90%, 70%, and 40% are applied to each project's reductions, depending on CMOP's level of involvement. For 2030 impacts, EPA used a marginal abatement cost (MAC) curve analysis to estimate program impacts (United States Environmental Protection Agency. 2019. Non-CO_2 Emission Projections and Mitigation Summary Report:2015-2050. EPA-430-R-19-010).

3. Information quality:
    a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: Federal data from the Energy Information Administration and the Department of Labor Mine Safety and Health Administration (MSHA); voluntary GHG/carbon registries; industry data through public annual reports; and direct reports from some coal companies; and federal estimates using technical expert judgment.

    b. What approaches are used to ensure data quality, if any?

A: Data are reviewed, analyzed, and compared with previous year(s) and across various sources.

Additional elements your agency may wish to include if available/applicable

1. Changes since NC7/BR3-4
    a. What changes to the methodology occurred?

A: No changes

b. If applicable, do these changes increase or decrease historic values or projections?

A: No changes

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: The measured GHG impacts reflect all of the actions of the program.

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: No.

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: The CMOP is the only federal voluntary program that tracks GHG emission reductions from the coal mining industry. There are no federal regulations requiring emissions reductions and no opportunity for double counting.

Federal Air Standards for Oil and Natural Gas Sector

Sector: Energy Supply

Agency Name: U.S. Environmental Protection Agency

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
   a. In what year did the program start?

A: On April 17, 2012, the EPA issued New Source Performance Standards (NSPS) under the Clean Air Act to reduce emissions of volatile organic compounds (VOC) from the oil and natural gas industry. On May 12, 2016, the EPA issued an update to the NSPS to further reduce emissions of VOC and methane.

   b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

A: 2016

2. Emissions:
   a. Which gases are measured?

A: Methane. The NSPS reduces emissions of methane, VOC, and hazardous air pollutants (HAP).

   b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: IPCC 4th Assessment Report (AR4) GWP values were used.

   c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: Projected reductions due to the NSPS were estimated by applying reduction percentages to projections of applicable sources for the 2016 NSPS. Reduction percentages are described within the background technical support document for the rule and the projections of sources are described in the regulatory impact analysis (RIA). These sources include oil well completions and workovers with hydraulic fracturing, fugitive emissions at new and modified well sites and compressor stations, new and modified pneumatic pumps at well sites, new and modified pneumatic controllers at transmission and storage compressor stations, and new and modified reciprocating and centrifugal compressors at transmission and storage compressor stations.

3. Information quality:
   a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: Emissions reductions appear in the 2016 NSPS RIA. In the RIA, potential emissions for each source were estimated using information from the 2014–2016 U.S. GHG Inventories, Drilling Info data accessed in 2014, and projections of new well drilling from the Energy Information Administration's 2015 Annual Energy Outlook.

   b. What approaches are used to ensure data quality, if any?

A: EPA relied on the above published reference documents that were subject to rigorous public review.

Additional elements your agency may wish to include if available/applicable

1. Changes since NC7/BR3-4
    a. What changes to the methodology occurred?

A: No emissions reductions were provided in the NC7/BR3-4. Estimates now reflect anticipated emissions reductions resulting from the 2016 NSPS, using results for 2025 as a proxy for 2030 estimates.

    b. If applicable, do these changes increase or decrease historic values or projections?

A: N/A, see previous response.

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: Some. The 2012 NSPS provisions, which were estimated at the time the rule was published to produce approximately 18 million tons of CO_2-eq emissions reductions in 2015, are not reflected in the estimates.

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: The estimates presented attribute reductions subject to the requirements of the NSPS to the rule, although some of these actions may have taken place voluntarily in the absence of the requirement as oil and natural gas producers improved the environmental and economic efficiency of their activities.

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: Yes, the Natural Gas STAR Program. It is unclear to what extent the methodology from the RIA accounts for potential for double counting.

Electric Loan Program

Sector: Energy Supply

Agency Name: U.S. Department of Agriculture

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
   a. In what year did the program start?

A: 1936

   b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

N/A

2. Emissions:
   a. Which gases are measured?

A: CO2, N2O

   b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: 310 CO_2e multiplier for N_2O

   c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: As a proxy for a 2030 mitigation impact, the figure provided is estimated indirectly through National Rural Electric Cooperative Association (NRECA) reports that estimate US electric cooperative emission reductions for 2016-2019 averaged over 3 years, in order to produce an annual estimate. Sum of 5.67M short tons/year reduction of CO2 and 11.67K short tons/year reduction of N_2O with a 310 CO_2e multiplier. Converted to metric tons. For USDA Rural Utilities Service (RUS) creditable share of the total: RUS Borrowers are 65% of the sector and RUS provides 50% of the long term debt. This results in: 2,745 kt CO_2e 1,675 kt CO_2e from CO_2 annual reduction + 1,070 kt CO_2e from N_2O annual reduction).

3. Information quality:
   a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: NRECA (which uses EPA and EIA data) reports.
2019 Report - https://www.pec.coop/wp-content/uploads/2021/04/NRECA-Co-op-Facts-and-Figures.pdf

2016 Report - https://noblesce.coop/sites/nobles/files/NCS-2815_Co-op-Facts-and-Figures-Packet_Individual-Letter-Sheets.pdf

   b. What approaches are used to ensure data quality, if any?

A: N/A

Additional elements your agency may wish to include if available/applicable

1. Changes since NC7/BR3-4
   a. What changes to the methodology occurred?

A: N/A

b. If applicable, do these changes increase or decrease historic values or projections?

A: N/A

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: All, although precision from estimation procedure is lacking.

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: No.

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: Unknown.

Rural Energy for America Program (REAP)

Sector: Energy Supply

Agency Name: U.S. Department of Agriculture

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
   a. In what year did the program start?

A: 2008

   b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

N/A

2. Emissions:
   a. Which gases are measured?

A: CO2, CH4

   b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: N/A

   c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: Conversion from energy generated/saved for a project to metric tons of CO2 equivalent reduced based on the state's electric grid emission rate for the time that the project was implemented. All projects (biomass, wind, solar, energy efficiency etc) are converted to electric energy (kilowatt hours) and then multiplied by the state's eGRID factor (see below) to measure reduction of CO2 equivalent in metric tons.
For this program, an estimate of mitigation impact in 2021 is being used as a rough proxy for the 2030 impact.

3. Information quality:
   a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: Energy values come from self-reports of USDA loan specialists that service the obligation. The emission rates for a state come from EPA's Emissions & Generation Resource Integrated Database (eGRID): https://www.epa.gov/egrid/download-data

   b. What approaches are used to ensure data quality, if any?

A: Environmental assessment required for obligations and loan specialists verify authenticity of estimated energy savings/production. After data entry, outlier checks are also performed.

Additional elements your agency may wish to include if available/applicable

1. Changes since NC7/BR3-4
   a. What changes to the methodology occurred?

A: Previous estimates used national 2010 eGRID value for conversion of energy into CO2e, current estimates are based on state level eGRID values for the time the project was implemented.

   b. If applicable, do these changes increase or decrease historic values or projections?

A: This reduced the historical value for two reasons 1) the CO2e emission rate has trended downward since 2010 (1,2358 lb/MWh in 2010 versus 822 lb/MWh in 2020 for US nationally) and 2) location of projects has typically been in areas with lower national average CO2e emission rates and we now incorporate location into these estimates.

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: Most of the GHG impacts are being measured, especially as it relates to CO_2e. Some projects, such as anaerobic digestors, also produce benefits of reducing methane emissions that are not yet measured.

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: No.

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: Potential issues for certain types of energies to be double counting GHG reduction based on inputs used for a project but there should not be double counting issues related to outputs.

Biorefinery, Renewable Chemical, and Biobased Product Manufacturing Assistance Program

Sector: Energy Supply

Agency Name: U.S. Department of Agriculture

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
    a. In what year did the program start?

A: 2010

    b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

N/A

2. Emissions:
    a. Which gases are measured?

A: CO2, CH4

    b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: N/A

    c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: Program still in process of implementing strategy for data collection and reporting. As a proxy for a 2030 mitigation impact, the figure provided is a projected annual estimate of two recently funded Renewable Diesel projects and the one Anaerobic Digester Project.

3. Information quality:
    a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: When up and running, this data will be self-reported.

    b. What approaches are used to ensure data quality, if any?

A: Environmental assessment required for obligations and loan specialists verify authenticity of estimated energy savings/production.

Additional elements your agency may wish to include if available/applicable

1. Changes since NC7/BR3-4
    a. What changes to the methodology occurred?

A: N/A

    b. If applicable, do these changes increase or decrease historic values or projections?

A: N/A

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: Unknown

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: No.

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: Unknown

Advanced Biofuel Payment Program

Sector: Energy Supply

Agency Name: U.S. Department of Agriculture

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
   a. In what year did the program start?

A: 2009

   b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

N/A

2. Emissions:
   a. Which gases are measured?

A: CO2, CH4

   b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: N/A

   c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: Program still in process of implementing strategy for data collection and reporting. As a proxy for a 2030 mitigation impact, the figure provided here uses the estimated program impact in billions of gallons of advanced biofuels for biofuels between 2014-2019, averaged out to express an annual estimate of a representative year between 2014-2019. Assumes 1 Billion gallons GPY Advanced Biofuels- Gasoline 116,090 Btu/gallon, ethanol 76,330 Btu/gallon. Biofuel and fossil fuel changes accounted in a gasoline basis.

3. Information quality:
   a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: When up and running, this data will be self-reported.

   b. What approaches are used to ensure data quality, if any?

A: Environmental assessment required for obligations and loan specialists verify authenticity of estimated energy savings/production.

Additional elements your agency may wish to include if available/applicable

1. Changes since NC7/BR3-4
   a. What changes to the methodology occurred?

A: N/A

   b. If applicable, do these changes increase or decrease historic values or projections?

A: N/A

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: Unknown

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: No.

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: Unknown

Better Buildings Initiative

Sector: Energy: Residential and Commercial End-Use

Agency Name: U.S. Department of Energy

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
    a. In what year did the program start?

A: 2011

    b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

A: The base year for emissions savings is based on the year participating partners chose as their baseline when they joined the program (2011 is used if the partner baseline was before 2011)

2. Emissions:
    a. Which gases are measured?

A: All

    b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: Partners that report non-CO2 gases calculate their own greenhouse gas inventories and report to DOE. They are encouraged to use the most recent IPCC Assessment Report for GWP values.

    c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: Better Buildings Challenge program partners share portfolio-wide actual energy consumption by year. Better Climate Challenge program partners share portfolio-wide actual greenhouse gas emissions and energy consumption by year.

3. Information quality:
    a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: Self-reporting by partners

    b. What approaches are used to ensure data quality, if any?

A: Program staff review partner data submissions for data quality, including checking for outliers or unusual results in facility-level energy intensity data, or confirming reasonableness of portfolio-level greenhouse gas inventory data. In some cases, program staff provide technical assistance with energy savings and greenhouse gas calculations, allowing for more direct assurance of data quality.

Additional elements your agency may wish to include if available/applicable

1. Changes since NC7/BR3-4
    a. What changes to the methodology occurred?

A: Adjusted estimates to account for increase in program growth due to the focus on greenhouse gas emissions via the Better Climate Challenge.

b. If applicable, do these changes increase or decrease historic values or projections?

A: These changes increase projected emissions reductions.

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: Just some. The program tracks reduction in energy consumption for program partners, but the program offers tools and technical assistance to amplify best practices in energy management, which are available to the broader commercial building market

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: No.

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: The program's methodology captures all energy savings achieved by program partners. It is possible that these program partners are influenced by other federal policies and measures. The methodology excludes industrial challenge partners to avoid double-counting with the Better Plants estimate, but does not adjust for potential double counting with other buildings sector policies and measures. Industrial partners are included in the Better Plants entry.

Appliance, Equipment, and Lighting Energy Conservation Standards

Sector: Energy: Residential and Commercial End-Use

Agency Name: U.S. Department of Energy

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
    a. In what year did the program start?

A: The Energy Policy and Conservation Act (EPCA) was enacted in 1975, and established a federal program consisting of test procedures, labeling, and energy targets for consumer products. EPCA was amended in 1979 and directed the Department of Energy (DOE) to establish energy conservation standards for consumer products. The first energy conservation standards were enacted in 1987 with the National Appliance Energy Conservation Act.

    b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

A: Emissions reductions are calculated from the starting year of each individual energy conservation standard.

2. Emissions:
    a. Which gases are measured?

A: The GHG gases included in the analyses are CO2, CH4, and N20.

    b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: DOE's analyses do not evaluate the GWP of emissions. The analyses estimate emissions reductions in physical units for each GHG gas. The benefits of emissions reductions are also monetized using a social cost of GHG appropriate to each GHG gas.

    c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: Emissions reductions are estimated from modeling. Energy savings (in quads) resulting from an energy conservation standard are combined with emission factors appropriate to the sector and end use of the appliance or equipment, in order to estimate emissions reductions. The low end of the range represents estimated avoided emissions from rules already promulgated, while the high end of the range includes estimated reductions from additional rules promulgated through 2025.

3. Information quality:
    a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: Emissions modeling relies heavily on the Energy Information Administration's Annual Energy Outlook (AEO) publication and data tables/files to derive the appropriate emissions factors. AEO projections are based on the National Energy Modeling System (NEMS). The social costs are the recommended values from the Interagency Working Group (IWG) on Social Cost of Greenhouse Gases.

    b. What approaches are used to ensure data quality, if any?

A: No specific additional steps are implemented. AEO and NEMS are ubiquitous tools used in the energy systems modeling community. The social costs are the recommended values from the IWG.

Additional elements your agency may wish to include if available/applicable

1. Changes since NC7/BR3-4
   a. What changes to the methodology occurred?

A: None

   b. If applicable, do these changes increase or decrease historic values or projections?

A: N/A

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: All policy actions. The low end of the range represents estimated avoided emissions from rules already promulgated, while the high end of the range includes estimated reductions from additional rules promulgated through 2025.

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: No. The methodology accounts for all domestic energy/emissions savings from the usage of a given appliance or equipment, but there may be spill-over effects in other international markets or jurisdictions. These are not analyzed.

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: The program's methodology accounts for Energy Star with the efficiency distributions to avoid double counting.

Home Performance with ENERGY STAR

Sector: Energy: Residential and Commercial End-Use

Agency Name: U.S. Department of Energy

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
    a. In what year did the program start?

A: The program started in 2002.

b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

A: Emissions were projected for the year 2030 and include savings realized from projects completed prior to that year.

2. Emissions:
    a. Which gases are measured

A: CO_2

b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: The vast majority of greenhouse gas mitigation for Home Performance with ENERGY STAR occurs through CO2 mitigation. Home Performance with ENERGY STAR does not track non-CO2 GHG mitigation, such as HFCs from decommissioned AC systems or appliances.

c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: Estimated impacts are based on reaching program targets in terms of the number of homes meeting the performance standard.

3. Information quality:
    a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: Data sources include estimates reported by participating utility program sponsors and Federal estimates using national datasets of baseline home energy consumption, such as EIA's Residential Energy Consumption Survey (RECS). Based on the number of homes meeting the performance standard, energy savings are converted into GHG impacts using EPA's marginal carbon emissions factor (national average) for the electricity sector, and EIA emissions factor for natural gas.

b. What approaches are used to ensure data quality, if any?

A: Figures were carefully reviewed by DOE staff and contractor support team managing the HPwES program. Estimates were made using federally produced datasets. Reported projects and measures are reviewed by DOE staff.

Additional elements your agency may wish to include if available/applicable

1. Changes since NC7/BR3-4
    a. What changes to the methodology occurred?

A: The HPwES program adopted a simplified model based on carbon emissions factors for the electricity sector developed by EPA, EIA carbon emissions factors for natural gas, and the number of completed projects.

b. If applicable, do these changes increase or decrease historic values or projections?

A: These changes resulted in no material changes to historic values or projections of avoided emissions in 2030.

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: All.

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: No. Residential emissions reductions from utility programs that do not participate in HPwES (or no longer participate but continue to offer other programs and services, such as heating and cooling rebates) are not included in the HPwES estimates. The program also does not track savings from households that may benefit from HPwES services (i.e., an energy assessment) and then choose to make improvements independent of the HPwES program, such as self-installed measures.

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: Weatherization Assistance Program projects are tracked separately and there may be limited double-counting with HPwES, but the overlap is minimal. Some growth due to the Inflation Reduction Act may end up being attributable to HPwES, if states (or their utilities) become Sponsors using IRA funding.

Building Energy Codes Program

Sector: Energy: Residential and Commercial End-Use

Agency Name: U.S. Department of Energy

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
   a. In what year did the program start?

A: DOE's Building Energy Codes Program was established in 1991.

   b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

A: 2010. Previous benefits from state and local codes improvements through construction prior to 2010 not included.

2. Emissions:
   a. Which gases are measured?

A: The GHG gases included in the analyses are CO_2, CH_4, and N_20.

   b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: Not Applicable. DOE's analyses do not evaluate the GWP of non-CO_2 emissions. The analyses estimate emissions reductions in physical units for each GHG gas.

   c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: Estimated from computer modeling of building codes, U.S. climates, industry data, and emissions factors. For detailed methodology, please refer to:
Tyler, M. et al., "Impacts of Model Building Energy Codes—Interim Update", (PNNL, 2021) https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-31437.pdf.

3. Information quality:
   a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: Site Energy savings estimates developed by DOE by code version and by state for both residential and commercial building codes, using computer modeling (EnergyPlus) and standard set of building models and U.S. climates.

Building new construction estimates developed using industry data (FW Dodge).

Adoption rate assumptions at state level based on historical data on state adoption speed.

Realization factors (e.g., compliance) used in going from EnergyPlus modeled savings estimates to predicted savings in actual constructed buildings.

Emission factors are marginal emission factors developed originally for DOE's Appliance and Equipment Standards program (AESP) based on analysis of DOE/EIA 2022 Annual Energy Outlook publication and data *tables/files to derive marginal emission factors for electrical grid energy reductions year by year through 2050. Emission factors for site fossil fuel combustion from EPA.*

Note. Savings estimates do not include estimates from states whose energy codes are significantly different than the model codes (90.1, International Energy Conservation Code) that DOE's efforts primarily address, nor do the estimates account for all alterations and additions to existing buildings that may also be impacted by building codes.

b. What approaches are used to ensure data quality, if any?

A: No specific external evaluation. Analysis estimates reflect engineering judgment for modeling of code-impacts, use of standardized suite of building model and climates, and internally developed weighting factors. Calculations reviewed internally in depth. Emission factor estimates are national based on EIA's AEO and NEMS tool and are identical to those used in DOE's AESP.

Additional elements your agency may wish to include if available/applicable

1. Changes since NC7/BR3-4
   a. What changes to the methodology occurred?

A: Only slight updates to the calculation methodology including updates to the development of marginal electric grid emission factors consistent with the DOE/EIA 2022 Annual Energy Outlook. Reporting of N_2O and CH4 are addition from previous year submittal.

   b. If applicable, do these changes increase or decrease historic values or projections?

*A: CO_2 estimate is very close to previously submitted values for saving from energy codes (*NC7). *Other GHG emissions are now available.*

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: Most. The savings estimates are a based on modeled historical improvement in building driven energy consumption and historical adoption rates. Higher adoption and compliance rates could come from more aggressive/program policy efforts.

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: Generally, no. The estimate is for code adoption in states which adopt codes similar to the ASHRAE 90.1 or IECC codes. The analysis looks at code adoption as a whole in these states, although both code adoption and code development are significantly due to the efforts of a variety of stakeholder and state government policies. Further the analysis focuses on energy consumption related (operational) emission and does not take into account lifecycle/embodied carbon increases or reductions in societal emission that might occur due to updated building codes.

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: Yes. The estimate is developed to specifically avoid double counting the impact of higher equipment standards (AESP program related) emission benefits.

Manufactured Homes Regulatory Program

Sector: Energy: Residential and Commercial End-Use

Agency Name: U.S. Department of Energy

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
    a. In what year did the program start?

A: The Energy Independence and Security Act of 2007 (EISA, P.L. 110-140) directs the U.S. Department of Energy (DOE) to establish energy conservation standards for manufactured housing.

    b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

A: Emissions reductions are calculated from the starting year of each individual energy conservation standard.

2. Emissions:
    a. Which gases are measured?

A: The GHG gases included in the analyses are CO2, CH4, and N20.

    b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: DOE's analyses do not evaluate the GWP of emissions. The analyses estimate emissions reductions in physical units for each GHG gas. The benefits of emissions reductions are also monetized using a social cost of GHG appropriate to each GHG gas.

    c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: Emissions reductions are estimated from modeling. Energy savings (in quads) resulting from an energy conservation standard are combined with emission factors appropriate to the sector and end use of the appliance or equipment, in order to estimate emissions reductions.

3. Information quality:
    a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: Emissions modeling relies heavily on the Energy Information Administration's Annual Energy Outlook (AEO) publication and data tables/files to derive the appropriate emissions factors. AEO projections are based on the National Energy Modeling System (NEMS). The social costs are the recommended values from the Interagency Working Group (IWG) on Social Cost of Greenhouse Gases.

    b. What approaches are used to ensure data quality, if any?

A: No specific additional steps are implemented. AEO and NEMS are ubiquitous tools used in the energy systems modeling community. The social costs are the recommended values from the IWG.

Additional elements your agency may wish to include if available/applicable

1. Changes since NC7/BR3-4
    a. What changes to the methodology occurred?

A: None

b. If applicable, do these changes increase or decrease historic values or projections?

A: N/A

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: All policy actions.

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: No. The methodology accounts for all domestic energy/emissions savings from the usage of a given appliance or equipment, but there may be spill-over effects in other international markets or jurisdictions. These are not analyzed.

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: The program's methodology accounts for Energy Star with the efficiency distributions to avoid double counting.

Federal Buildings Rulemakings (Codes and Clean Energy)

Sector: Energy: Residential and Commercial End-Use

Agency Name: U.S. Department of Energy

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
    a. In what year did the program start?

A: DOE's Federal Building Energy rulemakings began in 1992.

    b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

A: 2010. Previous benefits from state and local codes improvements through construction prior to 2010 not included.

2. Emissions:
    a. Which gases are measured?

A: The GHG gases included in the analyses are CO_2, CH_4, and N_20.

    b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: Not Applicable. DOE's analyses do not evaluate the GWP of non-CO_2 emissions. The analyses estimate emissions reductions in physical units for each GHG gas.

    c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: Estimated from computer modeling of building codes, U.S. climates, industry data, and emissions factors. For detailed methodology, please refer to: Tyler, M. et al., "Impacts of Model Building Energy Codes—Interim Update", (PNNL, 2021) https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-31437.pdf.

3. Information quality:
    a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: Site Energy savings estimates developed by DOE by code version and by state for both residential and commercial building codes, using computer modeling (EnergyPlus) and standard set of building models and U.S. climates.

Building new construction estimates developed using industry data (FW Dodge).

Adoption rate assumptions at state level based on historical data on state adoption speed.

Realization factors (e.g., compliance) used in going from EnergyPlus modeled savings estimates to predicted savings in actual constructed buildings.

Emission factors are marginal emission factors developed originally for DOE's Appliance and Equipment Standards program (AESP) based on analysis of DOE/EIA 2022 Annual Energy Outlook publication and data tables/files to derive marginal emission factors for electrical grid energy reductions year by year through 2050. Emission factors for site fossil fuel combustion from EPA.

Note. Savings estimates do not include estimates from states whose energy codes are significantly different than the model codes (90.1, International Energy Conservation Code) that DOE's efforts primarily address, nor do the estimates account for all alterations and additions to existing buildings that may also be impacted by building codes.

b. What approaches are used to ensure data quality, if any?

A: No specific external evaluation. Analysis estimates reflect engineering judgment for modeling of code-impacts, use of standardized suite of building model and climates, and internally developed weighting factors. Calculations reviewed internally in depth. Emission factor estimates are national based on EIA's AEO and NEMS tool and are identical to those used in DOE's AESP.

Additional elements your agency may wish to include if available/applicable

1. Changes since NC7/BR3-4
   a. What changes to the methodology occurred?

A: Only slight updates to the calculation methodology including updates to the development of marginal electric grid emission factors consistent with the DOE/EIA 2022 Annual Energy Outlook. Reporting of N_2O and CH_4 are addition from previous year submittal.

   b. If applicable, do these changes increase or decrease historic values or projections?

*A: CO_2 estimate is very close to previously submitted values for saving from energy codes (*NC7).
Other GHG emissions are now available.

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: Most. The savings estimates are a based on modeled historical improvement in building driven energy consumption and historical adoption rates. Higher adoption and compliance rates could come from more aggressive/program policy efforts.

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: Generally, no. The estimate is for code adoption in states which adopt codes similar to the ASHRAE 90.1 or IECC codes. The analysis looks at code adoption as a whole in these states, although both code adoption and code development are significantly due to the efforts of a variety of stakeholder and state government policies. Further the analysis focuses on energy consumption related (operational) emission and does not take into account lifecycle/embodied carbon increases or reductions in societal emission that might occur due to updated building codes.

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: Yes. The estimate is developed to specifically avoid double counting the impact of higher equipment standards (AESP program related) emission benefits.

Weatherization Assistance Program

Sector: Energy: Residential and Commercial End-Use

Agency Name: U.S. Department of Energy

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
   a. In what year did the program start?

A: 1976

   b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

A: 2022

2. Emissions:
   a. Which gases are measured?

A: CO_2, CH_4, N_2O

   b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: For Electricity - NREL's Cambium database is used for current and projected grid-based electricity emissions factors and combines CO_2 and non-CO_2 gases into CO_2e based upon GWP.

For All Other fuel types – EPA's Simple Greenhouse Gas Emissions Calculator emission factors are assumed to be constant over time and combines CO_2 and non-CO_2 gases into CO_2e based upon GWP.

   c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: Impacts are based on a detailed program evaluation study (National Weatherization Assistance Program Impact Evaluation: Energy impacts for Single Family Homes – ORNL/TM-2015/13) that utilizes direct measurements of energy savings from a statistical sample of program participants. This provides an estimate of the GHG emissions savings per weatherized home. Emissions reductions from electricity are updated using latest emissions rate projections (Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis – 2022: Annual Supplement to NIST Handbook 135).

3. Information quality:
   a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: The Weatherization Assistance program periodically conducts evaluation studies to develop estimates of the program impact including reductions in GHG emissions per weatherized home. Estimates are based on two DOE sponsored national evaluations of the Weatherization Assistance Program (WAP). The evaluation study is peer-reviewed and uses statistically robust efforts led by the Oak Ridge National Laboratory. The Retrospective Evaluation covered Program Year (PY) 2008 and is reflective of a typical year in WAP operations (National Weatherization Assistance Program Impact Evaluation: Energy impacts for Single Family Homes – ORNL/TM-2015/13).

   b. What approaches are used to ensure data quality, if any?

A: Peer-review of impact evaluation studies.

Additional elements your agency may wish to include if available/applicable

1. Changes since NC7/BR3-4
   a. What changes to the methodology occurred?

A: The methodology relies on the same program impact evaluations conducted by the Oak Ridge National Laboratory but updates the projected emissions rates for electricity.

   b. If applicable, do these changes increase or decrease historic values or projections?

A: This decreases the emissions reductions that we attribute to this program.

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: The estimated GHG impacts reflect a portion of the targets. Missing from the methodology are the impact of other policy/programmatic changes that allow for electrification/decarbonization, renewable technologies, or other carbon reduction measures.

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: No

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: Other energy efficiency programs administered by the U.S. Department of Energy (DOE) may be related, and it is possible that one household could realize GHG reductions through participation in multiple DOE programs. In addition, it is possible that other federal funds such as U.S. Department of Health and Human Services Low-Income Energy Assistance Program (LIHEAP) funds are braided with DOE WAP. If WAP and LIHEAP funds are braided on a single building, that building would be reported by the Grantee as a completion to both DOE and HHS. Likelihood of double counting is related to the frequency of braided funding from multiple programs on a single home. The methodology has not been adjusted for the unknown frequency of mixed funding.

ENERGY STAR Products Program

Sector: Energy: Residential and Commercial End-Use

Agency Name: U.S. Environmental Protection Agency

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
   a. In what year did the program start?

A: 1992

   b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

A: Start year

2. Emissions:
   a. Which gases are measured?

A: CO_2

   b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: N/A

   c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: EPA calculates ENERGY STAR's emission reductions by applying pollutant emission factors to net annual electricity and fossil fuel savings attributable to the program. For electricity, EPA uses national marginal pollutant emission factors to estimate reduced emissions from power plants that run less due to reduced demand. These factors are derived using EPA's Avoided Emissions and Generation Tool (AVERT). Emission factors applied to direct fossil fuel savings are derived from on-site fuel combustion emissions using EPA's GHG Emission Factors Hub.
Sales of products attributed to the ENERGY STAR program are based on shipments of products to the U.S. and are defined as those that are above and beyond efficient product purchases that would have been occurred without ENERGY STAR actions. These sales are estimated by:
Collecting annual shipment data on ENERGY STAR certified products from participating product manufacturers, provided to EPA as a condition of partnership, and comparing these data to industry reports on total annual product shipments. EPA screens for data quality to ensure an accurate reflection of ENERGY STAR sales.

Establishing reference case baselines for annual product sales for each product category without ENERGY STAR, based on percent of models that meet the ENERGY STAR requirements when they are initially set, as well as an analysis of the market barriers for each product related to the benefit/cost ratio.

ENERGY STAR products with a lower benefit/cost ratio face higher market barriers, and it is assumed those products are more likely to be purchased due to the ENERGY STAR label and less likely to be prevalent in a reference case baseline than products with a higher benefit/cost ratio.

Annual energy savings are calculated using standardized values for the difference in annual energy use between a product that meets the ENERGY STAR requirements and a product that is not ENERGY STAR certified. For these values, EPA:

- *Assumes that ENERGY STAR certified products just meet the ENERGY STAR minimum savings thresholds, even though there are some products that exceed those levels.*
- *Assumes non-ENERGY STAR products meets minimum efficiency standards where standards exist. If standards do not exist, assumes the average energy use of available products within a category that do not meet the ENERGY STAR criteria prior to the introduction of an ENERGY STAR specification. EPA updates the baseline assumptions for products based on changes in ENERGY STAR requirements, as well as Federal Standards.*
- *Uses primary data from third parties, such as product metering on power use information, where additional information is necessary to estimate energy savings.*
- *Uses product-specific lifetimes that vary from 4 to 25 years.*
- *Subtracts the savings associated with products used in ENERGY STAR Certified New Homes to avoid double counting savings.*
- *Accounts for interactive effects from HVAC products and windows by assuming that consumers would apply the most cost-effective measure first. For example, ENERGY STAR attributes savings from windows decrease when they are applied to homes that have already installed efficient HVAC equipment.*
- *Energy savings goals for 2030 were estimated by applying adjusted growth rates to program savings based on an informed examination of the opportunity for reductions from new products.*

For more information on ENERGY STAR'S program impacts and methodologies, see https://www.energystar.gov/impacts.

3. Information quality:
   a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: Product sales data is provided by manufacturer partners as a condition of the partnership, as well as gathered from industry reports.

   b. What approaches are used to ensure data quality, if any?

A: EPA screens the shipment data provided by partners and resolves any issues. EPA also takes steps to reconcile any discrepancies between annual product sales data and product stock accounting. Where additional information is necessary to estimate energy savings, EPA supports primary data collection, such as product metering to collect power use information.

<u>Additional elements your agency may wish to include if available/applicable</u>

1. Changes since NC7/BR3-4
   a. What changes to the methodology occurred?

A: None.

   b. If applicable, do these changes increase or decrease historic values or projections?

A: N/A

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: All

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: No.

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: Methodology avoids potential double counting of emissions reductions from Lighting Energy Efficiency Standards, Appliance and Equipment Efficiency Standards, and ENERGY STAR Certified New Homes.

ENERGY STAR Commercial Buildings

Sector: Energy: Residential and Commercial End-Use

Agency Name: U.S. Environmental Protection Agency

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
   a. In what year did the program start?

A: 1993

   b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

A: Start year

2. Emissions:
   a. Which gases are measured?

A: CO_2

   b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: N/A

   c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: EPA calculates ENERGY STAR's emission reductions by applying pollutant emission factors to net annual electricity and fossil fuel savings attributable to the program. For electricity, EPA uses national marginal pollutant emission factors to estimate reduced emissions from power plants that run less due to reduced demand. These factors are derived using EPA's Avoided Emissions and Generation Tool (AVERT). Emission factors applied to direct fossil fuel savings are derived from on-site fuel combustion emissions using EPA's GHG Emission Factors Hub.

EPA develops commercial buildings impact evaluations using econometric modeling. The research design is outlined in a series of peer reviewed articles. Generally, the methodology attributes certain aggregate national energy savings in the commercial sector to the ENERGY STAR program, controlling for the impact of other federal and non-federal energy efficiency programs.

To calculate the national impacts of ENERGY STAR for commercial buildings, EPA uses historical energy consumption data for relevant fuel types from the U.S. Energy Information Administration, and other publicly available data, to estimate the differential effects of voluntary energy efficiency programs on electricity and natural gas consumption. A quasi-experimental research design is formed by designating state treatment and control groups and then using the control group energy consumption behavior to simulate counterfactual energy consumption for the treatment group. Being comprehensive in scope, the impact estimates incorporate other notable secondary effects, including spillover and market transformation savings.

Energy savings goals for 2030 were estimated by applying adjusted growth rates to program savings based on an informed examination of the opportunity for reductions from commercial buildings.

For more information on ENERGY STAR'S program impacts and methodologies, see https://www.energystar.gov/impacts.

3. Information quality:
    a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: Federal data from the Energy Information Administration and Department of Energy programs. Industry reports referenced for energy efficiency program information include Consortium for Energy Efficiency, American Council for an Energy Efficient Economy, and electricity and natural gas utilities.

    b. What approaches are used to ensure data quality, if any?

A: The soundness of the data used for energy consumption modeling is ensured through the peer-review process prior to journal publication. The data and calculations employed in the post-model estimation analyses are thoroughly reviewed by EPA staff and outside consultants.

Additional elements your agency may wish to include if available/applicable

1. Changes since NC7/BR3-4
    a. What changes to the methodology occurred?

A: None.

    b. If applicable, do these changes increase or decrease historic values or projections?

A: N/A

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: All

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: The spillover and market transformation effects of the program are captured in this methodology.

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: Methodology avoids potential double counting of energy savings reported from ENERGY STAR Labeled Products, Lighting Energy Efficiency Standards, Appliance and Equipment Efficiency Standards, Building Energy Codes, Federal Energy Management Programs, State Energy Program, Energy Efficiency and Conservation Block Grants, and other publicly funded commercial building energy efficiency programs, including state and local programs.

ENERGY STAR Residential New Construction Programs

Sector: Energy: Residential and Commercial End-Use

Agency Name: U.S. Environmental Protection Agency

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
   a. In what year did the program start?

A: 1995

   b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

A: Start year

2. Emissions:
   a. Which gases are measured?

A: CO_2

   b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: N/A

   c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: EPA calculates ENERGY STAR's emission reductions by applying pollutant emission factors to net annual electricity and fossil fuel savings attributable to the program. For electricity, EPA uses national marginal pollutant emission factors to estimate reduced emissions from power plants that run less due to reduced demand. These factors are derived using EPA's Avoided Emissions and Generation Tool (AVERT). Emission factors applied to direct fossil fuel savings are derived from on-site fuel combustion emissions using EPA's GHG Emission Factors Hub.

To account for the energy savings resulting from the operation of ENERGY STAR certified homes across a range of climates, sizes, and fuel types, EPA estimates a composite energy consumption of a standard (i.e., code-minimum) home constructed in each of seven climate zones, taking into account regional construction characteristics (e.g., foundation type, typical fuel use profile) and configuring the home to the applicable model energy code. EPA then applies ENERGY STAR requirements to each modeled home to determine an estimated composite energy consumption of ENERGY STAR homes in each climate zone. These calculated energy consumptions are used to calculate savings.

Energy savings goals for 2030 were estimated by applying adjusted growth rates to program savings based on an informed examination of the opportunity for reductions from new homes.

For more information on ENERGY STAR'S program impacts and methodologies, see https://www.energystar.gov/impacts.

3. Information quality:
   a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: On a quarterly basis, independent oversight organizations called Home Certification Organizations (HCO) submit data to EPA on the number of homes that have been certified to meet ENERGY STAR program requirements. This reporting is a condition of approval to be an HCO for ENERGY STAR.

b. What approaches are used to ensure data quality, if any?

A: Performance independently verified through modeling, on-site testing and inspections by certified third parties. HCOs must abide by a set of quality assurance practices to ensure data quality. In addition, EPA reviews the submitted data and resolves any data irregularities.

<u>Additional elements your agency may wish to include if available/applicable</u>

1. Changes since NC7/BR3-4
   a. What changes to the methodology occurred?

A: None

   b. If applicable, do these changes increase or decrease historic values or projections?

A: N/A

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: All

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: No.

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

Methodology avoids potential double counting of emissions reductions from Building Energy Codes. ENERGY STAR Labeled Products adjusts its emissions savings to avoid double counting due to ENERGY STAR products installed in ENERGY STAR certified homes.

Better Plants

Sector: Energy: Industrial End-Use

Agency Name: U.S. Department of Energy

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
    a. In what year did the program start?

A: 2011

    b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

A: The base year for emissions savings is based on the year participating partners chose as their baseline when they joined the program (2011 is used if the partner baseline was before 2011).

2. Emissions:
    a. Which gases are measured?

A: All

    b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: Partners that report non-CO2 gases calculate their own greenhouse gas inventories and report to DOE. They are encouraged to use the most recent IPCC Assessment Report for GWP values.

    c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: Program partners share portfolio-wide actual energy consumption by year. Better Plants Challenge and Better Plants Program partners share portfolio-wide actual energy consumption by year. Better Climate Challenge industrial partners share portfolio-wide actual greenhouse gas emissions and energy consumption by year.

3. Information quality:
    a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: Self-reporting by partners

    b. What approaches are used to ensure data quality, if any?

A: Program staff review partner data submissions for data quality, including checking for outliers or unusual results in facility-level energy intensity data, or confirming reasonableness of portfolio-level greenhouse gas inventory data. In some cases, program staff provide technical assistance with energy savings and greenhouse gas calculations, allowing for more direct assurance of data quality.

Additional elements your agency may wish to include if available/applicable

1. Changes since NC7/BR3-4
    a. What changes to the methodology occurred?

A: Adjusted estimates to account for increase in program growth due to the Better Climate Challenge.

b. If applicable, do these changes increase or decrease historic values or projections?

A: These changes increase historic projections.

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: Just some. The program tracks reduction in energy consumption for program partners, but the program offers tools and technical assistance to amplify best practices in energy management, which are available to the broader industrial market.

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: No.

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: The program's methodology captures all energy savings achieved by program partners. It is possible that these program partners are influenced by other federal policies and measures. The methodology does not adjust for potential double counting.

Combined Heat and Power (CHP) Deployment Program

Sector: Energy: Industrial End-Use

Agency Name: U.S. Department of Energy

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
    a. In what year did the program start?

A: 2004

    b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

A: CO_2 savings from operating combined heat and power (CHP) systems that received technical assistance from the DOE CHP Technical Assistance Partnerships calculated on an annual basis – base year calculation is 2021

2. Emissions:
    a. Which gases are measured?

A: CO_2

    b. For non-CO_2 gases, what global warming potential (GWP) values were used

A: N/A

    c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: Modeling - GHG reductions are calculated by subtracting the estimated emissions from specific Combined Heat and Power (CHP) systems from the estimated emissions of the conventional electricity and thermal sources (i.e., electric power grid and comparable boilers) displaced by those systems. CHP system emissions are calculated using fuel-specific emissions factors and operational data (kWh generated, heat rate) reported in EIA Form-860 or modeled based on technology and fuel type. Emissions from displaced grid generation are calculated using regional marginal carbon emissions factors for grid-supplied electricity from EPA's AVERT database. Emissions from displaced thermal energy (e.g., steam or hot water) are calculated based on fuel-specific emissions factors and thermal efficiencies. Each project's CO_2 reduction is calculated individually and includes a credit for avoided transmission and distribution (T&D) losses based on a published national factor.

3. Information quality:
    a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: Federal estimates (EPA AVERT marginal grid emissions factors), industry reporting (Form EIA-860), modeled CHP system performance

    b. What approaches are used to ensure data quality, if any?

A: N/A

Additional elements your agency may wish to include if available/applicable

1. Changes since NC7/BR3-4
    a. What changes to the methodology occurred?

A: N/A

b. If applicable, do these changes increase or decrease historic values or projections?

A: N/A

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: Some - the installation of CHP systems resulting from broad DOE CHP Deployment Program market transformation efforts, without direct CHP Technical Assistance Partnership-related involvement, is not reflected in this methodology.

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: No, see above

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: CHP users may also receive assistance from the U.S. Environmental Protection Agency's CHP Partnership Program or participate in state and local programs, including programs that receive funding through federal grant programs. No adjustments are made for potential double counting with respect to those organizations, as the magnitude of potential overlap is estimated to be equal to or less than projects not included in this estimate, though influenced by DOE's CHP Deployment Program.

ENERGY STAR Industrial Program

Sector: Energy: Industrial End-Use

Agency Name: U.S. Environmental Protection Agency

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
   a. In what year did the program start?

A: 2001

   b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

A: Start year

2. Emissions:
   a. Which gases are measured?

A: CO_2

   b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: N/A

   c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: EPA calculates ENERGY STAR's emission reductions by applying pollutant emission factors to net annual electricity and fossil fuel savings attributable to the program. For electricity, EPA uses national marginal pollutant emission factors to estimate reduced emissions from power plants that run less due to reduced demand. These factors are derived using EPA's Avoided Emissions and Generation Tool (AVERT). Emission factors applied to direct fossil fuel savings are derived from on-site fuel combustion emissions using EPA's GHG Emission Factors Hub.

EPA develops industrial plants impact evaluations using econometric modeling. The research design is outlined in a series of peer reviewed articles. Generally, the methodology attributes certain aggregate national energy savings in the industrial sector to the ENERGY STAR program, controlling for the impact of other federal and non-federal energy efficiency programs.

To calculate the national impacts of ENERGY STAR for industrial plants, EPA uses historical energy consumption data for relevant fuel types from the U.S. Energy Information Administration, and other publicly available data, to estimate the differential effects of voluntary energy efficiency programs on electricity, natural gas, and other fuels consumption. A quasi-experimental research design is formed by designating state treatment and control groups and then using the control group energy consumption behavior to simulate counterfactual energy consumption for the treatment group. Being comprehensive in scope, the impact estimates incorporate other notable secondary effects, including spillover and market transformation savings.

Energy savings goals for 2030 were estimated by applying adjusted growth rates to program savings based on an informed examination of the opportunity for reductions from industrial plants.

For more information on ENERGY STAR'S program impacts and methodologies, see https://www.energystar.gov/impacts.

3. Information quality:
   a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: Various federal data sources, including the Energy Information Administration and Department of Commerce's Annual Survey of Manufactures.

   b. What approaches are used to ensure data quality, if any?

A: The soundness of the data used for energy consumption modeling is ensured through the peer-review process prior to journal publication. The data and calculations employed in the post-model estimation analyses are thoroughly reviewed by EPA staff and outside consultants.

Additional elements your agency may wish to include if available/applicable

1. Changes since NC7/BR3-4
   a. What changes to the methodology occurred?

A: None

   b. If applicable, do these changes increase or decrease historic values or projections?

A: N/A

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: All

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: The spillover and market transformation effects of the program are captured in this methodology.

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: Methodology avoids potential double counting of energy savings reported by US DOE industrial programs, as well as savings from state and local energy efficiency programs.

American Innovation and Manufacturing Act

Sector: Industrial Processes and Product Use

Agency Name: U.S. Environmental Protection Agency

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
    a. In what year did the program start?

A: The first implementing regulation was promulgated in 2021 and the production and consumption phasedowns began January 1, 2022.

    b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

A: 2021 is used as the "zero" year, with reductions beginning in 2022.

2. Emissions:
    a. Which gases are measured?

A: Eighteen HFCs listed in the AIM Act (e.g., HFC-125, HFC-134a, HFC-23) and their isomers.

    b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A:100-year GWPs from IPCC 4th Assessment Report (AR4, 2007)

    c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: EPA's Vintage Model (described in Inventory of U.S.GHG Emissions and Sinks) is used. Emission reductions are based on the modeled pathway towards compliance with HFC consumption phasedown steps in 2022, 2024, 2029, 2034 and 2036. Resulting emission reductions are calculated through 2050 to account for the lag time between chemical consumption and emissions.

3. Information quality:
    a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: Data and assumptions are obtained from published sources, including federal and industry reporting, as well as confidential business information.

    b. What approaches are used to ensure data quality, if any?

A: The EPA Vintage Model used was peer-reviewed in 2017. As part of the annual review of the Inventory of U.S. GHG Emissions and Sinks, the inputs and assumptions of the model are first reviewed by industry and government experts before being opened for public comment, and then submitted to the UNFCCC, where it undergoes additional review. A regulatory impact analysis was provided as part of the notice-and-comment rulemaking which included information on the data used.

Additional elements your agency may wish to include if available/applicable

1. Changes since NC7/BR3-4
    a. What changes to the methodology occurred?

A: This is a new PAM.

b. If applicable, do these changes increase or decrease historic values or projections?

A: N/A

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: The measured impacts reflect some to most but not all of the actions that are to be undertaken under the authority of the AIM Act. At this time, we cannot determine to what extent other actions will result in additional emission reductions.

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: No.

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: Yes. The DOT/EPA National Program for Heavy-Duty Vehicle GHG Emissions and Fuel Efficiency Standards and the DOT/EPA National Program for Light-Duty Vehicle GHG Emissions and CAFE Standards account for HFC emission reductions from vehicular air conditioning. The modeling performed for this PAM does not include such emission reductions in the calculations presented.

The Significant New Alternatives Policy (SNAP) program lists HFCs as acceptable, acceptable with restrictions, or unacceptable in specific end-use subsectors, resulting in emission reductions. To avoid double-counting, the version of the model used to simulate compliance with the AIM Act is used as the version of the model to calculate emission reductions under SNAP. Additional reductions from the HFC-using sectors beyond those projected for SNAP using that model are attributed to the AIM Act.

Significant New Alternatives Policy Program

Sector: Industrial Processes and Product Use

Agency Name: U.S. Environmental Protection Agency

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
   a. In what year did the program start?

A: Start year is taken as 1990, when the CAA Amendments were signed. Initial SNAP rule was finalized and published in 1994; however, industry reactions to the CAAA and the SNAP ANOPR and NOPR led to changes in the use of ODS and uptake of HFCs that are accounted for in the methodology.

   b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

A: 1989 is used as the "zero" year, with changes beginning in 1990.

2. Emissions:
   a. Which gases are measured?

A: Ozone Depleting Substances (e.g., CFC-11, CFC-12, CFC-115, HCFC-22, HCFC-141b, HCFC-142b) and fluorinated substitutes (e.g., HFC-32, HFC-125, HFC-134a, HFC-143a). ODS are not included in the totals.

   b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: AR4 100-year GWPs.

   c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: EPA's Vintage Model (described in Inventory of U.S.GHG Emissions and Sinks) is used. Consumption and emission of ODS substitutes are modeled by estimating the size of the markets, the uptake of non-ODS substitutes within each end-use, changes in technologies, and emissions factors. To determine emissions reductions, EPA compares two Vintage Model Scenarios: (1) Estimates of emissions assuming all requirements under Title VI of the Clean Air Act. (2) Estimates of emissions assuming the ODS phase out occurs in compliance with the Montreal Protocol on Substances that Deplete the Ozone Layer. Developed as a business-as-usual scenario assuming that trends that were in place prior to establishment of SNAP continue.

3. Information quality:
   a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: Data and assumptions are obtained from published sources, including federal and industry reporting, as well as confidential business information.

   b. What approaches are used to ensure data quality, if any?

A: As part of the annual review of the Inventory of U.S. GHG Emissions and Sinks, the inputs and assumptions of the Vintaging Model are first reviewed by industry and government experts before being submitted to the UNFCCC, where it undergoes an additional review. The model was peer reviewed in 2017.

Additional elements your agency may wish to include if available/applicable

1. Changes since NC7/BR3-4
    a. What changes to the methodology occurred?

A: No changes.

    b. If applicable, do these changes increase or decrease historic values or projections?

A: N/A – no changes.

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: The GHGs reported only include HFCs, PFCs and SF6. Reductions of other GHGs, specifically ODSs, are not included. The reductions of ODSs have not been quantified.

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: No.

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: Yes. The DOT/EPA National Program for Heavy-Duty Vehicle GHG Emissions and Fuel Efficiency Standards and the DOT/EPA National Program for Light-Duty Vehicle GHG Emissions and CAFE Standards account for HFC emission reductions from vehicular air conditioning. The modeling performed for this PAM does not include such emission reductions in the calculations presented.

The American Innovation and Manufacturing (AIM) Act establishes a phasedown in the production and consumption of HFCs. Such changes will lead to emission reductions and are covered as a new PAM. To avoid double-counting, the version of the model used to simulate compliance with the AIM Act is used as the version of the model to calculate emission reductions under SNAP. Additional reductions from the HFC-using sectors beyond those projected for SNAP using that model are attributed to the AIM Act.

GreenChill Advanced Refrigeration Partnership

Sector: Industrial Processes and Product Use

Agency Name: U.S. Environmental Protection Agency

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
   a. In what year did the program start?

A: Reduction calculations began in 2007, the year the partnership started (i.e., zero-year is 2006).

   b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

A: 2006

2. Emissions:
   a. Which gases are measured?

A: Ozone Depleting Substances (e.g., CFC-12, HCFC-22) and HFCs (e.g., HFC-134a, HFC blends including R-404A and R-507A). Only HFCs are reported; ODS are not included in totals.

   b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: AR4 100-year GWPs

   c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: Average partner emissions are compared to national average for typical U.S. supermarkets. Past emission reductions from the partnership are then taken as the difference of the typical U.S. store and the partnership average store, multiplied by the number of stores represented by the data provided by partners.

3. Information quality:
   a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: Annual partner reports used to characterize partner stores. Typical U.S. supermarket based on information from EPA's Vintaging Model, the partners, and other industry experts.

   b. What approaches are used to ensure data quality, if any?

A: To ensure calculations are correct, each partner is given a report to double-check their individual corporate-wide emissions rates and partnership averages are provided so that partners can assess the reasonableness of those averages, benchmark their own emission rates, and set goals to improve.

Additional elements your agency may wish to include if available/applicable

5. Changes since NC7/BR3-4
   a. What changes to the methodology occurred?

A: Since the last CAR, additional annual reports from partners, including some new to the program since the last CAR, have been incorporated into the methodology.

   b. If applicable, do these changes increase or decrease historic values or projections?

A: Increase

6. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: The GHGs reported only include HFCs. Reductions of other GHGs, specifically ODSs, are not included. The reported GHG impacts reflect approximately 50% of the GHG reductions in the early years, rising to ~90% in 2020 (and eventually 100% once the ODS phaseout is complete and ODS stocks are depleted).

7. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: No

8. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: No

Responsible Appliance Disposal Program

Sector: Industrial Processes and Product Use

Agency Name: U.S. Environmental Protection Agency

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
    a. In what year did the program start?

A: Program began in 2006; data collection began in 2007.

    b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

A: Start year (2006)

2. Emissions:
    a. Which gases are measured?

A: Ozone Depleting Substances (e.g., CFC-11, CFC-12, HCFC-22, HCFC-1241b) and HFCs (e.g., HFC-134a, HFC-245fa). Only HFCs are reported; ozone depleting substances (ODS) are not included in totals.

    b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: AR4 100-year GWPs

    c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: Emission reductions are based on partner reports that detail the number of appliances and pounds of chemical reclaimed and destroyed. Results are adjusted to account for the recycling of durable components (metal, plastic, glass) that also occurs under Resist-Accept-Direct (RAD) program, using EPA's Waste Reduction Model (WARM).

3. Information quality:
    a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: Annual partner reports.

    b. What approaches are used to ensure data quality, if any?

A: The reporting form features tabs for quality assurance, including typical reported average quantities across partners. Aggregated totals from all partners are published and provided so that partners can assess the reasonableness of those totals and benchmark their own data.

Additional elements your agency may wish to include if available/applicable

1. Changes since NC7/BR3-4
    a. What changes to the methodology occurred?

A: Since the last CAR, additional annual reports from partners, including some new to the program, have been incorporated into the methodology.

    b. If applicable, do these changes increase or decrease historic values or projections?

A: Increase

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: The GHGs reported only include HFCs. Reductions of other GHGs, specifically ODSs, are not included. The reported GHG impacts reflect approximately 5-20% of the GHG reductions in the early years, rising to about 40% in 2020 and increasing thereafter.

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: No.

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: No.

SF_6 Emission Reduction Partnership for Electric Power Systems

Sector: Industrial Processes and Product Use

Agency Name: U.S. Environmental Protection Agency

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
   a. In what year did the program start?

A: 1999

   b. If emissions were calculated using a year other than the start year as the “zero” point for reductions, what was that year?

A: N/A

2. Emissions:
   a. Which gases are measured?

A: Sulfur hexafluoride (SF_6)

   b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: IPCC 4th Fourth Assessment Report (AR4)

   c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: Facility-specific mass-balance methodology. The mass-balance method works by tracking and systematically accounting for all company uses of SF6 during the reporting year. This method is provided by the 2006 IPCC Guidelines as the Tier 3 approach for estimating emissions from electrical transmission and distribution facilities. EPA calculates program achievements as the difference between annual estimated emissions under “Business as Usual” practices and annual reported emissions under “business as usual” practices based on baseline emissions reported by partners in 1999 and annual reported emissions under the program.

For 2030 impacts, EPA used a marginal abatement cost (MAC) curve analysis to estimate further reductions that could be achieved in the sector in 2030 (United States Environmental Protection Agency. 2019. Non-CO_2 Emission Projections and Mitigation Summary Report:2015-2050. EPA-430-R-19-010.)

3. Information quality:
   a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: Partner data is reported either through the Greenhouse Gas Reporting Program (GHGRP) (facilities above the mandatory reporting threshold) or voluntarily (facilities below the mandatory GHGRP reporting threshold). The GHGRP began collecting annual facility-level emissions data from this sector in 2012, from both partners and non-partners.

   b. What approaches are used to ensure data quality, if any?

A: Data collected through the Greenhouse Gas Reporting Program is based on regulatory requirements in the Greenhouse Gas Reporting Rule (40 CFR Part 98). This regulation has specific Quality Assurance/Quality

Control and data quality reporting requirements for the data submitted to EPA. The agency conducts a thorough verification process for all data received including automated data quality checks using a verification tool and analyses of data, and works directly with reporting facilities to address any issues that arise. Data collected through voluntary submission uses the same mass-balance methodology as the mandatory GHGRP and is reviewed with data quality checks and EPA works directly with voluntary reporting facilities to address any issues that arise.

Additional elements your agency may wish to include if available/applicable

1. Changes since NC7/BR3-4
   a. What changes to the methodology occurred?

A: No changes

   b. If applicable, do these changes increase or decrease historic values or projections?

A: No changes

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: The impacts reflect all of the activities achieved by the SF_6 Emission Reduction Partnership for Electric Power Systems.

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: N/A

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: No similar or related programs.

Conservation Reserve Program (CRP)

Sector: Agriculture

Agency Name: U.S. Department of Agriculture

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
   a. In what year did the program start?

A: 1985

   b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

N/A

2. Emissions:
   a. Which gases are measured?

A: CO2, N2O

   b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: 298 for N2O (based off of COMET-Planner report)

   c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: For this program, an estimate of mitigation impact in 2021 is being used as a rough proxy for the 2030 impact.

Emissions factors based off of COMET-Planner model for woody biomass and grass practices; wetlands are not modeled and a factor is applied over total wetland acreage.

The 2021 CRP benefits estimates are calculated using IPCC Tier-3 methods. Colorado State University provided the analysis underlying the 2021 estimate presented. The grass and woody biomass conservation practices are estimated using the DayCent model and the wetlands and avoided farm equipment usage estimates are dervied from the best available values from the literature.

3. Information quality:
   a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: Federal CRP GIS data (acres by practice and location).

   b. What approaches are used to ensure data quality, if any?

A: N/A

Additional elements your agency may wish to include if available/applicable

5. Changes since NC7/BR3-4
   a. What changes to the methodology occurred?

A: N/A

b. If applicable, do these changes increase or decrease historic values or projections?

A: N/A

6. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: All

7. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: No

8. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: No

Environmental Quality Incentives Program (EQIP)

Sector: Agriculture

Agency Name: U.S. Department of Agriculture

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
   a. In what year did the program start?

A: 1996

   b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

N/A

2. Emissions:
   a. Which gases are measured?

A: CO2, N2O, CH4

   b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: N/A

   c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: For this program, an estimate of mitigation impact in 2020 is being used as a rough proxy for the 2030 impact.
USDA's Natural Resources Conservation Service (NRCS) uses model-based emission factors primarily derived from COMET-Planner, which uses a meta-modeling analysis of Land Resource Regions (LRR), Cropland Data Layer (CDL) and local meteorological data.
The 2020 benefits included in this estimate include the Conservation Legacy Effect (CLE). The CLE represents the benefits of current year's conservation practices and a fractional component of historic conservation practice investments. See April 2021 presentation explaining the benefits calculations of the Conservation Technical Assistance program (CTA): https://nrcs.adobeconnect.com/pisysk7nhp72/

3. Information quality:
   a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: Federal estimates of emission benefits utilize conservation practice delivery data sets from the Agency's program activity data, alongside land-grant university emission factors and available literature base.

   b. What approaches are used to ensure data quality, if any?

A: Several steps are taken to ensure data quality, including error trapping and removal of erroneous data inputs. There are multiple aspects of data quality, including but not limited to: conservation practice implementation, emissions factor generation, and longevity/permanence of conservation practice implementation.

Additional elements your agency may wish to include if available/applicable

1. Changes since NC7/BR3-4
   a. What changes to the methodology occurred?

A: Yes, actual activity data has been leveraged to calculate the emissions benefits and carbon sequestration. The Natural Resources Conservation Service has been investing in improving quantification methodologies, further advancing science, and delivering voluntary climate solutions. the National Resources Conservation Service (NRCS) is dedicated to continual improvement of conservation practice data collection and emission factor refinement.

b. If applicable, do these changes increase or decrease historic values or projections?

A: N/A

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: The modeled and quantified carbon sequestration and emission reduction benefits currently represent several of NRCS's largest programs but the Agency would like to continually refine quantification methods for all programs to facilitate their inclusion in future reporting.

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: No, these are direct benefits delivered by NRCS and currently represent on-farm benefits that are exclusive to the agricultural sector. This includes direct benefits from practices implemented in the current reporting year and a proportion of historical conservation practice investments that remain on the landscape. Estimates include benefits beyond the funded lifespan of NRCS conservation practices, based on available literature supporting practice longevity. Scientists within NRCS are familiar with the National Inventory and make efforts to align quantification methodologies with the National Inventory. The National Inventory would represent the larger market impact of climate-smart practices on our Nation's working lands

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: NRCS currently includes the Regional Conservation Partnership Program in the EQIP estimates presented here. Beginning in FY21, the programs will be tracked separately.

Corporate Scope 3 emissions could represent a double-counting concern, but that concern would not technically be double counting for the United States. As NRCS implements new funding delivered through the Inflation Reduction Act and other Climate-Smart priorities, the agency will attempt to only present a single authoritative set of numbers. NRCS is fortunate to have developed a quantification methodology that is financial program neutral.

Conservation Stewardship Program (CStP)

Sector: Agriculture

Agency Name: U.S. Department of Agriculture

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
   a. In what year did the program start?

A: 2014

   b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

N/A

2. Emissions:
   a. Which gases are measured?

A: CO2, N2O, CH4

   b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: N/A

   c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: For this program, an estimate of mitigation impact in 2020 is being used as a rough proxy for the 2030 impact.
NRCS uses model-based emission factors primarily derived from COMET-Planner, which uses a meta-modeling analysis of Land Resource Regions (LRR), Cropland Data Layer (CDL) and local meteorological data.
The 2020 benefits included in this estimate include the Conservation Legacy Effect (CLE). The CLE represents the benefits of current year's conservation practices and a fractional component of historic conservation practice investments. See April 2021 presentation explaining the benefits calculations of CTA: https://nrcs.adobeconnect.com/pisysk7nhp72/

3. Information quality:
   a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: Federal estimates of emission benefits utilize conservation practice delivery data sets from the Agency's program activity data, alongside land-grant university emission factors and available literature base.

   b. What approaches are used to ensure data quality, if any?

A: Several steps are taken to ensure data quality, including error trapping and removal of erroneous data inputs. There are multiple aspects of data quality, including but not limited to: conservation practice implementation, emissions factor generation, and longevity/permanence of conservation practice implementation.

Additional elements your agency may wish to include if available/applicable

5. Changes since NC7/BR3-4
   a. What changes to the methodology occurred?

A: Yes, actual activity data has been leveraged to calculate the emissions benefits and carbon sequestration. The Natural Resources Conservation Service has been investing in improving quantification methodologies, further advancing science and delivering voluntary climate solutions. NRCS is dedicated to continual improvement of conservation practice data collection and emission factor refinement.

b. If applicable, do these changes increase or decrease historic values or projections?

A: N/A

6. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: The modeled and quantified carbon sequestration and emission reduction benefits currently represent several of NRCS's largest programs but the Agency would like to continually refine quantification methods for all programs to facilitate their inclusion in future reporting.

7. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: No, these are direct benefits delivered by NRCS and currently represent on-farm benefits that are exclusive to the agricultural sector. This includes direct benefits from practices implemented in the current reporting year and a proportion of historical conservation practice investments that remain on the landscape. Estimates include benefits beyond the funded lifespan of NRCS conservation practices, based on available literature supporting practice longevity. Scientists within NRCS are familiar with the National Inventory and make efforts to align quantification methodologies with the National Inventory. The National Inventory would represent the larger market impact of climate-smart practices on our Nation's working lands

8. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: Corporate Scope 3 emissions could represent a double-counting concern, but that concern would not technically be double counting for the United States. As NRCS implements new funding delivered through the Inflation Reduction Act and other Climate-Smart priorities, the agency will attempt to only present a single authoritative set of numbers. NRCS is fortunate to have developed a quantification methodology that is financial program neutral.

Conservation Technical Assistance Program (CTA)

Sector: Agriculture

Agency Name: U.S. Department of Agriculture

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
   a. In what year did the program start?

A: 1935

   b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

N/A

2. Emissions:
   a. Which gases are measured?

A: CO2, N2O, CH4

   b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: N/A

   c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: For this program, an estimate of mitigation impact in 2020 is being used as a rough proxy for the 2030 impact.
NRCS uses model-based emission factors primarily derived from COMET-Planner, which uses a meta-modeling analysis of Land Resource Regions (LRR), Cropland Data Layer (CDL) and local meteorological data.
The 2020 benefits included in this estimate include the Conservation Legacy Effect (CLE). The CLE represents the benefits of current year's conservation practices and a fractional component of historic conservation practice investments. See April 2021 presentation explaining the benefits calculations of CTA: https://nrcs.adobeconnect.com/pisysk7nhp72/

3. Information quality:
   a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: Federal estimates of emission benefits utilize conservation practice delivery data sets from the Agency's program activity data, alongside land-grant university emission factors and available literature base.

   b. What approaches are used to ensure data quality, if any?

A: Several steps are taken to ensure data quality, including error trapping and removal of erroneous data inputs. There are multiple aspects of data quality, including but not limited to: conservation practice implementation, emissions factor generation, and longevity/permanence of conservation practice implementation.

Additional elements your agency may wish to include if available/applicable

9. Changes since NC7/BR3-4
   a. What changes to the methodology occurred?

A: Yes, actual activity data has been leveraged to calculate the emissions benefits and carbon sequestration. The Natural Resources Conservation Service has been investing in improving quantification methodologies, further advancing science and delivering voluntary climate solutions. NRCS is dedicated to continual improvement of conservation practice data collection and emission factor refinement.

b. If applicable, do these changes increase or decrease historic values or projections?

A: N/A

10. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: The modeled and quantified carbon sequestration and emission reduction benefits currently represent several of NRCS's largest programs but the Agency would like to continually refine quantification methods for all programs to facilitate their inclusion in future reporting.

11. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: No, these are direct benefits delivered by NRCS and currently represent on-farm benefits that are exclusive to the agricultural sector. This includes direct benefits from practices implemented in the current reporting year and a proportion of historical conservation practice investments that remain on the landscape. Estimates include benefits beyond the funded lifespan of NRCS conservation practices, based on available literature supporting practice longevity. Scientists within NRCS are familiar with the National Inventory and make efforts to align quantification methodologies with the National Inventory. The National Inventory would represent the larger market impact of climate-smart practices on our Nation's working lands

12. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: Conservation Technical Assistance is a component of NRCS Conservation Planning but not duplicative of the Environmental Quality Incentives Program, Conservation Stewardship Program, Conservation Innovation Grants, or the Regional Conservation Partnership Program.

Corporate Scope 3 emissions could represent a double-counting concern, but that concern would not technically be double counting for the United States. As NRCS implements new funding delivered through the Inflation Reduction Act and other Climate-Smart priorities, the agency will attempt to only present a single authoritative set of numbers. NRCS is fortunate to have developed a quantification methodology that is financial program neutral.

AgSTAR

Sector: Agriculture

Agency Name: U.S. Environmental Protection Agency / U.S. Department of Agriculture

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
   a. In what year did the program start?

A: 1994

   b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

A: N/A

2. Emissions:
   a. Which gases are measured?

A: CH_4

   b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: IPCC 4th Fourth Assessment Report (AR4)

   c. How are GHG impacts measured? (direct measurements, emissions factor, modeling

A: The AgSTAR Program calculates its annual emission reductions achieved based on 40% of the emissions reductions voluntarily reported to the program by industry members on an annual basis. Industry members provide facility-level data and the corresponding emissions reductions are calculated using IPCC methodologies. These data are used to determine program emission reduction totals and measure the overall effectiveness of the AgSTAR Program. For 2030 impacts, EPA used a marginal abatement cost (MAC) curve analysis to estimate program impacts.

3. Information quality:
   a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: Voluntary data submitted by industry members (under ICR regulations), publicly available information via press releases, news articles and project developer websites.

   b. What approaches are used to ensure data quality, if any?

A: Each submission is reviewed to ensure that the data is reasonable and does not conflict with other publicly reported data for that facility. Any inconsistencies are resolved through direct correspondence with the facility owner or operator. As appropriate, these data are omitted or adjusted prior to their inclusion in the AgSTAR Program annual totals.

Additional elements your agency may wish to include if available/applicable

1. Changes since NC7/BR3-4
   a. What changes to the methodology occurred?

A: No changes.

b. If applicable, do these changes increase or decrease historic values or projections?

A: No changes.

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: The impacts reflect all of the activities achieved by the AgSTAR Program.

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: Yes

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: There is a small subset of projects funded by USDA PAMs in Chapter 4 that are also accounted for by AgSTAR. The revised AgSTAR methodology to estimate annual achievements generally accounts for this and other market impacts by not crediting 100% of industry achievements. The projections methodology to estimate impacts in 2030 does account for USDA actions.

Standards for New Sources and Emission Guidelines for Existing Sources - LandFillS

Sector: Waste

Agency Name: U.S. Environmental Protection Agency

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
   a. In what year did the program start?

A: EPA promulgated New Source Performance Standards and Emission Guidelines (NSPS/EG) for municipal solid waste landfills in 1996.

   b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

A: The NSPS/EG requires landfills to install gas collection and control systems (GCCS) when the landfill exceeds the emission rate and design capacity cutoffs. As such, the reductions begin happening in various years depending on when each landfill exceeds the threshold to install controls. Under the NSPS/EG, once a landfill exceeds the thresholds it has 30 months to install a GCCS. Therefore the earliest date reductions would start occurring would be 1999. Once a landfill is closed, it can remove a GCCS after a) the GCCS operated 15 years and b) the landfill no longer exceeds the thresholds.

2. Emissions:
   a. Which gases are measured?

A: The NSPS/EG require collection and control of landfill gas (LFG) through the use of flares or other enclosed combustion devices at new and existing landfills that meet the size and emission threshold criteria specified in the regulations. LFG is comprised of approximately 50% methane, 50% carbon dioxide, and trace amount of nonmethane organic compounds (NMOC). Although the NSPS/EG measures NMOC as a surrogate for LFG, the destruction of NMOC also controls methane.

   b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: IPCC 4th Assessment Report (AR4)

   c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: Modeled. Estimates of annual methane emissions were developed for each landfill in the database using a first-order decay equation to model the emissions from each
landfill over time. Inputs to the model include landfill-specific waste data from the database and emission factors for NMOC. Methane reductions resulting from controls installed under NSPS/EG regulations were calculated by determining when the modeled NMOC emissions from each landfill exceeded the emission thresholds specified in the regulation. Currently, the regulations require landfills of at least 2.5 million megagrams (Mg) and 2.5 cubic meters in size with estimated NMOC emissions of at least 50 Mg per year to collect and control LFG. EPA estimated emission reductions in terms of the amount of methane combusted, which was calculated by multiplying the modeled LFG collected amount by a destruction efficiency of 98 percent.

3. Information quality:

a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: To estimate the methane reductions resulting from the NSPS/EG regulations, a landfill database was developed using mandated data submitted to the Greenhouse Gas Reporting Program (GHGRP). This data was supplemented with voluntarily submitted data from a landfill and LFG energy project database maintained by EPA's Landfill Methane Outreach Program (LMOP). The EPA also consulted with regional offices, states and local authorities to identify new landfills anticipated to build or modify over the next 5 years. Since a review of the NSPS is currently underway, EPA also developed and projected model landfills expected to come online in the next 5 years (2014-2018). This approach is consistent with the timeline necessary to complete a regulatory impacts analysis of the NSPS review. EPA also developed model landfills to fill gaps in the existing data.

b. What approaches are used to ensure data quality, if any?

A: The two data sources were compared with one another to assess which source to use and resolve inconsistencies in the dataset. Further, GHGRP data went through an internal data verification process prior to being used in this dataset. Several automated data checks were employed to ensure that various model inputs related to one another and that data gaps could be filled based on a practical set of assumptions.

Additional elements your agency may wish to include if available/applicable

1. Changes since NC7/BR3-4
   a. What changes to the methodology occurred?

A: No changes

   b. If applicable, do these changes increase or decrease historic values or projections?

A: N/A

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: Estimated methane impacts include all aspects of the required NSPS/EG.

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: No.

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: The Landfill Methane Outreach Program (LMOP) also measures methane reductions from non-NSPS landfills (i.e. voluntary reductions). Because the NSPS/EG rule methodology estimates emissions based on modeling, while LMOP estimates its emission reductions based on a NSPS/EG flag field in the LMOP database, there is likely a small amount of double counting occurring. The NSPS/EG methodology does not adjust for this overlap.

Landfill Methane Outreach Program

Sector: Waste

Agency Name: U.S. Environmental Protection Agency

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
   a. In what year did the program start?

A: 1994

   b. If emissions were calculated using a year other than the start year as the “zero” point for reductions, what was that year?

A: N/A

2. Emissions:
   a. Which gases are measured?

A: CH_4

   b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: IPCC 4th Fourth Assessment Report (AR4)

   c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: The Landfill Methane Outreach Program (LMOP) calculates annual reductions from operational energy projects and flares at landfills not subject to New Source Performance Standard (NSPS) and Emission Guideline (EG) regulations under the Clean Air Act for which the Program provides assistance, including technical information, and/or where there is Partner involvement in implementing the project. For operational landfill gas (LFG) energy projects, the LMOP database includes the estimated MW capacity of each electricity project and the estimated amount of LFG utilized by each direct-use project. These values are used in the calculations to determine annual emission reductions. *For 2030 impacts, EPA used a marginal abatement cost (MAC) curve analysis to estimate program impacts (United States Environmental Protection Agency. 2019. Non-CO_2 Emission Projections and Mitigation Summary Report:2015-2050. EPA-430-R-19-010.)*

3. Information quality:
   a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: The data is updated annually based on information gathered from LMOP Partners other stakeholders in the LFG industry as well as information reported directly to EPA through the Greenhouse Gas Reporting Program (GHGRP). Landfills above the reporting threshold began reporting GHG emissions data to EPA through the GHGRP in 2011 for the calendar year 2010. LMOP collects data annually on LFG energy production from LMOP industry Partners in the LFG industry through an information collection request.

   b. What approaches are used to ensure data quality, if any?

A: LMOP verifies the energy production data after the collection process and resolves inconsistencies with the appropriate LMOP Partner company.

Additional elements your agency may wish to include if available/applicable

1. Changes since NC7/BR3-4
   a. What changes to the methodology occurred?

A: No changes

   b. If applicable, do these changes increase or decrease historic values or projections?

A: No changes

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: These measured GHG impacts reflect the direct methane emissions reductions achieved through LMOP.

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: N/A

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: LMOP is the only voluntary federal program that tracks GHG impacts from the landfill gas energy industry. Under the Clean Air Act, there are landfill regulations that control GHG emissions by limiting landfill gas emissions from landfills of a certain size and emissions threshold. EPA's method for calculating annual achievements and for projecting future impacts accounts for the impacts from regulations to avoid potential double counting.

Executive Order 14057: Catalyzing Clean Energy Industries and Jobs through Federal Sustainability

Sector: Cross-Cutting

Agency Name: Office of the Federal Chief Sustainability Officer, and multiple agencies

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
    a. In what year did the program start?

A: 2021

    b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

A: 2008

2. Emissions: For more information see: https://www.energy.gov/eere/femp/articles/annual-energy-management-data-report
    a. Which gases are measured?

A: Carbon dioxide	*PFC-318 or PFC-c318*
Methane	*PFC-4-1-12*
Nitrous oxide	*PFC-5-1-14*
HFC-23	*PFC-6-1-16*
HFC-32	*PFC-7-1-18*
HFC-41	*PFC-9-1-18*
HFC-125	*HCFE-235da2 (Isoflurane)*
HFC-134	*HFE-43-10pccc (H-Galden 1040x)*
HFC-134a	*HFE-125*
HFC-143	*HFE-134*
HFC-143a	*HFE-143a*
HFC-152	*HFE-227ea*
HFC-152a	*HFE-236ca12 (HG-10)*
HFC-161	*HFE-236ea2 (Desflurane)*
HFC-227ea	*HFE-236fa*
HFC-236cb	*HFE-245cb2*
HFC-236ea	*HFE-245fa1*
HFC-236fa	*HFE-245fa2*
HFC-245ca	*HFE-254cb2*
HFC-245fa	*HFE-263fb2*
HFC-365mfc	*HFE-329mcc2*
HFC-c-447ef	*HFE-338mcf2*
HFC-43-10mee	*HFE-338pcc13 (HG-01)*
Sulfur hexafluoride	*HFE-347mcc3*
Trifluoromethyl sulphur pentafluoride	*HFE-347mcf2*
Nitrogen trifluoride	*HFE-347pcf2*
PFC-14	*HFE-356mec3*
PFC-116	*HFE-356pcc3*
PFC-218	*HFE-356pcf2*
Perfluorocyclopropane	*HFE-356pcf3*
PFC-3-1-10	*HFE-365mcf3*

HFE-374pc2	*(Octafluorotetramethy-lene) hydroxymethyl group*
HFE-449sl (HFE-7100) Chemical blend	*HFE-347mmy1*
HFE-569sf2 (HFE-7200) Chemical blend	*Bis(trifluoromethyl)-methanol*
Sevoflurane	*2,2,3,3,3-pentafluoropropanol*
HFE-356mm1	*PFPMIE*
HFE-338mmz1	*Carbon dioxide (biogenic)*

b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: GWPs as indicated in EPA Mandatory Reporting Rule, Federal Register, Friday, October 30, 2009, Table A-1 to Subpart A of Part 98.

c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: Direct measurement and emissions factors.

3. Information quality:

a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: Self-reported by Federal agencies

b. What approaches are used to ensure data quality, if any?

A: Agency-level audits. Review of annual data submissions by DOE Federal Energy Management Program. A limited set of agencies, e.g. United States Postal Service, may employ third-party auditing.

Additional elements your agency may wish to include if available/applicable

9. Changes since NC7/BR3-4

a. What changes to the methodology occurred?

A: n/a

b. If applicable, do these changes increase or decrease historic values or projections?

A: n/a

10. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

A: Most: Policy targets Scopes 1, 2, and 3. Currently report and track Scopes 1 and 2. Scope 3 data expected in 2023.

11. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

A: No

12. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: Mandatory reporting under US EPA GHGRP (Greenhouse Gas Reporting Program (GHGRP) | US EPA). Certain military installations are required to report emissions through this program. Additionally, emissions from power plants reported under EPA's program could be included as Scope 2 emissions in Federal operations.

Section 1703/1705 Loan Guarantee Program

Sector: Cross-Cutting

Agency Name: U.S. Department of Energy

Key parameters for policy and measures GHG benefits methodology documentation for BR5

1. Timeframe:
   a. In what year did the program start?

A: The Loan Program was authorized under Title XVII of the Energy Policy Act of 2005, specifically Section 1703. The American Recovery and Reinvestment Act of 2009 amended the Energy Policy Act of 2005 by adding Section 1705. Section 1705 was created as a temporary program, and 1705 loan guarantee authority ended on September 30, 2011. The Loan Program was implemented under a Final Rule issued on December 4, 2009.

   b. If emissions were calculated using a year other than the start year as the "zero" point for reductions, what was that year?

A: The Title XVII Program calculates emissions reductions each year starting in FY 2011.

2. Emissions:
   a. Which gases are measured?

A: CO_2

   b. For non-CO_2 gases, what global warming potential (GWP) values were used?

A: N/A. Section 1703/1705 measures CO2 reductions only.

   c. How are GHG impacts measured? (direct measurements, emissions factor, modeling)

A: The impacts are measured using emissions factors based on either direct measurement of electricity generated for past years or an estimate of the electricity that will be generated for future years.

Calculation Details:

Annual Avoided CO2 is calculated from electricity generation directly (2011, 2013) or estimated (2015, 2020) in MWh from the renewable generation projects for which DOE has closed a loan.

The estimate of future annual generation is calculated by multiplying the capacity of the facility in MW by the average annual capacity factor for the project's technology and converting the years to hours for MWh units.

The CO2 avoided by the renewable projects assumes the renewable energy generated displaces the CO2 that would have otherwise been emitted by U.S. generating facilities and is calculated using EIA actual data for emissions emitted from the net electricity produced in the US in 2011.

The 2013 EIA estimate of annual U.S. Electric Power Industry Net Generation is 4,065,964,000 MWh. Website: http://www.eia.gov/electricity/annual/

The 2013 U.S. Energy Information Administration (EIA) estimate of annual CO2 Emissions from Energy Consumption at Conventional Power Plants and Combined-Heat-and-Power Plants is 2,180,316,000 Metric Tonnes. Website: http://www.eia.gov/electricity/annual/html/epa_09_01.html

Using the 2013 EIA data, the calculation is:

$$Annual\ CO_2 Avoided = \left[\frac{Project's\ Annual\ Generation\ Output\ (MWh)}{4{,}065{,}964{,}000\ MWh}\right] * 2{,}180{,}316{,}000\ tonnes$$

Or

$$Annual\ CO_2 Avoided = Project's\ Annual\ Generation\ Output\ (MWh) * 0.5362\ tonnes$$

3. Information quality:
   a. What are the primary data sources used? (Federal estimates, industry reports, self-reporting, etc.)

A: Industry Reports and Federal emissions factors are used.

   b. What approaches are used to ensure data quality, if any?

A: Site visits to verify and validate facilities are operating in accordance with the Projects' reporting.

Additional elements your agency may wish to include if available/applicable

1. Changes since NC7/BR3-4
   a. What changes to the methodology occurred?

   A: The Title XVII Projects were not selected for the last CAR, so no estimates were included.

   b. If applicable, do these changes increase or decrease historic values or projections?

   A: N/A. See part a. of this question.

2. Do these measured GHG impacts reflect all, most, or just some of the actions which your policy or measure targets to reduce GHG emissions?

   A: The measures reflect only closed loans and direct emissions reductions. Additional Loan authority exists for renewable, fossil, and nuclear.

3. Does your methodology account for GHG impacts related to actions that are occurring outside of its primary actions or sector (such as broader market impact or lifecycle effects)?

   A: No

4. Are there other federal policies and measures that measure GHG impacts from similar or related actions? If applicable, does the program's methodology adjust for potential double counting?

A: Yes, other policies/measures that reduce GHG emissions from the electric power sector could potentially double count emissions reductions from this policy/measure. No, this methodology does not adjust for potential double counting

Annex 4.

METHODOLOGY FOR PROJECTED GREENHOUSE GAS EMISSIONS

Annex 4. METHODOLOGY FOR PROJECTED GREENHOUSE GAS EMISSIONS

Methodology

This annex describes the methodology used for Chapter 5 – Projected Greenhouse Gas Emissions.

The 2021 Policy Baseline ("With Measures") projections incorporate energy-related CO_2 emissions from the Energy Information Administration's AEO2022 Reference Case, with adjustments to reflect categorization of emissions in the UNFCCC and in the U.S. Inventory of Greenhouse Gas Emissions and Sinks: 1990-2020. Non-energy CO_2 and non-CO_2 greenhouse gas emissions projections are developed by EPA and USDA. The land use, land use change, and forestry projections are developed by EPA, USDA, and the U.S. Forest Service (USFS). These projections are based on the Global Timber Model (GTM), the Forest and Agriculture Sector Optimization Model with Greenhouse Gases (FASOMGHG), and results from the USFS Resources Planning Act (RPA) Forest Dynamics model, Land Use Change model, and Global Trade Model (FOROM).

For descriptions of methods used in the preliminary analysis of the Inflation Reduction Act and reductions beyond BIL and IRA (Box 5.1), please see the methodological appendix to the DOE's preliminary assessment of the IRA and BIL,[575] and the U.S. Long-Term Strategy.[576]

Description of NEMS Methodology

NEMS is organized and implemented as a modular system. The modules represent each of the fuel supply markets, conversion sectors, and end-use consumption sectors of the energy system. NEMS also includes macroeconomic and international modules. The primary flows of information among the modules are the delivered prices of energy to end users and the quantities consumed by product, region, and sector. The delivered fuel prices encompass all the activities necessary to produce, import, and transport fuels to end users. The information flows also include other data on such areas as economic activity, domestic production, and international petroleum supply. Each NEMS component represents the impacts and costs of existing legislation and environmental regulations that affect that sector. NEMS accounts for all combustion-related CO_2 emissions, as well as emissions of sulfur dioxide, nitrogen oxides, and mercury from the electricity generation sector. The potential impacts of pending or proposed federal and state legislation, regulations, or standards—or of sections of

[575] https://www.energy.gov/policy/methodological-appendix
[576] https://whitehouse.gov/wp-content/uploads/2021/10/US-Long-Term-Strategy.pdf

legislation that have been enacted but that require funds or implementing regulations that have not been provided or specified—are not reflected in NEMS.

Key Variables and Assumptions

Table A4-1 summarizes key variables and assumptions used in the projections included in this report, while Table A4-2 captures changes in key socioeconomic factors over time.

Table A4-1: Summary of Key Variables and Assumptions Used in the Projections Analysis

		Historical				Projected		
Key Factor	Units	2005	2010	2015	2020	2025	2030	2035
Energy Intensity	Thousand Btu per Chained (2012) Dollar	6.7	6.2	5.6	5.1	4.5	4.1	3.7
Population	millions	295.5	309.3	320.6	331.5	338.1	347.3	355.9
Real Gross Domestic Product	Billion chained (2012) dollars	14,901.3	15,649.0	17,390.3	18,384.7	22,061.1	24,555.0	27,278.8
Coal Consumption	Quads	22.8	20.8	15.6	9.2	8.5	7.9	7.1
Natural Gas Consumption	Quads	22.6	24.6	28.2	31.5	31.6	31.5	31.7
Petroleum Consumption	Quads	40.2	35.3	35.4	32.3	38.0	37.8	37.9
Total Primary Energy Consumption	Quads	100.1	97.5	97.4	93.0	99.8	100.0	100.8
Vehicle Miles Travelled	Billion miles	2,989.4	2,967.3	3,095.4	2,895.7	3,502.2	3,655.3	3,770.9

Table A4-2: Comparison of Key Factors to Previous National Communications and Biennial Reports

		Assumptions For 2040			
Key Factor	Units	2014 NC	2016 BR	2021 NC	2022 NC
Population	Millions	372.00	359.00	353.00	347.00
Real GDP	Billion dollars	29,172.66	29,655.13	27,625.58	29,000.00
Energy Intensity	Btu per dollar of GDP	3,521.40	3,472.39	3,565.50	3,446.00
Light-Duty Vehicle Miles Traveled	Billion miles	3,323.00	3,287.00	3,121.00	3,207.00
Average Imported Crude Oil Cost	Dollars per barrel	151.35	111.85	73.29	70.00
Henry Hub	Dollars per MMBtu	6.50	6.62	3.50	3.46
Minemouth Coal Price	Dollars per ton	67.03	50.83	30.78	30.90
Average Electricity Price	Cents per kilowatt-hour	11.69	12.91	10.78	10.60
All-Sector Motor Gasoline Price	Dollars per gallon	4.42	3.72	2.93	2.80
Energy Consumption	Quadrillion Btu	103.00	103.00	99.00	100.00

Changes in Current Policy Projection Methodology from Previous Reports

The projections in this chapter are compiled using the same approach as used in past reports such as the 2021 National Communication and 2016 Biennial Report. Updated versions of data sources and modeling have been used, and each of the underlying data sources reflected updated characterization of macroeconomic, technology, and policy.

Energy CO_2 Projections Methodology

Emissions projections of CO_2 from fossil fuel combustion are drawn from the EIA Annual Energy Outlook 2022 (AEO2022). The AEO2022 is based on the National Energy Modeling System (NEMS), described below. Adjustments are made to the results of the AEO2022 Reference scenario as part of their use in the 2021 Policy Baseline presented here in order to conform to international reporting conventions and categorization and to make them as consistent as possible with the historical greenhouse gas inventory, described below.

Adjustments to the Annual Energy Outlook Results

The primary adjustments to energy CO_2 emissions projections from AEO are:

- The AEO energy CO_2 totals include emissions from international shipping and air travel. These emissions are not included in the totals for the projections in this chapter per UNFCCC reporting conventions for international bunker fuel emissions.
- Emissions from U.S. territories are not generally included in AEO energy CO_2 totals, so they are added in for the purpose of the projections in this chapter.
- Emissions from feedstock and process uses of fossil fuels are included in the AEO, but do not fully encompass the emission estimated as part of the non-energy uses of fossil fuels category in the Inventory. Estimates for the 2021 Policy Baseline are adjusted to reflect the full scope comparable to historical estimates.
- Sectoral and source categorization are adjusted to reflect designations used in the greenhouse gases inventory, which sometimes differ from the economic sector categorizations in the AEO (e.g., industry CO_2 emissions in the AEO included in the energy sector here).

Non-Energy CO_2 and Non-CO2 GHG Projections Methodology

Non-energy CO_2 and non-CO_2 GHG emissions projections are developed by EPA and USDA. CH_4 and N_2O projections for the agriculture sector are developed by USDA. Projection methodologies are informed by calculation methodologies published by the IPCC for inventory calculations. EPA used information from the most recent greenhouse gas inventory as the starting point for emissions and underlying activities. EPA projected changes in activity data and emission factors from that base year. Activity data projections include macroeconomic drivers such as population, gross domestic product, and energy use, and source-specific activity data such as fossil fuel production, industrial production, or livestock population and crop production. Where possible, activity projections were drawn from the

EIA AEO, USDA Long-Term Agricultural Projections, or EPA Vintaging Model for HFCs from ODS-substitutes. Future changes in emissions factors were based on continuation of past trends and expected changes based on implementation of policies and measures. The methodology document with drivers and equations for each source was published in 2013.

USDA projections for agriculture sector CH_4 and N_2O start by using activity data and emissions factor from the 2022 GHGI for historical years and extend to future years assuming a continuation of current trends in acres, production, and yields in the 2022 USDA Long-Term Agricultural Projections.

LULUCF Methodology

To better reflect the uncertainties associated with estimating the complex carbon dynamics of different terrestrial ecosystems and related market interactions, and the potential extent of land use change between sectors, the U.S. LULUCF projections through 2035 are presented in Figure 5-5. This range was developed via a collaborative multi-agency effort using different models reflecting alternate modeling techniques. Using different model types in concert allows for a more robust range of projections. These models represent different perspectives on future macroeconomic outlooks (derived from recent U.S. Government projections for GDP, population, and forest products demand) as well as forest characteristics and management trends.

The high sequestration projection range reflects results from EPA using a dynamic intertemporal optimization forestry model (the Global Timber Model) (Sohngen and Mendelsohn 2003, Baker et al 2019, Austin et al 2020). [577] This model's approach provides a simulation of harvesting, planting, and management intensity (e.g., variety of selection, fertilizer, water management, thinning) decisions that landowners might undertake in response to timber and carbon market demands, including future price expectations. Specifically, it is a dynamic intertemporal economic model that determines timber harvests, timber investments, and land use optimally over time under assumed future market, policy, and environmental conditions. The model generates projections using detailed biophysical and economic forestry data for different countries/regions globally, including the U.S., Europe, China, Canada, Russia, and Japan. It used macroeconomic data from AEO2022 for the U.S. and global parameters from Shared Socioeconomic Pathway 2 (SSP2) (Riahi et al

[577] Austin, K.G., Baker, J.S., Sohngen, B.L., Wade, CM, Daigneault, A. Ohrel, SB, Ragnauth, S, and Bean, A. 2020. The economic costs of planting, preserving, and managing the world's forests to mitigate climate change. Nature Communications 11, 5946 https://doi.org/10.1038/s41467-020-19578-z
Baker, J.S., Wade, C.M., Sohngen, B.L., Ohrel, S. and Fawcett, A.A. 2019. Potential complementarity between forest carbon sequestration incentives and biomass energy expansion. Energy Policy. 126: 391-401.
Sohngen, B. and R. Mendelsohn. 2003. "An Optimal Control Model of Forest Carbon Sequestration" American Journal of Agricultural Economics. 85(2): 448-457.

2016).[578] Key updates to the model since the 2021 BR include: 1. Recalibration of the prices and relative proportions of pulpwood and sawtimber volumes and 2. Updated data for European Union forests. On net, these changes resulted in slightly smaller projected volume of U.S. forest CO_2 fluxes in the 'with measures' scenario versus the 2021 BR. The model also was updated to include parameters from the AEO 2022, though the impacts of this update element were minimal.

Also used to inform this analysis is the Forest and Agriculture Sector Optimization Model with Greenhouse Gases (FASOMGHG), which constitutes the middle range of estimates shown. FASOMGHG is a partial equilibrium dynamic optimization model of the U.S. forestry and agriculture sectors (Beach et al 2010, Latta et al 2013, Wade et al 2022).[579] FASOMGHG includes detailed representations of agricultural and forest product markets, contemporary forest inventories, inter-sectoral resource competition and land change costs, and costs of mitigation strategies. Specifically, FASOMGHG's detailed representation of the entire U.S. land base is brought into the solution maximizing consumer and producer surplus across the agricultural and forestry sectors, and represents production possibilities for crop production, livestock production, and forestry production. The result provides insight into cross-sectoral inter- and intra-regional responses to policy stimuli reflecting the spatial heterogeneity in production of agriculture and forestry products across the U.S. Key model updates since the 2021 BR include: 1. Updated costs associated with transportation and harvests and 2. Lengthened modeling timeframe (from 2080 to 2100). Updates that influence results to a lesser extent include new accounting for forest product carbon quantities, which are determined endogenously in the model, and inclusion of the AEO2022 macroeconomic information.

The lower sequestration projection range includes results from the USFS Resources Planning Act (RPA) modeling system which includes the Forest Dynamics model (Coulston et al. 2022),

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[578] Riahi, K., Van Vuuren, D.P., Kriegler, E., Edmonds, J., O'neill, B.C., Fujimori, S., Bauer, N., Calvin, K., Dellink, R., Fricko, O. and Lutz, W., 2017. The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview. *Global environmental change*, *42*, pp.153-168.

[579] Beach, R., Adams, D., Alig, R., Baker, J., Latta, G., McCarl, B. A., Murray, B., Rose, S., & White, E. 2010. Model documentation for the Forest and Agricultural Sector Optimization Model with Greenhouse Gases (FASOMGHG). U.S Environmental Protection Agency.
Latta, G. Justin S. Baker, Robert H. Beach, Steven K. Rose, Bruce A. McCarl. 2013. A multi-sector intertemporal optimization approach to assess the GHG implications of U.S. forest and agricultural biomass electricity expansion,
Journal of Forest Economics, Volume 19, Issue 4.
Wade C. M., J. S. Baker, J. P. H. Jones, K. G. Austin, Y. Cai, A. B. de Hernandez, G. S. Latta, S. B. Ohrel, S. Ragnauth, J. Creason, and B. McCarl. 2022. Projecting the Impact of Socioeconomic and Policy Factors on Greenhouse Gas Emissions and Carbon Sequestration in US Forestry and Agriculture. Journal of Forest Economics, 2022, 37: 127–161. DOI 10.1561/112.00000545

[580] Land Use Change model (Mihiar and Lewis 2021),[581] and Global Trade Model (FOROM, Johnston et al. 2021).[582] The RPA modeling system is tied to growth under SSP2, which suggests moderate rates of population and socioeconomic growth in the United States (Wear and Prestemon 2019).[583] The Forest Dynamics Model, the Land Use Change Model and FOROM are harmonized based on timber prices and inventory growth rates, and driven by shifts in population, income, and radiative forcing (RCP 8.5 from the NorESM1-M climate model). The land use change projections also account for differential land rents among land uses. The Forest Dynamics Model projects forest ecosystem carbon and other land converted to forest carbon. The FOROM model projects harvested wood products carbon. The WOODCARB II model offered by Skog (2008) is used to project wood products carbon stored in solid waste disposal site Key model updates since the 2021 BR include: incorporating additional management strategies to combat the wildfire crises (USFS 2022) and planting on additional non-stocked Forest Service land.

The U.S. forest representation for all three modeling approaches above is derived from the USFS U.S. forest inventory data (Forest Inventory and Analysis, FIA). The results include representation of the following forest carbon pools: aboveground live biomass (including trees, seedlings, and saplings), belowground live biomass such as roots, litter, and soil carbon, deadwood, and harvested wood products. Projected CO_2 estimates for urban forests, agricultural soils and landfilled yard trimmings/food scraps were not produced by the models discussed above but derived by USDA using projection methodologies based off the U.S. Inventory of Greenhouse Gas Emissions and Sinks: 1990-2020 (EPA 2022).

GDP, population, and bioenergy demand within GTM and FASOMGHG are based on EIA's Annual Energy Outlook 2022 for the U.S. and global parameters are aligned with SSP2 expectations for this analysis (Riahi et al, 2017).[584] The USDA-FS approach also follows SSP2 expectations as well as observed U.S. population and income changes rates. Increased carbon fertilization (above that embodied in the historic data) and climate change are

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[580] forthcoming
[581] forthcoming
[582] Johnston, C; Guo, J; Prestemon, J. 2021. The Forest Resource Outlook Model (FOROM): a technical document supporting the Forest Service 2020 RPA Assessment. Gen. Tech. Rep. SRS-254. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 19 p. https://doi.org/10.2737/SRS-GTR-254.
[583] Wear, David N.; Prestemon, Jeffrey P. 2019. Spatiotemporal downscaling of global population and income scenarios for the United States. PLOS ONE. 14(7): e0219242. 19 p. https://doi.org/10.1371/journal.pone.0219242.
[584] Riahi, K., Van Vuuren, D.P., Kriegler, E., Edmonds, J., O'neill, B.C., Fujimori, S., Bauer, N., Calvin, K., Dellink, R., Fricko, O. and Lutz, W., 2017. The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview. *Global environmental change*, *42*, pp.153-168.

included in the GTM estimates, but they are not accounted for in the FASOMGHG and USFS models' projections.

U.S. CLIMATE AMBITION REPORT

Annex 5.

PROVISION OF PUBLIC FINANCIAL SUPPORT TABLES

Annex 5. PROVISION OF PUBLIC FINANCIAL SUPPORT TABLES

Table A5-1: Provision of Public Financial Support: Contributions Through Multilateral Channels FY19-FY20

Donor Funding	Total Amount				Status	Funding Source	Financial Instrument	Type of Support	Sector
	Core/General		Climate-Specific						
	Domestic Currency	USD	Domestic Currency	USD					
2019									
Total contributions through multilateral channels									
Multilateral climate change funds									
1. Global Environment Facility	135,575,000.00	135,575,000.00	118,821,000.00	118,821,000.00	Committed	ODA	Grant	Cross-cutting	Cross-cutting
2. Least Developed Countries Fund									
3. Special Climate Change Fund									
4. Adaptation Fund									
5. Green Climate Fund									
6. UNFCCC Trust Fund for Supplementary Activities									
7. Other multilateral climate change funds									
Multilateral financial institutions, including regional development banks									
1. World Bank	1,097,010,000.00	1,097,010,000.00			Committed	ODA	Grant		
2. International Finance Corporation									
3. African Development Bank	203,717,159.00	203,717,159.00			Committed	ODA	Grant		

4. Asian Development Bank	47,395,000.00	47,395,000.00			Committed	ODA	Grant		
5. European Bank for Reconstruction and Development									
6. Inter-American Development Bank									
7. Other									
Specialized United Nations bodies									
1. United Nations Development Programme									
2. United Nations Environment Programme									
3. Other									
Montreal Protocol Multilateral Fund	31,000,000.00	31,000,000.00	31,000,000.00	31,000,000.00	Committed	ODA	Grant	Mitigation	Cross-cutting
UNFCCC Trust Fund for the Core Budget	2,510,000.00	2,510,000.00	2,510,000.00	2,510,000.00	Committed	ODA	Grant	Cross-cutting	Cross-cutting
Intergovernmental Panel on Climate Change	400,000.00	400,000.00	400,000.00	400,000.00	Committed	ODA	Grant	Cross-cutting	Cross-cutting
Global Climate Observing System	90,000.00	90,000.00	90,000.00	90,000.00	Committed	ODA	Grant	Cross-cutting	Cross-cutting
2020									
Total contributions through multilateral channels									
Multilateral climate change funds									
1. Global Environment Facility	135,575,000.00	135,575,000.00	118,821,000.00	118,821,000.00	Committed	ODA	Grant	Cross-cutting	Cross-cutting
2. Least Developed Countries Fund									
3. Special Climate Change Fund									

4. Adaptation Fund									
5. Green Climate Fund									
6. UNFCCC Trust Fund for Supplementary Activities									
7. Other multilateral climate change funds									
Multilateral financial institutions, including regional development banks									
1. World Bank	1,303,510,000.00	1,303,510,000.00			Committed	ODA	Grant		
2. International Finance Corporation									
3. African Development Bank	171,300,000.00	171,300,000.00			Committed	ODA	Grant		
4. Asian Development Bank	47,395,000.00	47,395,000.00			Committed	ODA	Grant		
5. European Bank for Reconstruction and Development									
6. Inter-American Development Bank									
7. Other									
Specialized United Nations bodies									
1. United Nations Development Program									
2. United Nations Environment Program									
3. Other									
Montreal Protocol Multilateral Fund	32,000,000.00	32,000,000.00	32,000,000.00	32,000,000.00	Committed	ODA	Grant	Mitigation	Cross-cutting
UNFCCC Trust Fund for the Core Budget	5,600,000.00	5,600,000.00	5,600,000.00	5,600,000.00	Committed	ODA	Grant	Cross-cutting	Cross-cutting
Intergovernmental Panel on Climate Change	800,000.00	800,000.00	800,000.00	800,000.00	Committed	ODA	Grant	Cross-cutting	Cross-cutting
Global Climate Observing System	200,000.00	200,000.00	200,000.00	200,000.00	Committed	ODA	Grant	Cross-cutting	Cross-cutting

Table A5-2: Summary of provision of bilateral financial support FY2019-2020

	Clean Energy	Adaptation	Sustainable Landscapes	Total
Total Bilateral Climate Finance	2230	484	352	3067
Multiple Countries and Regions	44	165	63	271
Africa				
Burkina Faso	289			289
Burundi	11			11
Cameroon	1			1
Central African Republic	6			6
Chad	10			10
Cote d'Ivoire	10			10
Egypt	84			84
Ethiopia	1	45		46
Ghana	1		2	3
Kenya	26	9	1	35
Liberia			5	5
Madagascar		7	2	9
Malawi	53	5	6	65
Mali		3		3
Mozambique	3	3		6
Niger		10		10
Nigeria	4	2		6
Rwanda		5		5
Senegal	315	8		323
Sierra Leone	1			1
Somalia	1			1
Tanzania		15		15
Uganda	1	7	2	9
Zambia	3		8	11
Zimbabwe		26		26
Multiple Countries	120	14	29	163
Asia				
Bangladesh	1	12	9	22
Burma	1			1
Cambodia		3	14	17
India	522	21	12	555
Indonesia	3	4	13	20
Kazakhstan	2			2
Laos	9			9
Malaysia		1		1
Maldives		4		4
Marshall Islands		<1		<1
Micronesia		<1		<1
Mongolia		<1		<1
Nepal	3	6	0	9
Pakistan	1			1

Papua New Guinea	1			1
Philippines	5	6	13	24
Sri Lanka	8	2		10
Tajikistan	3			3
Thailand	1			1
Timor-Leste		2		2
Uzbekistan	1			1
Vietnam	5	3	13	22
Multiple Countries	15	18	17	51

Europe and Eurasia				
Armenia	6	<1		6
Bosnia and Herzegovina	2			2
Georgia	10			10
Kosovo	5			5
Moldova	2	1		3
North Macedonia	1			1
Serbia	5			5
Ukraine	15			15
Multiple Countries	10			10

Latin America & Caribbean				
Argentina	288			288
Barbados and Eastern Caribbean		1		1
Brazil	14	25	25	64
Colombia	13	10	26	49
Dominican Republic	3	2		5
Ecuador	2		4	6
Guatemala	4	2	14	20
Haiti		21	9	29
Honduras		5		6
Jamaica	2	1		3
Mexico	243		17	260
Peru		3	26	29
Multiple Countries	22	9	23	54

Middle East				
Jordan	5			5
Lebanon	7			7
Pakistan	<1			<1
Tunisia	8			8

Values in millions of USD; No regional totals are provided as "multiple region" and "global" funds also go to each region.

Annex 6.

METHODOLOGY FOR REPORTING FINANCIAL INFORMATION

Annex 6. : METHODOLOGY FOR REPORTING FINANCIAL INFORMATION

The UNFCCC reporting guidelines for national communications and biennial reports also specify that Parties are to provide the underlying methodology for all financial assistance provided (UNFCCC 2013a). Specifically, the guidelines state: "Parties shall report in a rigorous, robust and transparent manner the underlying assumptions and methodologies used to produce information on finance."

The United States conducted an interagency process to compile methodology documents for all figures for financial assistance provided in the BR, particularly those figures listed in Table 7, 7(a) and 7(b) of the Common Tabular Formatting of the Fifth BR.

Pursuant to paragraph 15 of the 2011 UNFCCC biennial reporting guidelines for developed country Parties, this appendix provides background information on the underlying assumptions and methodologies used to produce information on finance for the Fifth BR. Specifically, this appendix describes:

- The overall methodology used for producing information on finance for the BR,
- The methodology for determining which funds are "climate-specific,"
- The methodology used to specify funds as "committed,"
- The methodology used for reporting core/general contributions through multilateral channels, and
- Other methodological issues.

OVERALL METHODOLOGY FOR PRODUCING INFORMATION ON CLIMATE FINANCE

The Fifth BR covers U.S. international climate finance for FY 2019-2020 (October 1, 2018, through September 30, 2020). U.S. international climate finance is provided through the following channels:

- Grant-based finance, which is delivered through both bilateral and multilateral channels, and includes foreign assistance funding for international development through USAID, the Departments of State and Treasury, and MCC;
- Development finance through DFC; and
- Export credit finance through Ex-Im.

To ensure accurate and comprehensive reporting, interagency data requests were issued government-wide for in 2019 and 2020 to request information on climate-related international programs or activities supported with FY 2019-20 resources. In addition, DOS and USAID issued internal data calls for climate-related finance as part of their annual Operational Plan process.

METHODOLOGY FOR DETERMINING WHICH FUNDS ARE "CLIMATE-SPECIFIC"

Climate-specific funds reported in the 2022 national communication and biennial report are those assessed to support climate adaptation or mitigation. This includes activities that were conceived and funded specifically to achieve climate-related objectives, as well as activities that provide climate co-benefits. In cases where only a portion of a program's budget supports climate benefits, only that relevant fraction was counted—not the entire program budget. U.S. international climate finance is categorized under the three thematic pillars:

- Adaptation—increasing resilience to the impacts of climate change;
- Clean Energy—reducing greenhouse gas emissions from energy, industry, and transportation by greater use of renewable energy, increased energy efficiency, and other means; and
- Sustainable Landscapes—reducing greenhouse gas emissions from forests, agriculture and land use.

Further details on each pillar follow. These details are specific to the data in the 2022 national communication and biennial report (i.e., data for FYs 2019-20) and are subject to change in future reporting.

ADAPTATION

Adaptation activities seek to reduce the vulnerability of people, places, and livelihoods to the negative impacts of climate change. Adaptation will help people, communities and countries anticipate, and prepare for current and future climate impacts. Adaptation can save lives, reduce food and water insecurity and malnutrition, and improve health outcomes.

Adaptation may include activities from a broad array of sectors, including but not limited to national and sub-national adaptation planning, agriculture, food security, nutrition, natural resource management, infrastructure, health, water, disaster preparedness and recovery, disaster risk finance, governance, economic growth, education, urban resilience, coastal management, and conflict prevention. Adaptation activities include, but are not limited to activities that:

CLIMATE INFORMATION AND SERVICES

- Deepen understanding of climate risks, vulnerabilities, and adaptation solutions;
- Support the expanded development, innovation, use, and delivery of climate information services, decision support tools, and early warning systems;

DIRECT INVESTMENTS IN RESILIENT INFRASTRUCTURE AND ADAPTATION IN KEY SECTORS

- Provide resilient, stable power supply for facilities responsible for continuation of provision of essential services during disasters or other disruptions;
- Develop and support the implementation of flood management infrastructure, management plans, zoning and building codes, or coastal zone management activities, to reduce vulnerability to rising sea levels, saltwater intrusion into ground water, and storm surges;
- Develop and increase the adoption of climate-smart agriculture practices and approaches from farm to landscape levels, promoting management practices that increase the ability of agricultural households and communities to maintain livelihoods in the face of climate change impacts;
- Increase the resilience of water and sanitation products and services, and which address water scarcity and unpredictability through improved water resources management;

HEALTH

- Support access to climate resilient health services and facilities and ensure continuation of essential services during disruptions;
- Integrate climate information into health early warning systems and link those to health management information systems and community health systems;
- Provide extra support for vulnerable populations, such as children and pregnant people, and for patients on treatment (especially for TB and HIV/AIDS) in areas that regularly experience climate-related food insecurity to ensure the treatment is uninterrupted and is effective;
- Address air pollution worsened by increasing temperatures associated with climate change;

GOVERNANCE, POLICIES, AND ENABLING ENVIRONMENTS

- Support governance and management processes to address climate-related risks, including activities that improve the capacity of national, sub-national and municipal level governments to assess and embed climate risks into their budgets, plans, policies, and operations; improving coordination by government institutions on climate change adaptation policy and implementation;
- Increase public, civil society, and private sectors’ awareness of and participation in climate change adaptation policy, planning, and action;

- Support locally-led adaptation that enables climate-vulnerable communities and people to meaningfully participate in and lead adaptation-related decisions;
- Strengthen government and local community response and communications capacity for climate change-related disasters, including supporting governments to develop comprehensive risk management and anticipatory financing plans, as well as develop shock responsive and adaptive social protection programs that reduce negative impacts of climate shocks and stresses;
- Promote or establish critical preconditions for future adaptation activities, including the development or reform of planning, policies, laws, regulations, and institutions;
- Strengthen capacity to access finance for adaptation and develop bankable investments, including climate and disaster risk financing, and private capital;

MIGRATION

- Strengthen local governance and inclusive approaches that empower and increase the resilience of populations most vulnerable to climate impacts, including migrants;
- Address climate-related migration and/or planned relocation by working with people in place and migrants to limit displacement and support safer and more productive migration, including in sending and receiving communities.

CLEAN ENERGY

Clean Energy activities seek to enable reliable, efficient, sustainable, and secure energy systems by promoting and enabling the production, procurement, and use of zero-carbon and clean energy technologies. Clean energy will help to reduce the emission of greenhouse gasses that contribute to climate change. All non-land-based activities which aim to reduce the emission of greenhouse gasses that contribute to climate change are included under this pillar. Clean energy activities include, but are not limited to, the following activities that support the:

DIRECT INVESTMENTS IN CLEAN ENERGY

- Promotion, deployment, and management of renewable energy in all end-use sectors;
- Decarbonization technologies and pathways across energy-producing and –consuming sectors, including power, transport, industry, and buildings;
- Use of renewable energy and non-carbon intensive technologies to produce alternative fuels such as hydrogen;

- Distributed energy resources such as photovoltaic (PV) power and energy storage;
- Accelerated retirement of emissions-intensive power plants (especially coal-fired facilities), including technical, financial, environmental and social activities necessary to enable this objective;
- Reduction of methane, black carbon, and hydrofluorocarbons, collectively known as short-lived climate pollutants (SLCPs);
- Nuclear for production, direct use, and electricity generation, including the improvement of existing generation, including expenditures that are intended to integrate renewable energy systems into advanced nuclear technologies;
- Utilization of Carbon Capture, Utilization and Storage (CCUS) technologies and/or SLCP mitigation approaches to reduce the emissions intensity of existing coal, oil and natural gas equipment or infrastructure;

ENERGY STORAGE, EFFICIENCY, AND MANAGEMENT

- Energy storage, smart grids, and the deployment and management of energy efficiency and demand-side management measures (including efficient appliances and machinery, building designs, and consumer behavior change) designed to reduce energy intensity and/or moderate demand;
- Investments in transmission and system operations that enable or increase the evacuation, transport and trade in clean energy, including energy storage;
- Transmission and distribution infrastructure that advances clean-energy goals. This includes such infrastructure that substantially reduces transmission and distribution losses; connects to current or future clean energy generation; promotes regional energy integration that advances reserve sharing and grid stability;
- End-use energy efficiency and flexible demand, including in the transportation, industry, and building and construction sectors;

GOVERNANCE, POLICIES, AND ENABLING ENVIRONMENTS

- Facilitation of the design of or technical support for the development and implementation of clean energy programs and their components;
- Reforms that significantly improve cost recovery and establish the financial capacity in the power sector to make investments in clean energy;
- Market-based instruments, including Measurement, reporting, and Verification (MRV), and power sector planning including advanced considerations beyond just

least cost, such as resilience and the environment, to address environmental externalities;

- Transport programs such as analysis and planning, regulatory and policy reform, and financing and market development for electric vehicles and/or low-carbon mass transit and transport alternatives;
- Preparation and implementation of clean energy components of Nationally Determined Contributions (NDCs), and Long-Term Strategies (LTS);
- Promote or establish critical preconditions for future clean energy activities, including the development or reform of planning, policies, laws, regulations, and institutions;
- Workforce development and financial system strengthening designed to enhance the ability of countries to effectively staff and finance activities related to clean energy deployment, energy efficiency and other areas covered under this definition;

CRITICAL MINERALS AND SUPPLY CHAINS

- Clean energy technology supply chain resiliency, such as efforts to sustainably diversify, commercialize, and govern critical energy mineral sector resources, or to encourage the inclusion of responsible mineral supply chain sourcing principles in national climate strategies and procurement plans.

SUSTAINABLE LANDSCAPES

Sustainable Landscapes activities seek to reduce greenhouse gas emissions from land by promoting sustainable land use practices that reduce emissions or increase carbon sequestration. These programs support the implementation of natural climate solutions, which reduce net greenhouse gas emissions through the conservation, management, and restoration of forests, peatlands, mangroves, and other ecosystems, as well as low emissions practices in agriculture and other production systems, while supporting economic growth, resilience, and other co-benefits.

Sustainable Landscapes activities focus on reducing emissions, and can include, low emissions land use planning, Reducing Emissions from Deforestation and Forest Degradation (REDD+), improved data and analytical tools, monitoring, reporting, and verification systems; enabling laws and policies, effective implementing institutions, social and environmental safeguards, access to finance, mobilizing finance, work with banks, financial institutions, and participants in commodity supply chains, technical assistance, promotion of rule-of-law, governance, transparency, and programs to counter corruption, promoting enabling environments, including for engagement in market mechanisms and results-based finance, assistance with national policy, economic incentives, and low emissions agriculture. Sustainable Landscapes activities include, but are not limited to activities that support:

DIRECT INVESTMENTS IN SUSTAINABLE LANDSCAPES

- Biodiversity conservation which leads to reduced deforestation and associated emissions;
- Creation or effective management of protected areas where there is a risk of illegal deforestation, degradation or land conversion that would result in increased emissions;

LAND TENURE

- Improving land tenure systems that result in communities incentivized to manage and restore forested areas, resulting in increased carbon sequestration in tree biomass;
- Land tenure reform or improved land use planning for agriculture that results in reducing the conversion of high carbon natural habitats and associated emissions;

ECOSYSTEM RESTORATION OR PROTECTION

- Restoring wetlands to increase fisheries production that also returns wetland carbon storage potential, thus increasing carbon sequestration;
- Increasing tree cover on the landscape through practices such as living fences, shelterbelts and windbreaks, boundary trees and alley cropping, resulting in increased carbon sequestration;

AGRICULTURE

- Agricultural activity that promotes the incorporation of agricultural residue, leading to lower use of nitrogen fertilizers and associated emissions;
- Working on pasture management to implement improved grazing techniques and fire reduction methods, resulting in improved grassland health and greater carbon sequestration in the soil;

GOVERNANCE, POLICIES, AND ENABLING ENVIRONMENTS

- Developing economic incentives or alternative livelihoods to reduce the conversion of ecosystems in order to protect biodiversity, watersheds, or other ecosystem services that also will result in reduced emissions.

METHODOLOGY USED TO SPECIFY FUNDS AS "COMMITTED"

The common tabular format for UNFCCC biennial reporting includes three options for the status of financial support: "provided," "committed," and "pledged." All public financial support reported in the 2022 national communication and biennial report is considered to be "committed." Details regarding the meaning of "committed" across each of the channels of international climate finance follow:

For *grant-based finance*, funds reported as committed are those that have been appropriated by Congress and allocated by the funding agency for a specific fund, country, project, or program.

For *development finance*, funds reported as committed are those for which a commitment letter is signed and executed by all parties.

For *export credit*, funds reported as committed are those authorized by the Ex-Im for that particular purpose.

METHODOLOGY USED FOR REPORTING CORE/GENERAL CONTRIBUTIONS THROUGH MULTILATERAL CHANNELS

For core/general contributions to multilateral channels that do not include a climate-specific component, data shown in the 2022 BR reflect total U.S. contributions to covered institutions, as collected as part of the U.S. government's reporting to the OECD Development Assistance Committee. While a portion of these funds is used by the recipient institutions to finance climate change activities in developing countries, the United States does not include these non-climate-specific contributions in topline numbers presented in the 2022 BR.

OTHER METHODOLOGICAL ISSUES

Common Tabular Formatting Tables 7, 7(a), and 7(b) include four categories for "type of support": Mitigation, Adaptation, Crosscutting, and Other. With the exception of some multilateral funds that are listed as Cross-cutting, U.S. data are presented as follows:

- All U.S. "clean energy" funds, projects, programs, and activities are listed as Mitigation.
- All U.S. "sustainable landscapes" funds, projects, programs, and activities are listed as Mitigation.
- All U.S. "adaptation" funds, projects, programs, and activities are listed as Adaptation.

Tables 7(a) and 7(b) also include several options for "sector": Energy, Transport, Industry, Agriculture, Forestry, Water and Sanitation, Cross-cutting, Other, and Not Applicable (7(a) only). To ensure consistency across the data set, information on sectors is tied directly to the three thematic pillars noted earlier. Specifically, U.S. data are presented as follows:

- All U.S. "clean energy" funds are listed as Energy.
- All U.S. "sustainable landscapes" funds are listed as Forestry and Agriculture.
- All U.S. "adaptation" funds are listed as Cross-cutting.

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