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DELIVERING ON THE U.S. CLIMATE COMMITMENT: A 10-POINT PLAN TOWARD A LOW-CARBON FUTURE

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EXECUTIVE SUMMARY

Mounting evidence indicates that combating climate change is compatible with strong economic growth, and that the benefits of a low-carbon economy can outweigh the costs.[1] Many of the key drivers of economic growth—including more efficient use of resources, infrastructure investments, and technological innovation—can also drive a transition to a lower-carbon economy. This has been demonstrated across the United States, where numerous low-carbon investments are already saving money for businesses and consumers, creating new job opportunities in low-carbon technology sectors, and improving public health.[2]

Ambitious action is needed to avert the worsening impacts of climate change. In the absence of concerted, global efforts, greenhouse gas (GHG) emissions will continue to rise, posing huge economic, social, and environmental risks to the United States, as well as the global community. The year 2014 was the hottest on record, and the impacts of climate change are becoming more frequent and severe, with increasing costs to businesses, consumers, and public health.[3] The United States is already experiencing sea-level rise, higher frequency of flooding, heavier precipitation events, and more frequent heat waves and wildfires.[4]

As the largest economy and the second-largest emitter of GHGs, U.S. leadership is required for a global transition to a low-carbon economy. In this paper, we present pathways that illustrate how the United States could move toward a lower-carbon economy and meet its climate goals in the 2025–30 time frame. The policies we examine to achieve these reductions can encourage and accelerate recent market trends, including more fuel-efficient vehicles

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Working Papers contain preliminary research, analysis, findings, and recommendations. They are circulated to stimulate timely discussion and critical feedback and to influence ongoing debate on emerging issues. Most working papers are eventually published in another form and their content may be revised.

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coming to market and falling prices of renewable energy technologies. This analysis estimates the impact of those pathways on total U.S. emissions, incorporating many of the policies we identified in our 2013 report—*Can The U.S. Get There From Here?*[5]—and our 2014 study entitled *Seeing Is Believing: Creating a New Climate Economy in the United States*.[6]

Our analysis shows that the United States can make deep cuts in GHG emissions while taking advantage of the economic opportunities available in a low-carbon future and providing global leadership on climate change. The Administration has taken steps in this direction with the President's Climate Action Plan, which includes necessary action in several key areas, including power plants, energy efficiency, transport, and others.[7] But to get on track to meet its 2020 emission reduction target (17 percent below 2005 levels)[8] or its 2025 target of 26–28 percent below 2005 levels, the United States will need to go beyond actions taken to date.

We find that the United States can meet, and even surpass, its announced target to reduce GHG emissions by 26–28 percent below 2005 levels in 2025 with a comprehensive approach using existing federal laws and state action. This would include expanding and strengthening some current and proposed policies and standards and taking new action across emission sources that are not yet addressed. Figure ES-1 presents emissions projections for three low-carbon pathways that could reduce U.S. emissions by 26–30 percent below 2005 levels by 2025 and 34–38 percent by 2030. We present a 10-point action plan that outlines specific steps federal agencies and state governments can take to achieve these reductions, recognizing that other pathways could reach those targets as well by applying different policy portfolios.

Looking beyond 2025, even deeper reductions will be necessary in the long term to avoid the worst impacts of climate change.[9] New federal legislation will likely be needed to drive these deeper reductions; for example, a carbon tax, cap-and-trade program, or national clean energy standard. We modeled two pathways that could reduce emissions 40–42 percent below 2005 levels by 2030 and 50–53 percent by 2040 with new legislation that establishes a price on carbon together with complementary policies across the economy. These pathways would maintain robust economic growth while pursuing a low-carbon transition, with cuts in spending on energy in the residential, commercial, and transport sectors.

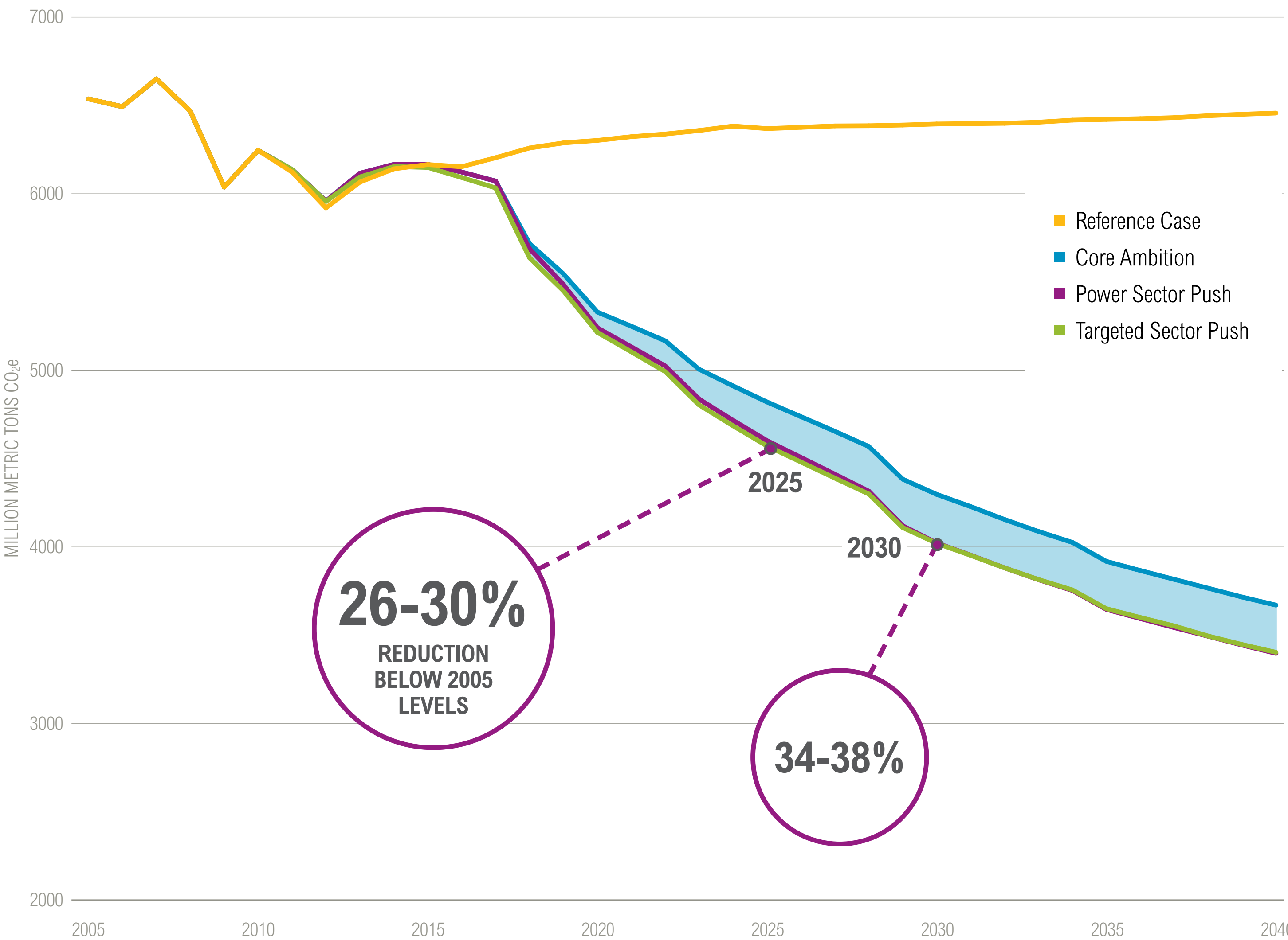
The United States' Emission Trends and Trajectory

U.S. GHG emissions have fallen by about 8 percent below 2005 levels in 2012 (the last year with historical data available at the time of this analysis), due to increased use of natural gas and renewable energy and improved energy efficiency across the economy, among other factors. Federal and state policies—including fuel economy standards for vehicles and federal appliance efficiency standards—together with technological innovation, have contributed to these trends. However, in recent years these reductions also were partly driven by reduced economic activity during the recession of 2008–10. In the absence of new policies and programs, emissions are expected to begin growing again as the economy continues to recover. Total GHG emissions are expected to grow slowly from current levels to 5 percent below 2005 levels by 2020 and 4 percent by 2025, far from the U.S. emission reduction targets for these years. Of course, future levels of GHG emissions could be higher or lower than these projected levels due to a variety of factors, including changes in fuel price trajectories and consumer behavior.

The United States is currently taking a number of steps that will reduce GHG emissions, using authority under several existing laws, including the Clean Air Act, the Energy Policy Act, and the Energy Independence and Security Act. The Administration's current activities build off of its Climate Action Plan, released in 2013, which developed reduction strategies across many critical sectors and emission sources—including the power sector, transportation, hydrofluorocarbons (HFCs), natural gas systems, and others—that could be implemented using existing laws. Many state and local authorities also are taking action on climate change by increasing their use of renewable energy and energy efficiency, incentivizing clean vehicle technologies, and developing alternative fueling infrastructure, among other strategies. Some are finding that these actions can result in economic benefits.[10]

The United States set a goal to reduce GHG emissions 26–28 percent below 2005 levels by 2025 as part of a new international agreement to be finalized under the United Nations Framework Convention on Climate Change (UNFCCC) by the end of this year.[11] As part of the negotiations, each country will submit an Intended Nationally Determined Contribution (INDC), representing its emission reduction pledge. The U.S. INDC did not provide a detailed action plan for meeting the 2025 target, but it

Figure ES-1 | **Net U.S. Greenhouse Gas Emissions: Reference Case and Low-Carbon Pathways Using Existing Federal Authorities and Additional State Action**



Note: This figure depicts net GHG emissions under three low-carbon pathways we modeled in our analysis that could be pursued using existing federal laws and additional state action. Core Ambition reflects the U.S. Environmental Protection Agency's (EPA) proposed Clean Power Plan (CPP), in addition to emission abatement opportunities across other sectors of the economy. Power Sector Push builds on Core Ambition by assuming that states and utilities go beyond the CPP as proposed, or that EPA strengthens the proposal to take advantage of cost-effective energy efficiency resources and continued decreases in renewable energy costs. Targeted Sector Push assumes that the CPP is finalized as proposed, but pushes the envelope in a few key areas outside the power sector to achieve economy-wide reductions similar to Power Sector Push. Both of these pathways were designed to achieve very similar levels of emission reductions, illustrating alternative ways to go beyond a 26 percent reduction across the economy, either through increased action in the power sector or outside the power sector. The shaded area between the pathways indicates that reductions anywhere in this range are possible given mixtures of policies that blend these three pathways. See text for more details on these pathways and the Reference Case.

makes clear that the United States will rely on core aspects of the Climate Action Plan. The U.S. Climate Action Plan is poised to make significant contributions toward meeting these goals, particularly if finalized standards and strategies across all aspects of the plan are sufficiently ambitious. To date, however, actions taken to implement the plan are not enough to get the United States to its 2020 or 2025 climate goals. To meet these goals, the country will need to strengthen and expand some of the actions already taken or proposed, and take action on additional sectors not yet addressed.

Pathways for the United States to Deliver on its Climate Commitment

We developed three pathways, described below and summarized in Table ES-1, to determine the types of action required to meet the country's 2025 emission reduction target. These pathways include mitigation opportunities and policy tools that can be pursued using current federal authorities, as well as additional state action. All three pathways require ambitious action, which we define to reflect measures that (1) are technically achievable; (2) take advantage of and reinforce recent low-carbon technology and market trends; and (3) are necessary to capture the full scope of emission reduction opportunities in a given sector. Our pathways serve as illustrative examples of different combinations of policies and measures that the United States can take to achieve its targets.

1. **Our Core Ambition pathway would cut GHG emissions by 26 percent below 2005 levels in 2025 and 34 percent in 2030.** This pathway assumes that the U.S. Environmental Protection Agency's (EPA) Clean Power Plan is finalized as proposed and actions are taken to harness low-carbon opportunities across most other sectors of the economy.[a] These actions include new and strengthened federal appliance efficiency standards, improved GHG and fuel efficiency standards for passenger vehicles and medium- and heavy-duty trucks, new GHG standards for industry, emissions standards for new and existing natural gas systems, reduced HFC consumption, and others. Under this pathway, power sector carbon dioxide (CO_2) emissions fall 40 percent below 2005 levels by 2030 as a result of both the Clean Power Plan (as proposed) and additional reductions in electricity demand from federal standards for residential, commercial, and industrial equipment.[b]

   Roughly 70–75 percent of the potential abatement we identified in 2025 under this pathway is in sectors in which the Obama Administration has already begun to act. The United States can capture the remaining abatement potential by taking new action across emission sources not yet addressed and strengthening those already in place.

Because the power sector is the largest source of potential emissions abatement in the United States, the stringency of actions in this sector significantly affects how much additional action is needed across other sectors to achieve deeper economy-wide reductions. Our next two pathways examine two alternative ways to go beyond the Core Ambition pathway, either through greater action in the power sector or greater action outside the power sector:

2. **Our Power Sector Push pathway reduces GHG emissions by 30 percent below 2005 levels in 2025 and 38 percent in 2030.** This pathway assumes that EPA strengthens the proposed standards for existing power plants under its Clean Power Plan, and renewable energy technology costs continue their rapid decline. This allows states and utilities to deploy more renewable energy and energy efficiency, leading to CO_2 emission reductions in the power sector of 45 percent below 2005 levels by 2025 and 52 percent by 2030. The Power Sector Push Pathway also includes policies affecting residential, commercial, and industrial energy use; transportation; natural gas systems; and various industrial gases consistent with the Core Ambition pathway.

[a] In June 2014, EPA used its authority under the Clean Air Act to propose the Clean Power Plan, which establishes state-specific CO_2 emission standards for existing power plants and provides states with flexibility in how they can comply. States will develop implementation plans after the rule is finalized in the summer of 2015. EPA estimates that the plan will cut national power sector CO_2 emissions 30 percent by 2030. For more information, see: <http://www2.epa.gov/carbon-pollution-standards/clean-power-plan-proposed-rule>.

[b] We assume that EPA sets separate standards for industry, and DOE establishes new and strengthened appliance and equipment standards (we do not assume implementation of any state appliance standards). We assume that CO_2 reductions resulting from these measures are additional to the CO_2 reductions resulting from EPA's proposed Clean Power Plan. Under this assumption, states would take credit only for efficiency measures that go beyond a baseline adjusted for these new federal measures. As the rule is implemented, it may be possible for states to receive credit for measures related to industrial efficiency and appliances regulated by federal standards, but EPA has not yet released guidance on these issues.

Table ES-1 | **Key Elements of the Pathways**

	CORE AMBITION	POWER SECTOR PUSH	TARGETED SECTOR PUSH
POWER SECTOR	■	●	■
OTHER ENERGY EMISSION SOURCES	▲	▲	●
NON-CO_2 EMISSION SOURCES	▲	▲	▲

■ Clean Power Plan as proposed combined with federal appliance and industrial efficiency standards (leading to power-sector emission reductions in the range of 36 percent below 2005 levels in 2025 and 40 percent in 2030).

● Low carbon trends are accelerated through the 2020s either in the power sector via greater deployment of renewables and energy efficiency (leading to power-sector emissions reductions in the range of 45 percent below 2005 levels in 2025 and 52 percent in 2030) or across four other key sectors (passenger vehicle CAFE standards, passenger vehicle travel demand, industrial energy efficiency, residential and commercial natural gas demand).

▲ Ambitious measures across all other emission sources analyzed in this study.

3. **Our Targeted Sector Push pathway also reduces GHG emissions by 30 percent below 2005 levels in 2025 and 38 percent in 2030.** This pathway limits the power sector to emission reductions consistent with the proposed Clean Power Plan, but achieves deeper economy-wide reductions by pushing the envelope in four key areas: passenger vehicle efficiency, travel demand, industrial energy use, and natural gas demand in buildings.

   The Targeted Sector Push pathway would require even more accelerated deployment of next generation vehicle technologies than has occurred in recent years, allowing current GHG and CAFE standards for light-duty vehicles (model years 2017–25) to be reached five years earlier than the Core Ambition pathway. In addition, this pathway reflects slower growth in personal travel demand, facilitated by supportive policies such as compact development patterns together with improved public transportation. In the industrial sector, both emissions standards and voluntary measures are scaled up to more fully capture efficiency opportunities and increased use of lower-carbon fuel sources. This pathway also captures greater natural gas savings in homes and commercial buildings through accelerated adoption of state efficiency savings targets. Outside these areas, the Targeted Sector Push Pathway includes policies affecting residential, commercial, and industrial energy use; transportation; natural gas systems; and various industrial gases consistent with the Core Ambition pathway.

While these pathways are based on existing federal authorities and action at the state level, implementation of policies that drive reductions at the upper end of the range (in particular those in our Targeted Sector Push pathway) would be enhanced by supportive congressional actions. These actions could include periodic transportation reauthorizations bills that help promote reduced travel demand (such as improvements to public transportation options), as well as new or reauthorized tax provisions promoting renewable energy and energy efficiency. At a minimum, we assume that Congress does not block executive branch actions using existing authorities.

Emission reduction opportunities

Figures ES-2 and ES-3 illustrate the emission reduction opportunities by sector. The power sector represents the largest opportunity for GHG emissions abatement across all our pathways, where cleaner generation combined with more efficient electricity use could reduce power-sector CO_2 emissions 45 percent below 2005 levels by 2025 and 52 percent by 2030. HFCs, industry,[12] vehicles and reduced transport demand, and natural gas systems also offer important abatement opportunities in the 2025–30 time frame.

Figure ES-2 | **U.S. Emissions by Sector in Reference Case and Low-Carbon Pathways in 2025**

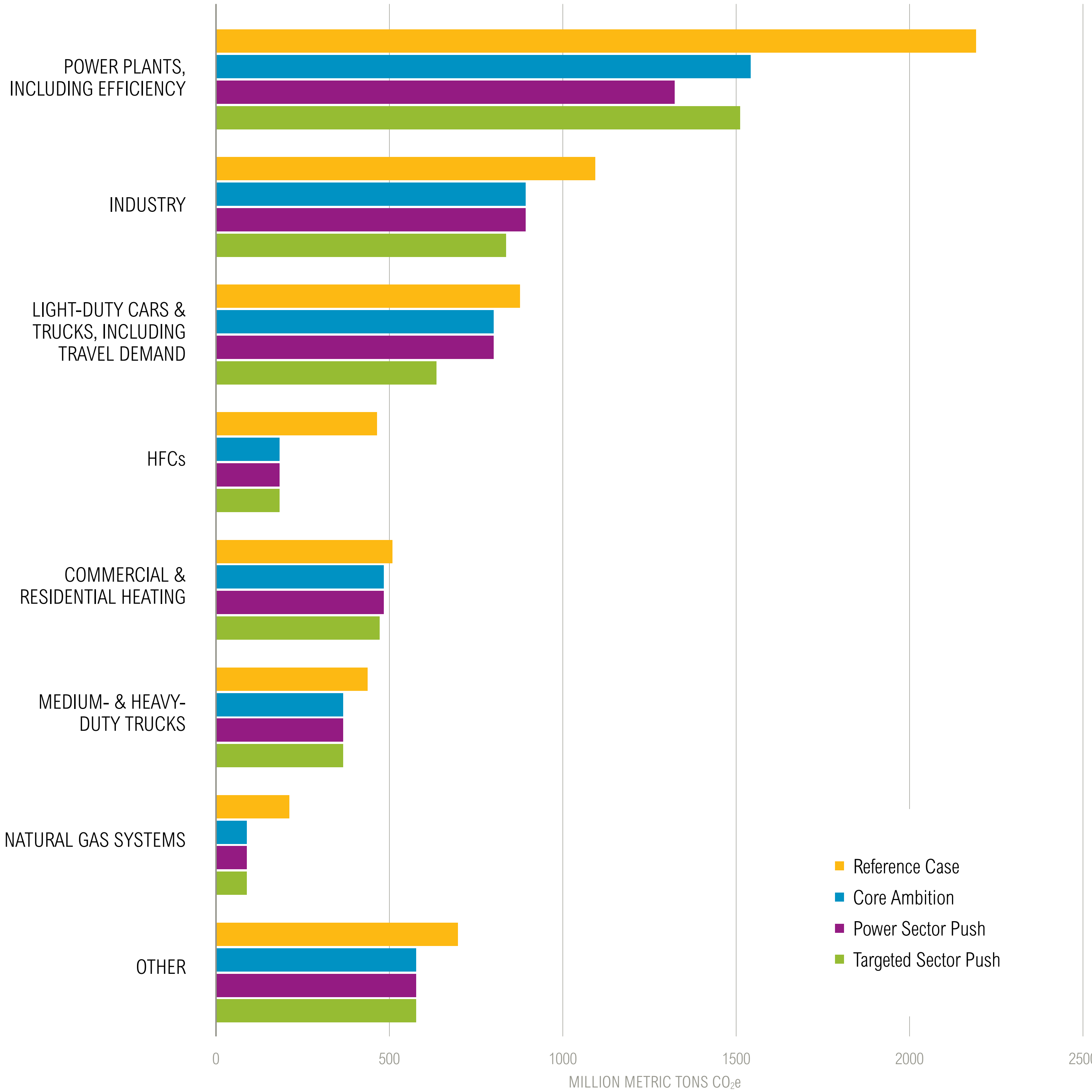
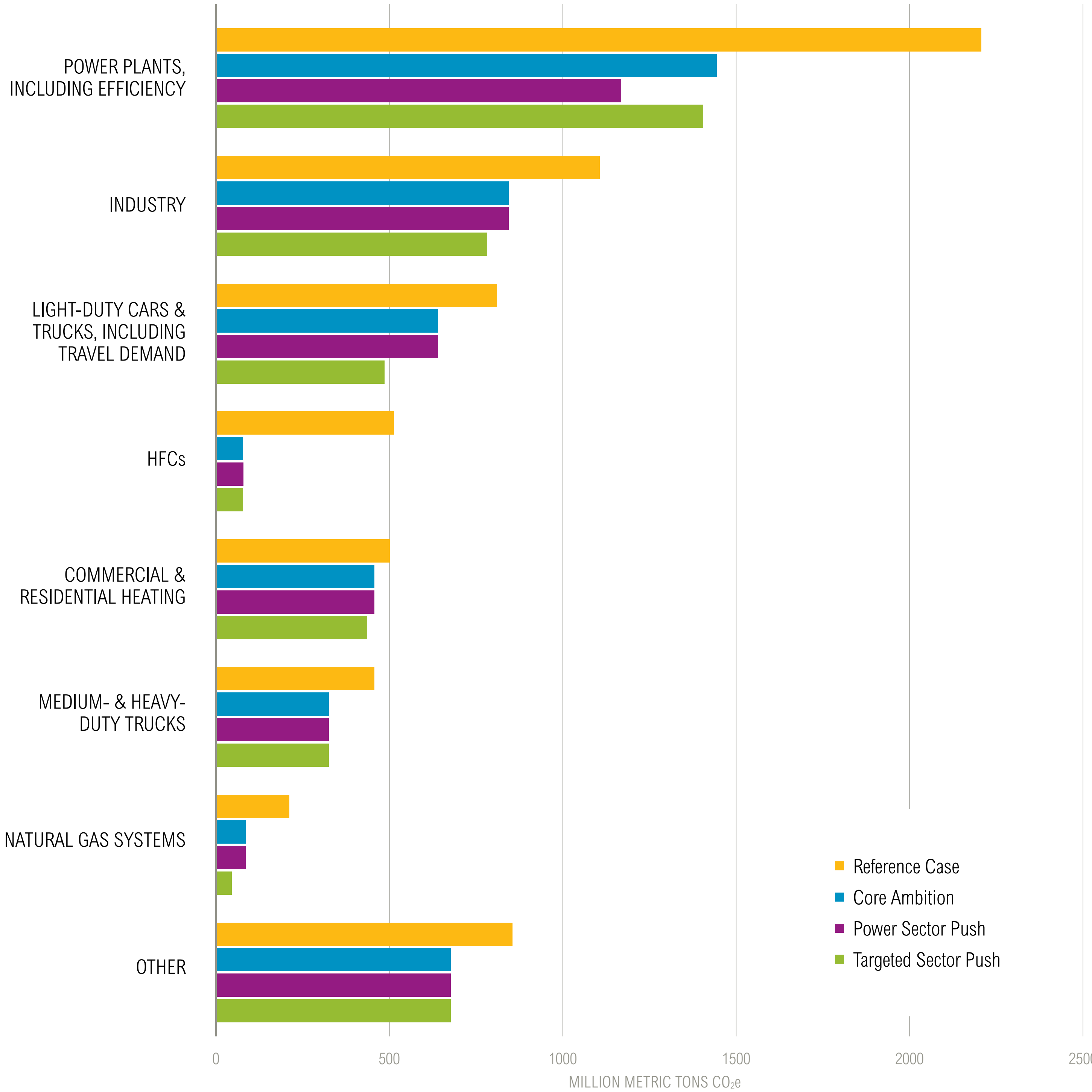


Figure ES-3 | **U.S. Emissions by Sector in Reference Case and Low-Carbon Pathways in 2030**



Box ES-1 | **Modeling Our Pathways**

We modeled three pathways that examine abatement opportunities under existing federal authorities and state action using WRI's Greenhouse Gas Abatement Model (WRI-GAM), a bottom-up, sector-by-sector, Excel-based model that estimates emission reductions resulting from implementation of a variety of policy levers. We developed our own Reference Case based largely on U.S. government projections by the U.S. Energy Information Agency (EIA) and the U.S. Environmental Protection Agency (EPA). Unless otherwise noted, "Reference Case" here always refers to the one constructed for this analysis, and not to any official EIA or EPA projections or reference cases. The model then incorporates the effects of sector-based and end-use-based policies with impacts across six GHGs—carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorinated compounds (PFCs), and sulfur hexafluoride (SF_6)—projected out to the year 2040. While we do not include specific policies addressing land use and forestry, all three pathways (along with the Reference Case) assume the "high sequestration" projection from the latest U.S. report to the UNFCCC.[a] WRI-GAM is not an economic model, thus we could not capture the economic impacts of policies using this model. See See Chapter 2 of the full working paper and the Appendix for further description of our model, data sources, and methodology.

We used the version of the Energy Information Administration's (EIA) National Energy Modeling System (DUKE-NEMS) maintained by Duke University's Nicholas Institute for Environmental Policy Solutions—which collaborated with WRI in this study—to model our two pathways, which examine longer-term abatement opportunities through new legislation and the economic impacts of these pathways. This modeling effort is described in more detail in Chapter 3 of the full working paper and the Appendix.

[a] U.S. Department of State. 2014. "2014 U.S. Climate Action Report to the UN Framework Convention on Climate Change." Accessible at: <http://www.state.gov/e/oes/rls/rpts/car6/>.

Ten-Point Action Plan to Meet the 2025 Reduction Target

The United States should move forward with ambitious action across the economy to make significant emissions cuts in the 2025–30 time frame and meet its 2025 climate target. The Administration's implementation of the Climate Action Plan has provided a valuable start for achieving the necessary reductions. However, to meet the target, the country will need to strengthen measures already taken or proposed and take action in areas that have not yet been addressed. We have developed a ten-point plan, described in more detail below, of specific steps federal agencies (acting within existing authority) and states can take to achieve the necessary reductions.

Table ES-2 | **10-POINT ACTION PLAN**

1	Strengthen the Clean Power Plan both in the near term and over time to fully reflect cost-effective renewable energy and energy efficiency potential.
2	Scale up programs for residential and commercial energy efficiency.
3	Continue and expand programs to reduce hydrofluorocarbon (HFC) emissions.
4	Use emissions standards and voluntary programs to improve industrial energy efficiency.
5	Set methane emissions standards for new and existing natural gas and oil infrastructure.
6	Extend and strengthen GHG and fuel economy standards for passenger cars while reducing travel demand.
7	Extend and strengthen GHG and fuel efficiency standards for medium- and heavy-duty vehicles.
8	Accelerate air travel management and establish standards for new aircraft.
9	Reduce methane emissions from landfills, coal mines, and agriculture through standards or other measures.
10	Reduce emissions from other sources while increasing carbon sequestration from forests and other land types.

1. Strengthen the Clean Power Plan both in the near term and over time to fully reflect cost-effective renewable energy and energy efficiency potential

Accounting for up to 49 percent of total reductions in our pathways in 2025 and 44 percent in 2030, the power sector presents the greatest opportunity for low-cost (and even no-cost) emission reductions. While our analysis shows that the Clean Power Plan does not need to be strengthened in order to reduce economy-wide emissions by 26 percent below 2005 levels in 2025 (as long as ambitious action is taken across other emission sources), doing so would enable the United States to more easily achieve the upper range of its 2025 target and achieve deeper reductions beyond the 2025–30 time frame.

The sector has already begun to decarbonize, with power sector CO_2 emissions 15 percent below 2005 levels in 2013 due to a combination of fuel-switching away from coal and slower growth in demand.[13] Natural gas supplies and prices will likely remain favorable to further fuel-switching, and the costs of solar and wind power will likely continue their long-term downward trends.[14] Leading states are finding that renewable energy investments are driving energy bill savings, supporting new jobs, and providing other economic benefits.[15] The shift away from coal also reduces emissions of other pollutants, including sulfur dioxide, nitrogen oxides, particulate matter, and mercury, which results in numerous public health benefits. These health benefits often outweigh the estimated cost of the transition to a low-carbon power system, usually many times over.[16]

The proposed Clean Power Plan would reduce power plant CO_2 emissions by roughly 30 percent below 2005 levels by 2030, but our analysis suggests that the United States can achieve even deeper reductions from the power sector—roughly 52 percent below 2005 levels by 2030. Even though there is a short window of time before EPA finalizes the Clean Power Plan in the summer of 2015, the final rule should reflect, to the extent possible, each state's cost-effective renewable and energy efficiency potential. Studies have shown that a more rapid decarbonization of the power sector in the post-2020 time period is possible, as well as legally defensible, especially when considering the declining costs of wind and solar energy.[17,18] As technological innovation continues and renewable energy costs continue to decline going forward, EPA should revisit these targets periodically (as it is planning to do with its passenger vehicle standards) to ensure that each state's standard continues to reflect the full scope of opportunities in this sector.

2. Scale up programs for residential and commercial energy efficiency

Energy efficiency is often less expensive for electric utilities than building new sources of electricity generation (power plants)—and deployment of efficiency technologies can lead to direct financial savings for homes and businesses. Federal and state programs—including federal appliance standards, state energy efficiency savings targets, state building energy codes, and others—have increased the deployment of more efficient technologies, such as heating and cooling systems, refrigerators, light bulbs, and many others. These programs have helped decouple economic growth from growth in energy demand and saved billions of dollars for households and businesses.[19]

However, market barriers—including misaligned incentives between those who make investment decisions and those who receive the benefits (such as landlords and tenants), lack of information about the benefits of efficient products, and others—can prevent the adoption of the most efficient technologies. Much greater efficiency potential is available in residential and commercial buildings, as well as in the industrial sector (discussed in action number 4).

In order to harness this potential, EPA should strengthen the Clean Power Plan by taking into account all cost-effective energy efficiency potential when developing state-specific standards. This would encourage more widespread deployment of state efficiency programs, leading to greater demand reductions and savings for consumers. The U.S. Department of Energy (DOE) and EPA also should continue to scale up existing policies and programs, which are already delivering benefits many times greater than their costs. This includes continuing to strengthen existing appliance standards (for example, for residential boilers, commercial unit heaters); setting appliance standards for equipment not currently covered (for example, for computer equipment, commercial ventilation equipment, general service lamps); increasing funding for research, development, and deployment of efficient technologies and processes; expanding partnerships with businesses and industry (for example, DOE's Better Buildings Challenge); and expanding efficiency labeling programs (for example, ENERGY STAR). New and strengthened appliance standards and less energy-intensive manufacturing together with the Clean Power Plan could lead to total electricity demand reductions of 9–10 percent below projected levels in 2025 and 11–13 percent in 2030.

3. Continue and expand programs to reduce hydrofluorocarbon (HFC) emissions

Emissions of HFCs, which are used primarily for refrigeration, air conditioning, and the production of insulating foams, have been increasing due to the phaseout of ozone-depleting substances (chlorofluorocarbons and hydrochlorofluorocarbons) under the Montreal Protocol and Clean Air Act, which HFCs replace. Some HFCs have very high global warming potential (GWP), though alternatives with low GWPs are increasingly available. Several companies have begun to use these alternatives, with many saving money and energy while they reduce GHG emissions.[20] For example, Coca-Cola, Pepsi, Heineken, Red Bull, and Ben & Jerry's have all achieved 10–40 percent efficiency improvements by adopting low- or zero-GWP refrigerants in equipment such as vending machines.[21] However, some low-GWP replacements have relatively high upfront costs, require the replacement of old equipment, or require equipment redesign.[22] Thus, there is little reason to believe that the U.S. market will rapidly move to these alternatives without new rules or other incentives.

Reducing the use of HFCs represents the second largest abatement opportunity—at least 16 percent in 2025 and 18 percent in 2030. While the United States (with Canada and Mexico) has proposed an amendment to the Montreal Protocol for the past several years that would phase down the use of HFCs globally, it has yet to be passed. To help spur reductions of HFCs domestically pending such an agreement, EPA has started to implement measures that address high-GWP HFC use in personal vehicles and in pickups, vans, and combination tractors.[23] In February 2015, EPA finalized rules through the Significant New Alternatives Program (SNAP) program to approve low-GWP alternatives. Proposed rules to move some higher-GWP HFCs out of the market for various applications are anticipated to be finalized this year.[24]

Opportunities exist to make HFC reductions beyond those proposed by EPA to date. While a global phasedown, through the Montreal Protocol, would be much more effective than a few individual countries taking action alone, EPA can use the SNAP program to jump start the removal of high-GWP HFCs from the market when low-GWP alternatives become available.[25] However, it will be important for EPA to ensure that new alternatives are both safe and efficient. EPA should also extend the servicing and disposal of air conditioning and refrigeration equipment requirements for ozone-depleting substances to HFCs in order to increase HFC reclamation and recycling.[26]

4. Encourage industrial energy efficiency

Industry is a broad category that includes a wider range of economic activities than the residential, commercial, and transport sectors. The energy and emissions intensiveness of industrial activity varies among manufacturing, construction, agriculture, energy transformation, mining, and forestry subsectors.[27] Total U.S. industrial sector emissions peaked at 1.9 billion metric tons of CO_2 in 1979 and have intermittently declined since the late 1990s. In 2013, total U.S. industrial sector emissions amounted to 1.5 billion metric tons CO_2 (accounting for both direct emissions and indirect emissions attributable to electricity use).[28]

Within the industrial end use of energy, energy efficiency improvements (including technical improvements, material efficiency, and waste reduction) and fuel-switching are the primary levers for industrial sector emission reduction, while the growth of combined heat and power offers additional reductions. Industrial sector demand, as reflected in the value of shipments, is expected to grow by more than a third between 2015 and 2030.[29]

Industrial energy efficiency is inhibited by persistent barriers, including financing (such as intra-company competition for capital, corporate tax structures that allow companies to treat energy expenditures as tax offsets, split incentives, and energy price trends), regulation (monopolistic utility business models and cost-recovery mechanisms, exclusion of efficiency from energy resource planning), and informational barriers (ignorance of incentives and risks, unavailable energy use data, and lack of technical expertise). Barriers to energy efficiency improvement combine with industrial sector demand growth to create a range of challenges and opportunities that will influence the absolute level of industrial-sector GHG emissions in the United States. Achieving absolute industrial sector GHG emission reductions below 2012 levels will require additional investment and policy action as described in the Core Ambition, Targeted Sector Push, and Power Sector Push pathways.

Emissions mitigation in the industrial sector represents the third largest near-term abatement opportunity modeled in our assessment. Industrial end-use efficiency and fuel switching account for about 11 percent of abatement opportunities in 2025 and 2030, separate from the emission reduction related to electricity generation (from Clean Power Plan implementation) and natural gas production. To achieve these emission reductions, EPA should combine ambitious minimum performance standards for equipment with voluntary benchmarking and labeling programs to encourage further industrial efficiency improvements.

5. Reduce methane emissions from natural gas systems

Leakage and venting of natural gas during its production, processing, transmission, and distribution represents a significant source of methane emissions and other air pollutants such as volatile organic compounds. But methane emissions also present an opportunity for cost-effective reductions by reducing the waste of this resource. Addressing these leaks means more natural gas is available to bring to market. These reduced methane emissions account for at least 7 percent of the abatement opportunity in 2025 and 5 percent in 2030. Market barriers can prevent drillers and other service providers from updating their equipment and practices to avoid methane losses. Additional policies are needed to spur necessary investments in emissions control technologies and practices.

EPA rulemakings have taken the first steps by indirectly reducing methane emissions in this sector, and forthcoming methane standards for new oil and gas infrastructure are an important step in the right direction, but much remains to be done. One recent study estimated that 40 percent of emissions from onshore gas development can be eliminated at an average cost of a penny per thousand cubic feet.[30] EPA should propose and finalize standards on both new and existing natural gas systems by 2017, and phase in implementation through 2020, to reduce methane leakage by 67 percent below Reference Case projections. This can be achieved using existing technologies, many of which pay for themselves in three years or less.

6. Extend and strengthen standards for passenger cars while reducing travel demand

Passenger vehicles account for at least 4 percent of total reductions in 2025 and 7 percent in 2030. To capture this potential, EPA and the U.S. Department of Transportation (DOT) should continue to extend and strengthen existing standards for passenger vehicles. Greenhouse gas and fuel economy standards for light-duty vehicles enacted in 2012 will approximately double the fuel economy of new vehicles by 2025, delivering net savings to many consumers (due to decreased fuel use) and decreasing American reliance on oil imports.[31] But further progress is possible, especially with advances in conventional vehicle technologies and battery and fuel cell technologies. The continuation or acceleration of the trends in alternative vehicle technology we are seeing today can help make large improvements in fuel economy possible in 2025 and beyond, resulting in even larger fuel savings for drivers. When current standards for light-duty vehicles end in 2025, EPA and DOT should seek a 63 mpg CAFE standard (126 grams per mile) by 2030. This would require car manufacturers to innovate and federal and state governments to expand alternative vehicle infrastructure across the country. As a result, American drivers would benefit from annual fuel savings at the pump. Additional policies will be needed at the federal and state level (such as tax credits, zero emission vehicle mandates, research and development) to support the adoption of alternative fuel vehicles and to install the infrastructure required to support these technologies. Putting these policies in place can help accelerate the technology learning curve and bring lower-cost alternative vehicles to market faster.

Transportation policies can reduce travel demand, thus lowering fuel use and emissions from vehicles. Passenger vehicle travel demand is already growing more slowly now than in the past decades, due in part to social and demographic trends. It is uncertain whether these trends will continue or whether travel demand growth will rebound due to continued recovery from the recession, population growth, changes in oil prices (such as the rapid declines that occurred in late 2014), or other factors.

State and local policies should aim to reinforce recent trends, for instance, through compact development patterns coupled with improved public transportation and safe options for walking and biking. DOT, EPA, DOE, the U.S. Department of Housing and Urban Development, and other federal agencies can encourage and support these efforts in a number of ways, including increased funding for public transit infrastructure, implementation of performance criteria for funding that incentivizes compact development and related strategies, research and development, tax policies that promote infill development (such as renewal of the Federal Brownfield Tax Incentive), and technical assistance.[32]

7. Extend and strengthen fuel efficiency standards for medium- and heavy-duty vehicles

The heavy-duty truck sector accounts for at least 4 percent of abatement potential in 2025 and 6 percent in 2030. Current medium- and heavy-duty vehicle GHG and fuel consumption standards are estimated to result in $49 billion in net benefits to society (from fuel savings, CO_2 reductions, reduced air pollution, improved energy security due to decreases in the impacts of oil price shocks, and other benefits) over the lifetime of model year 2014–18 vehicles.[33] EPA and DOT have another big opportunity coming up when new standards are proposed for the post-2018 time frame sometime in 2015. EPA and DOT should set strong standards to reduce fuel consumption rates an average of 40 percent below 2010 levels by 2025.[34] This level of fuel savings can be achieved using technologies that are currently available—such as tractor and trailer aerodynamic enhancements, hybridization and electric drive, and weight reduction, among others—that are estimated to have an average payback period of less than two years.[35]

8. Accelerate air travel management improvements and establish standards for new aircraft

Improving the existing aircraft fleet operations and making new aircraft more efficient represents at least 2 percent of the abatement opportunities we identified in 2025 and 2030. To achieve these reductions, the Federal Aviation Administration should continue to reduce GHG emissions from aircraft by expanding initiatives—under its Next Generation Air Transport Systems program—that enhance the way air travel is managed across the country. In anticipation of international adoption of aircraft CO_2 emissions standard in 2016, EPA should stay on track to release an advanced notice of proposed rulemaking in 2015 and finalize its findings in 2016, and should aim to set standards that improve the fuel efficiency of new aircraft in the range of 2-3 percent annually.

9. Reduce methane emissions from landfills, coal mines, and agriculture

Taking action on additional methane sources represents at least 3 percent of the abatement opportunity in 2025 and 2 percent in 2030. EPA should finalize its proposed methane emissions standards for new landfills, and set standards or develop other programs that reduce methane emissions from existing landfills. The EPA should also take additional action, either using its authority under the Clean Air Act to set emissions standards, or through other measures, to reduce methane emissions from coal mines. Opportunities exist to reduce methane emissions from agricultural sources,[36] however, quantifying these sources was beyond the scope of this analysis.

10. Reduce emissions from other sources while increasing the U.S. carbon sink

Other emission sources, like off-highway vehicles, nitric and adipic acid manufacturing, and PFC and SF_6 emission sources, represent 4 percent of the abatement opportunity in 2025 and 5 percent in 2030. Federal agencies—including EPA and DOE—should establish emission or efficiency standards, expand existing voluntary programs, and/or establish new programs or other measures to address these sources. The United States should also develop a plan to maintain and even increase the nation's carbon sinks, especially given the uncertainty of current sequestration projections and the latest data suggesting that U.S. forests are likely to sequester carbon at a slower rate over the long term.[37]

Driving deeper reductions beyond 2025 in parallel with robust economic growth

Deeper GHG emission reductions will be needed beyond 2025 to avoid the worst impacts of climate change. A transition to a low-carbon economy in the 2030–40 time frame will likely require new legislation to overcome market barriers and provide the long-term, consistent policy signals that provide confidence for investors in new technologies and infrastructure.

We find that climate legislation—together with targeted complementary policies across the economy—can reduce U.S. GHG emissions 40–42 percent below 2005 levels in 2030 and 50–53 percent in 2040. Reductions of this magnitude would require greater action from the power sector than is likely possible using existing laws—more than double the reductions under the Clean Power Plan as proposed by 2030. We explored two policy pathways that could achieve these reductions, either through a carbon price that solely affects the power sector or a carbon price on all energy-related CO_2 emissions.[38] New legislation could establish a carbon price through a tax mechanism or a cap-and-trade program while a flexible national clean energy standard could effectively put a price on carbon in the power sector. These pathways also would require implementation of standards and other measures identified in our 10-point plan to drive deeper reductions across the economy.

A low-carbon transition of this magnitude does not require sacrificing the health of our economy. The legislative pathways we explored include actions that cover a range of costs—from negative costs with net savings accruing to consumers, to positive costs. Our results show that a long-term low-carbon transition could be pursued in parallel with robust economic growth, with relatively small shifts from the expected economic trajectory in the Reference Case scenario.

Economic modeling of our legislative low-carbon pathways indicates:

- **Little long-term impact on gross domestic product (GDP).** While GDP grows marginally slower through 2022 under our legislative pathways, it picks up and eventually grows slightly faster compared to the Reference Case starting in 2023. By 2030, GDP is on average 0.7 percent lower than Reference Case levels and by 2040, it's only 0.3 percent lower. These differences are fairly minor when one considers the size of the U.S. economy. In 2030, for example, GDP losses are equivalent to about three days of economic output that year ($170 billion less in GDP compared to a total economy of over $24 trillion). In addition, the United States would likely experience positive economic impacts related to public health benefits associated with accompanying reductions in conventional air pollutants, as well as longer-term climate-related benefits.

- **Little near-term impact, and no long-term impact, on employment.** Total employment is projected to show a similar pattern as impacts on GDP. Employment in some sectors would be expected to grow (for example, renewable energy) while others would decline (coal production). Overall, our legislative pathways result in slightly higher unemployment rates in the near term compared to the Reference Case, but nearly equivalent rates by 2030 (roughly 5 percent). The legislative pathways have slightly lower unemployment rates in the longer term (2030 to 2040). Of course, it will be important to manage the transition for future job seekers in declining sectors.

- **Lower energy bills in the residential, commercial, and transport sectors.** Significant demand reductions from energy efficiency policies more than offset higher electricity rates and higher fuel prices, resulting in lower energy spending compared to Reference Case levels. While electricity expenditures increased 6–15 percent by 2030 in the industrial sector under both of our legislative pathways, total energy spending in industry decreased by 15 percent in 2030 under the pathway that included targeted efficiency standards in addition to a price on carbon in the electricity sector.

Our results, in combination with recent trends and other analyses, suggest that the United States has an opportunity to capture multiple economic benefits by pursuing a long-term transition to a low-carbon economy. Well-designed policies can reduce GHG emissions while stimulating technological innovation, saving American consumers money, and improving public health. Three long-term recommendations can facilitate the transition to a low-carbon future:

1. Congress should implement new legislation to drive a deep decarbonization across all sectors.

2. Federal, state, and local authorities should continue to implement supportive policies across key emission sources.

3. The federal government should increase investment in research, development, and deployment of clean energy technology.

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INTRODUCTION

Ambitious action is needed to avert the worsening impacts of climate change. Building off of its Climate Action Plan in 2013, the United States is taking action to reduce its greenhouse gas (GHG) emissions and has committed to take action in the 2020-2025 time frame. Unlike the conventional wisdom of the past, many current studies find that taking climate action does not mean sacrificing economic growth.[1] Many of the key drivers of economic growth—including more efficient use of energy and natural resources, smart infrastructure investments, and technological innovation—can also drive the transition to a low-carbon future.[2] This has been demonstrated throughout the United States, where low-carbon investments are already saving money for citizens and businesses, creating new job opportunities, and improving public health.[3]

These opportunities are arising across many sectors of the economy. For instance, the capital costs of wind and solar photovoltaic systems continue a rapid downward trend.[4] Well-crafted energy efficiency programs are lowering utility bills and reducing energy demand, which indirectly reduces GHG emissions.[5] Increased production of low-cost shale gas, while raising concerns about methane emissions and other environmental impacts, has spurred fuel switching away from coal in power generation, reducing carbon dioxide (CO_2) emissions.[6] Technological progress on many fronts promises to create further opportunities, from creating climate-friendly refrigerants to breakthroughs in electric and fuel cell vehicles.[7]

Nevertheless, market barriers still exist, hindering investment and implementation of strategies needed to transition the United States toward a low-carbon economy. These barriers take many forms and cut across many sectors, for example:

- Split incentives - In the natural gas sector, for example, numerous independent companies are working along the entire system, and in some cases their incentives to invest in control technologies to reduce methane emissions are not well-aligned.
- Ownership transfer issues - In the residential sector, homeowners may not invest in energy efficient products or home upgrades, thinking they may move before reaping the cost savings.
- Network effects - Widespread penetration of alternative vehicles depends on availability of charging stations, but investment in charging stations may be limited while relatively few alternative vehicles are on the road.[8]

Additional policies and measures are necessary to overcome these barriers, including GHG and efficiency standards, increased research and development to stimulate innovation, and policies to stimulate market demand for new technologies.[9]

Failure to significantly curb GHG emissions will increase economic, social, and environmental risks for the United States, as well as the global community. With global GHG emissions still on the rise,[a,10] delaying action on climate change will only result in climate-change-related events becoming more frequent and severe, leading to mounting costs and harm to businesses, consumers, and public health. The world experienced the hottest year on record in 2014[11]—and fourteen of the fifteen hottest years on record have occurred since 2000—and recent trends of increasing climate-change-related impacts have continued.[12] These impacts have been seen throughout the United States, with some regions experiencing higher frequency of flooding, heavier precipitation events, and more frequent heat waves and wildfires.[13] While many factors contribute to the cost of these events, such as population density growth and increased development in vulnerable areas more prone to extreme events, increasing global temperatures and climate variability are making certain types of these costly events more frequent and severe. Between 1980 and 2014, the United States experienced 178 extreme weather and climate events, each of which cost at least $1 billion, for total damages of over $1 trillion.[14] The frequency and severity of these costly events

[a] Between 2005 and 2011, global GHG emissions increased by roughly 13 percent and it is unclear what trend emissions will follow in the future. While preliminary data from the International Energy Agency suggests that energy-related CO_2 emissions stalled in 2014 (the first time in 40 years a halt or reduction in emissions was not tied to an economic downturn), non-CO_2 GHG emissions will continue to rise nearly 44 percent above 2005 levels by 2030, according to data from the U.S. Environmental Protection Agency. In 2011, non-CO_2 emissions accounted for about 27 percent of global GHG emissions.

have increased over the same period, and four of the six years with the most billion dollar disasters on record in the United States have occurred since 2010. A similar increase in these costly events is happening around the world,[15] with seven of the ten costliest years on record occurring since 2000 (adjusted for inflation).[16]

Recent polling data reveal that most Americans are aware of the dangers posed by climate change and support action to reduce GHG emissions. In a poll conducted by the New York Times, Stanford University, and Resources for the Future, 78 percent of respondents said they think climate change will pose a somewhat serious or very serious problem if no action is taken. Most respondents (78 percent) also expressed support for general government action to limit U.S. GHG emissions.[17]

The Study in Brief

As the largest global economy and the second-largest emitter of GHG emissions, U.S. leadership is necessary for the world to shift to a low-carbon economy. Last November, the United States announced a target to reduce its GHG emissions by 26–28 percent below 2005 levels by 2025. In March 2015, the United States officially submitted these targets in its Intended Nationally Determined Contribution (INDC), as part of the negotiations toward a new international agreement under the United Nations Framework Convention on Climate Change (see Chapter 1 for more information on the U.S. INDC).[18]

This study examines:

1. Where GHG emissions are headed if the United States does not take any new action.
2. How the United States can meet its 2025 target using existing authorities and state action.
3. How the United States can use new legislation to achieve deeper cuts in GHG emissions over the longer term (2030–40) while still maintaining economic growth.

This analysis builds off our 2013 study—*Can the U.S. Get There From Here?*—which evaluated whether the United States could meet its commitment to reduce GHG emissions by 17 percent below 2005 levels by 2020.[19] As in that study, this working paper focuses on actions that can be taken using existing laws and state action, given that new national legislation, due to current political circumstances, would not form a viable basis for development of near- to medium-term emission reduction commitments. However, recognizing the need for deeper reductions beyond 2025, we also explore the possibility for new legislative measures in the future if the political climate in Congress shifts. Our analysis was also informed by our 2014 working paper *Seeing is Believing*, which provided an overview of some of the technologic and economic trends and opportunities in the United States for achieving cost-effective emission reductions across several key sectors.

In order to examine low-carbon pathways the United States can take to meet its 2025 emission reduction target, we conducted a bottom-up assessment of federal and state actions aimed at reducing emissions of six key GHGs—CO_2, methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6)—through 2040 across the following economic sectors and end uses: electric power, residential and commercial buildings (electricity demand and heating fuel), transportation (light-, medium-, and heavy-duty vehicles, travel demand, off-highway vehicles, aviation), industry (including manufacturing, construction, and other activities), refineries, natural gas systems, HFC consumption, coal mines, landfills, nitric and adipic acid production, as well as PFC and SF_6 emission sources. We also included biological carbon sequestration estimates from land use, land use change, and forestry (LULUCF) sources in our Reference Case and all our low-carbon pathways in order to estimate net GHG emissions. Modeling policies that affect sequestration were beyond the scope of this analysis.

Key Findings

Our analysis shows that the United States can make significant cuts in GHG emissions while taking advantage of the economic opportunities available in a low-carbon economy and providing greater leadership on climate change.

Specifically, we find that:

1. **The United States has begun to take strong action to reduce its GHG emissions. However, putting the country on track to meet its 2020 and 2025 climate targets will require going beyond the actions taken to date.**

   As we outline in Chapter 1, the administration has taken positive steps to reduce GHG emissions with the President's Climate Action Plan, which includes necessary action across several key areas including power plants, energy efficiency, transport, and others.[20] But the United States will need to go beyond actions taken to date to be on track to meet its 2020 emission reduction target (17 percent below 2005 levels) or 2025 reduction target (26–28 percent below 2005 levels).[21]

2. **By strengthening existing measures and taking new action, the United States can meet, or even surpass, its commitment to reduce emissions 26–28 percent below 2005 levels by 2025 using existing federal laws and state action.**

   This will require the United States to build on the Climate Action Plan, expanding and strengthening current policies and standards together with new action across emission sources not yet regulated. Our 10-point plan, presented in Chapter 2, provides specific actions the United States can take using existing laws, as well as state actions, to achieve its 2025 target and move toward a low-carbon future.

   The power sector is the largest source of emission reductions in the United States, thus the level of reductions possible in the 2025–30 time frame is strongly dependent on how fast and how far the United States moves toward low-carbon and zero-carbon power generation. In June 2014, the U.S. Environmental Protection Agency (EPA) used its authority under the Clean Air Act and proposed its Clean Power Plan, setting GHG standards for existing power plants. The proposed rule establishes state-specific CO_2 emission targets for existing power plants, taking into account each state's unique mix of electricity resources and opportunities to cut emissions. The rule provides states with flexibility in how they can comply, allowing them to take advantage of strategies such as greater use of natural gas and renewable energy, improved energy efficiency, and others. EPA is expected to finalize the Clean Power Plan in the summer of 2015, at which time states will develop their implementation plans. If the Clean Power Plan is finalized as proposed,[22] and ambitious action is taken across other sectors of the economy, the United States can place itself on track to reduce its GHG emissions by 26 percent below 2005 levels in 2025.

   We identified two alternative pathways using existing laws and state action that would allow the United States to reduce GHG emissions by 30 percent below 2005 levels in 2025. One option is for the EPA to strengthen the Clean Power Plan to more fully take into account the significant potential for clean energy development in the power sector when determining each state's emission standards. In developing its current proposal, EPA considered a variety of technical, economic, and legal factors. However, studies have shown that a more rapid decarbonization of the power sector in the post-2020 time period is possible as well as legally defensible.[23] The power sector contains some of the most cost-effective emission reductions, thus there is reason to aim for even deeper reductions beyond what could be achieved under the proposed Clean Power Plan.

   If the United States does not achieve reductions in the power sector beyond what could be achieved under the proposed Clean Power Plan, it could instead pursue greater economy-wide reductions in other sectors, but this would likely require pushing the envelope in terms of what is achievable in these sectors. The pathway we identified required significant shifts in four key areas: passenger vehicle efficiency, travel demand, industrial energy use, and natural gas demand in buildings.

3. **The United States could achieve even deeper reductions in the longer term, while still maintaining economic growth, if Congress passes new legislation in the future to accelerate technological innovation and cost declines in lower and zero-emission sources.**

   By implementing a carbon price on all energy CO_2 emission sources, or even on power sector CO_2 emissions alone, together with many other measures across the economy, the United States can reduce its GHG emissions 40–42 percent below 2005 levels in 2030, and 50–53 percent in 2040, putting itself on a pathway to even deeper cuts in the longer term. This type of action can also lead to robust economic growth, with households, drivers, and businesses also saving money on their energy bills. Chapter 3 examines these legislative pathways in more detail and provides long-term recommendations that can enable a deeper decarbonization of the American economy in the 2030–40 time frame.

Chapter 1

THE UNITED STATES' EMISSION TRENDS AND TRAJECTORY

Greenhouse gas (GHG) emissions in the United States have fallen since 2005, in part due to the economic recession and increased use of natural gas and renewables for electricity generation, among other factors. But this trend is not expected to continue. Without new policies to promote a low-carbon future, emissions will rise 8 percent above 2012 levels[b] by 2025 and remain relatively flat through 2030.

This chapter examines recent GHG emission trends in more detail, including recent action on climate change. Federal agencies and state governments have already started to put policies in place that will reduce GHG emissions in the near term, and a number of new actions are currently under development. As part of the Climate Action Plan, for example, agencies are developing emission standards for significant sources including power plants, medium- and heavy-duty vehicles, oil and natural gas systems, and others. However, the United States will likely need to go further—expanding and strengthening current policies and standards together with new action across emission sources not yet regulated—to meet its goals of reducing emissions 17 percent below 2005 levels by 2020 and 26–28 percent by 2025.

The discussion in this section of current trends—our Reference Case—is based on estimates that only include policies and actions that had been finalized when underlying modeling was conducted by federal agencies several years ago (see Box 1.1). Because of this, important policies that have been announced or proposed, including the Clean Power Plan to establish CO_2 emission standards for existing power plants, are not included in our Reference Case, and are considered new policies for this discussion. See Chapter 2 for more detail on the construction of our Reference Case.

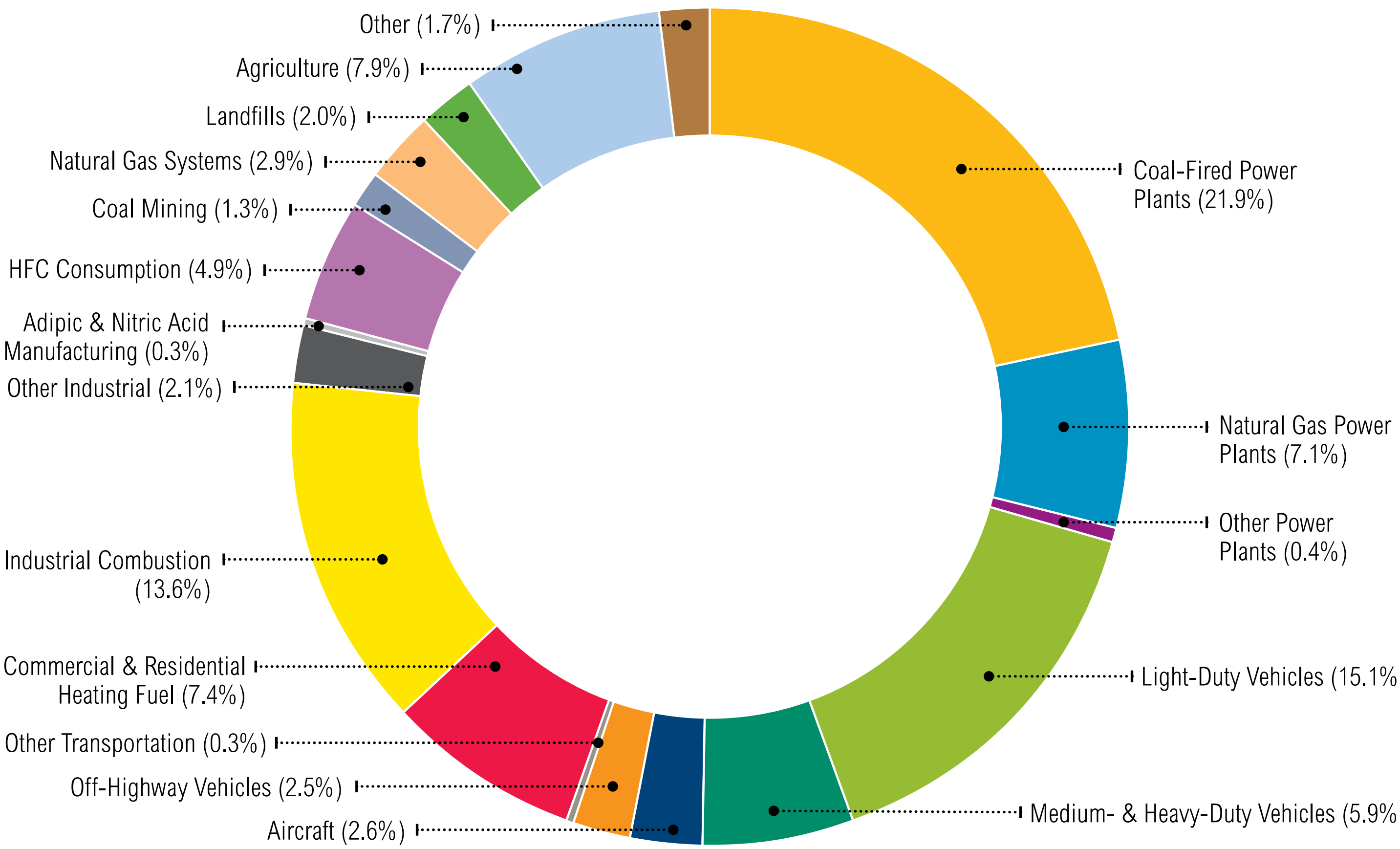
WHERE WE ARE NOW

According to our estimates, the United States emitted almost 7,000 million metric tons of carbon dioxide equivalents (CO_2e) in 2012, which is about 8 percent lower than 2005 levels and 6 percent above 1990 levels. When taking into account carbon sequestration from land use, land use change, and forestry sources (LULUCF), net GHG emissions in 2012 were just over 5,900 million metric tons of CO_2e. Fossil fuel combustion was responsible for roughly 75 percent of total U.S. emissions, with power plants accounting for almost 40 percent of combustion emissions, or almost 30 percent of the total U.S. GHG inventory, according to data from the U.S. Energy Information Administration (EIA) and the U.S. Environmental Protection Agency (EPA) (Figure 1.1). The transportation sector is the second largest contributor to total GHG emissions, comprising approximately 26 percent of U.S. emissions. Non-CO_2 emissions and CO_2 emissions that result from industrial processes (as opposed to combustion) represented approximately 25 percent of total U.S. GHG emissions.

Our estimates are based on a number of data sources. For energy CO_2 emissions, we relied on EIA's *Monthly Energy Review*. For most non-energy CO_2 and non-CO_2 gases, we used data from the Environmental Protection Agency's (EPA) national inventory. However, because EPA uses a proprietary model to estimate HFC emissions, and because of modeling limitations, we relied on projections of HFC consumption estimated by EPA in *Benefits of Addressing HFCs under the Montreal Protocol* instead of HFC emission estimates from EPA's inventory.[24] Where possible, we have attempted to provide emission and consumption estimates using the latest state of the science, as reported in the Intergovernmental Panel on Climate Change's (IPCC) *Fifth Assessment Report*.[25] Because of these last two factors, our historical and projected GHG emissions differ in magnitude with EPA's historical data and the projections used by the Administration in the *U.S. Climate Action Report*.[26]

[b] At the time of this analysis, 2012 was the latest year that complete historical emissions data were available.

Figure 1-1 | **U.S. Greenhouse Gas Emissions by Sector (2012)**



However, we believe our estimates of percent emission reductions can legitimately be compared to the Administration's targets because the methods we use to develop emission projections are consistent with the construction of our historical inventory. The difference between WRI and EPA's estimated GHG emissions in 2005 is very small (less than 0.5 percent) when EPA's estimates are adjusted to reflect the use of HFC consumption and updated global warming potential data for methane and N_2O. The minor difference is likely attributable to the different ways EPA and EIA treat non-energy use of fuels.[27] See the Appendix for more details on our data sources and methodology.

LOOKING AHEAD

Reference Case Emission Projections: Where Will U.S. Emissions Be Without New Policies?

We developed Reference Case projections of total U.S. GHG emissions to understand the trajectory in the absence of new policies and to form the baseline for the analysis we conduct in Chapters 2 and 3 (see Box 1.1 for an outline of what policies are, and are not, included in our Reference Case). We developed these Reference Case projections using a variety of data sources. Unless otherwise noted, "Reference Case" here always refers to the one constructed for this analysis, and not to any official projections or reference cases from EPA or EIA. For projections of CO_2 emissions from fossil fuel combustion, we began with the Reference Case projections in the EIA 2014 *Annual Energy Outlook* (AEO2014),[28] which was modeled using the version of the National Energy Modeling System (NEMS) maintained by Duke University's Nicholas Institute for Environmental Policy Solutions (DUKE-NEMS), which collaborated with WRI in this study. We made minor modifications to these projections, described in more detail in the Appendix, to better reflect recent market trends. For example, we used elements of the AEO2014 Low Renewable Technology Cost side case for the power sector in order to better reflect declining renewable technology costs, which are not captured well by the AEO2014 Reference Case.[29]

For most non-energy CO_2 and non-CO_2 gases, we used EPA projections contained in the U.S. State Department's 2014 *U.S. Climate Action Report*.[30] Consistent with our historical estimates, we relied on projections of HFC consumption estimated by EPA in *Benefits of Addressing HFCs under the Montreal Protocol* instead of HFC emission estimates from EPA's inventory.[31] We also used projections of methane emissions from natural gas systems using updated analysis from WRI's *Clearing the Air*, which we believe better captures the current methane leakage rate.[32,33]

Emission trends have shifted downward since WRI's release of *Can The U.S. Get There From Here?*, our 2013 study that evaluated whether the United States could meet its commitment to reduce GHG emissions by 17 percent below 2005 levels by 2020. This downward shift is largely due to improved efficiency in residential and commercial buildings (as a result of development of new appliance efficiency standards and the adoption of more efficient technologies) as well as reduced energy consumption in the transportation sector due to lower travel demand. Despite the downward shift, total U.S. GHG emissions are expected to rise slowly from current levels, nearly reaching 2005 levels by 2040 (see Figure 1.2). Of course, future levels of GHG emissions could be higher or lower than these projected levels due to a variety of factors, including changes in fuel price trajectories and consumer behavior. New policies, including finalization of some already proposed, are therefore needed as a backstop against the uncertainty of these factors and to drive significant emission reductions.

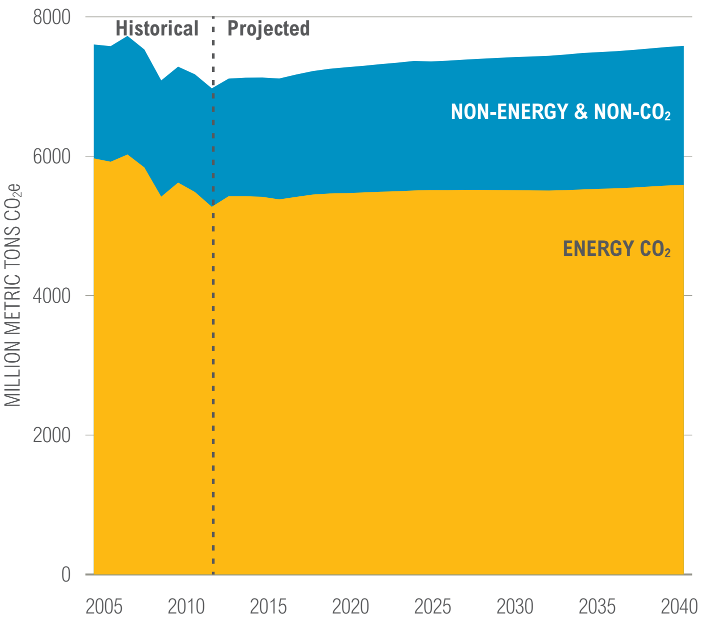
Box 1-1 | Recent Climate Action: What's Included in Reference Case Emission Projections?

Over the past several years, federal agencies have taken steps to reduce GHG emissions, and many are planning to take additional action across a number of sectors as part of the Climate Action Plan (discussed in more detail throughout the rest of this chapter). In general, the AEO2014 Reference Case, which forms the basis for most of our energy-related CO_2 emissions, includes existing legislation and implementation of regulations that were finalized as of October 2013. The *U.S. Climate Action Report*, our source for most non-energy and non-CO_2 GHG emissions, generally includes legislation or regulations finalized as of September 2012. Our Reference Case projections do not include proposed (or otherwise under development) legislation or regulations. Table 1.1 provides a quick reference for significant federal regulations that have recently been proposed or finalized, noting whether these policy developments are included in our Reference Case. See the Appendix for a more detailed description of Reference Case development.

TABLE 1-1 | ELEMENTS OF OUR REFERENCE CASE

INCLUDED IN REFERENCE CASE	NOT INCLUDED IN REFERENCE CASE
■ Final Mercury and Air Toxics Standards (MATS) for power plants ■ Final fuel economy standards for medium- and heavy-duty vehicles model years 2014–18 ■ Final fuel economy standards for light-duty vehicles model years 2012–25 ■ Expansion of industrial sector combined heat and power (CHP) capacity from 27 GW in 2012 to 38 GW in 2030 ■ Federal appliance standards in place or announced as final for future implementation as of 2012 ■ Final New Source Performance Standards for Volatile Organic Compound emissions and National Emissions Standards for Hazardous Air Pollutants from U.S. natural gas systems	■ Proposed GHG emission standards for new and existing power plants (EPA's proposed Clean Power Plan) ■ Post-2018 fuel economy standards for medium- and heavy-duty vehicles currently under development ■ Federal appliance standards under development at DOE, but which had not been announced as final as of 2012 ■ Methane emission standards for oil and natural gas systems and landfills currently under development for new sources ■ Proposed rules to delist some high-global warming potential hydrofluorocarbons (HFCs) and final rules listing some low-global warming potential HFC alternatives under EPA's Significant New Alternatives Program

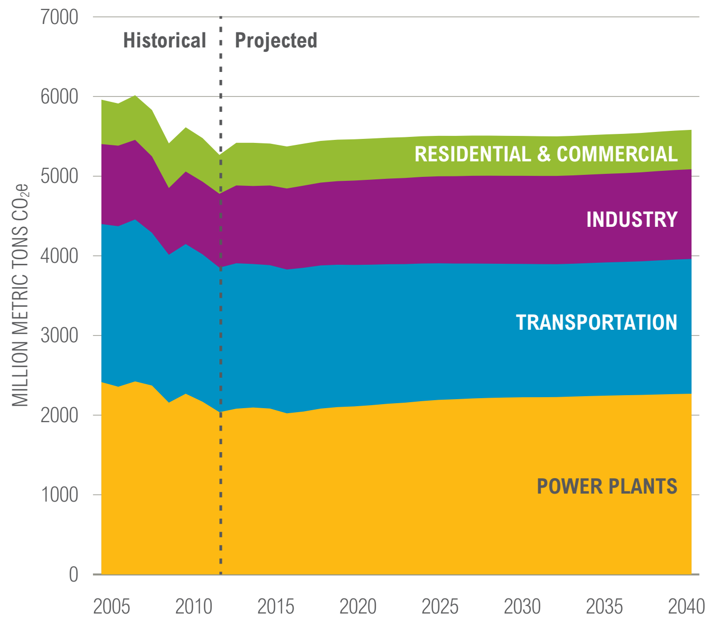
Figure 1-2 | **Historical and Projected U.S. Greenhouse Gas Emissions**



Note: Projected U.S. Emissions reflect the modifications we made to the AEO2014 Reference Case, including the use of some elements of the AEO2014 Low Renewable Technology Cost side case for the power sector in order to better capture declining renewable technology costs.

Source: Historical emissions- U.S. Energy Information Administration, Monthly Energy Review; U.S. Environmental Protection Agency, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2012 (April 2014) and Benefits of Addressing HFCs under the Montreal Protocol; Projected emissions- WRI-NEMS; U.S State Department, 2014 *U.S. Climate Action Report*; U.S. Environmental Protection Agency, Benefits of Addressing HFCs under the Montreal Protocol; World Resources Institute, Clearing the Air.

Figure 1-3 | **Historical and Projected Energy CO_2 Emissions, by Sector**



Note: Includes energy-related CO_2 emissions only. Projected U.S. Emissions reflect the modifications we made to the AEO2014 Reference Case, including the use of some elements of the AEO2014 Low Renewable Technology Cost side case for the power sector in order to better capture declining renewable technology costs.

Source: Historical emissions- U.S. Energy Information Administration, Monthly Energy Review; Projected emissions- DUKE-NEMS.

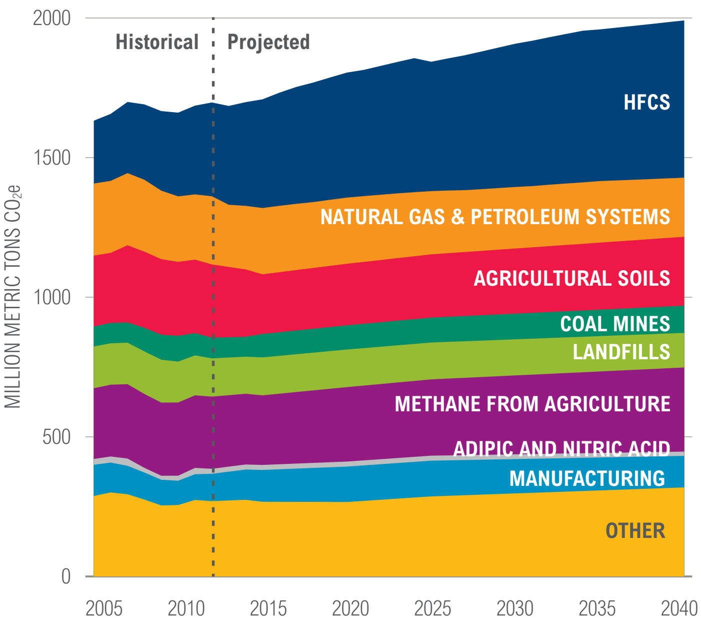
Reference Case Projections of CO_2 from Energy Use

In 2012, CO_2 emissions from energy sources, which account for about 75 percent of total U.S. GHG emissions, were 12 percent below 2005 levels.[34] Over half (54 percent) of these reductions came from the power sector. The rest of the reductions came from transportation (24 percent), industry (10 percent), and residential and commercial buildings (13 percent). These reductions show a decoupling of emissions from economic growth—as CO_2 emissions fell 12 percent between 2005 and 2012, real gross domestic product increased by 8 percent.[35] Our projections suggest that in the absence of new policies, energy CO_2 emissions will rise slowly to 4 percent above 2012 levels by 2025 and 6 percent by 2040 (Figure 1.3), but remain below 2005 levels through 2040.

Reference Case Projections of Non-Energy CO_2 and Non-CO_2 Emissions

In 2012, non-energy and non-CO_2 sources, such as natural gas systems and hydrofluorocarbons (HFCs), accounted for about 25 percent of total U.S. emissions. Emissions from these sources are projected to increase 13 percent above 2005 levels by 2025 and 22 percent by 2040 (Figure 1.4), due mostly to the projected growth of HFC use.

Figure 1-4 | **Historical and Projected Non-Energy and Non-CO_2 Greenhouse Gas Emissions in the United States**



Sources: U.S. Environmental Protection Agency, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2012 (2005-2012); U.S. State Department, 2014 *U.S. Climate Action Report* (2013-2040); World Resources Institute, Clearing the Air on Shale Gas Emissions (2013-2040); U.S. Environmental Protection Agency, Benefits of Addressing HFCs under the Montreal Protocol (2005-2040).

Recent Federal and State Climate Action

The United States is currently taking a number of steps that will reduce near-term GHG emissions and make progress toward near-term emission goals. The United States can take regulatory actions under several existing laws, including the Clean Air Act, the Energy Policy Act, and the Energy Independence and Security Act (Box 1.2). The Administration's current activities build off of President Obama's Climate Action Plan, released in 2013, which developed reduction strategies across many critical sectors and emission sources—including the power sector, transportation, HFCs, natural gas systems, and others—that could be implemented using existing laws.

State and local authorities are also taking action on climate change, and many are finding that climate action can result in economic benefits. Thirty-one states and the District of Columbia currently have renewable energy or alternative energy targets in place. As renewable technology costs fall, many states are finding that renewable development can decrease the carbon intensity of their power generation while creating local jobs, without increasing electricity prices.[36] Twenty-four states have mandatory energy efficiency savings targets in place for electricity. According to data from public utility commissions, program administrators, and utilities, these programs have proven cost-effective, saving customers about $2 for every $1 invested.[37] Nine states are participating in the Regional Greenhouse Gas Initiative, a cap-and-trade program for power sector CO_2 emissions in the Northeast and Mid-Atlantic region. This approach has been successful and cost-effective in the region: investments from the first three years of the program will save electricity customers nearly $1.1 billion

Box 1-2 | **The U.S. Climate Action Plan**

The U.S. Climate Action Plan, released in 2013, outlined emission reduction strategies across many sectors critical to achieving near-term reduction goals. Key components of the plan are listed below and discussed in more detail throughout Chapter 1:

- Cutting carbon pollution from power plants through standards for both new and existing power plants.
- A goal to double renewable generation between 2012 and 2020.
- Increasing fuel economy standards for heavy-duty vehicles beyond model year 2018.
- Developing and deploying advanced transportation technologies including cleaner fuels, and advanced batteries and fuel cell technologies.
- Implementing new appliance and equipment efficiency standards.
- Reducing barriers to investment in energy efficiency.
- Expanding the President's Better Buildings Challenge, which helps commercial and industrial buildings become at least 20 percent more energy efficient by 2020.
- Cutting hydrofluorocarbon emissions through EPA's Significant New Alternatives Program
- Reducing methane emissions through standards for natural gas and oil systems and landfills.
- Preserving the role of forests in mitigating climate change.

through 2021, while generating 16,000 net job-years and injecting over $1.5 billion in value-added to the economy.[38] California has also implemented a cap-and-trade program across the state, which initially covered major emitters in industry and the power sector, and was extended to cover fuel distributors in 2015.[39] Many other states and localities are pursuing a wide range of activities to reduce energy consumption in homes and businesses, create compact urban areas with safe and reliable public transportation, and many other strategies that harness economic opportunities while reducing GHG emissions.

The U.S. Intended Nationally Determined Contribution

In March 2015, the United States submitted its Intended Nationally Determined Contribution (INDC),[40] which outlines post-2020 climate actions it intends to take under a new international agreement to be created by the conclusion of the U.N. Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP21) in Paris in December 2015.[41]

The U.S. INDC states that the United States will reduce total emissions 26 to 28 percent from 2005 levels by 2025. It further states that this goal is economy-wide and covers:

- All IPCC sectors; these include emissions from energy, industrial processes, agriculture, forestry, other land use, and waste.
- All (100 percent of) greenhouse gases included in the 2014 Inventory of the United State Greenhouse Gas Emissions and Sinks: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3).[42]
- The INDC also specifies the "the United States does not intend to utilize international market mechanisms to implement its 2025 target," confirming that the U.S. GHG reduction target applies to domestic emissions only.

Additional information regarding the United States' GHG accounting methodologies is provided in the INDC, such as:

- The use of 100-year global warming potential values to calculate CO_2-equivalent totals consistent with the IPCC 4th Assessment Report (2007).
- The use of sector accounting consistent with IPCC guidelines and the U.S. National GHG Inventory.
- How the United States will account for emissions and removals from the land use and forestry (LULUCF) sector. The INDC makes it clear that the United States will consider all emission source and sink categories of the LULUCF sector included in its national inventory in evaluating its 2025 target. The INDC further specifies that accounting for the LULUCF sector will be done using a net-net approach (in other words, the United States will estimate net sequestration from land use, land-use change, and forestry activities) and provides additional details regarding accounting practices for harvested wood products[43] and natural disturbances.[44]

Details such as these promote transparency, which enables understanding of the U.S. contribution to post-2020 mitigation and can help encourage trust and accountability among countries and enable others to track U.S. progress. Consistent with the Lima Call for Climate Action and the GHG Protocol Mitigation Goal Standard[45] and Policy and Actions Standard,[46] WRI has developed a set of suggested indicators that countries can use as a reference to ensure their INDCs are adequately transparent. According to this framework, the U.S. INDC is generally excellent on transparency. However, possible improvements remain. For example, the U.S. INDC did not provide a specific action plan for meeting the 2025 target, though it did list the many regulatory actions it has already taken, and is planning to take, under several different U.S. laws (such as the Clean Air Act, the Energy Policy Act, and Energy Independence and Security Act).[47]

The United States could further improve the transparency of its INDC by providing more details regarding how it considers its INDC to be fair and ambitious. For example, the United States could clarify fairness by providing metrics that highlight its economic capacity, such as GDP per capita, how per capita GHG emissions relate to the global average, and the relative costs and benefits of taking climate action,[48] including any cost savings, efficiency gains, and avoided climate impacts. In addition, the United States could strengthen transparency regarding the description of its ambition by addressing its capabilities to act and any limitations on its domestic mitigation potential.

A full analysis according to WRI's transparency evaluation framework is provided in WRI's CAIT Paris Contributions Map, available at: <http://cait2.wri.org/indc/#/profile/United%20States%20of%20America>.

What Will Emissions be in 2025 and 2030 if the United States Achieves its INDC?

Given the above, if the United States meets its INDC pledge, its 2025 emissions will be 4,481–4,605 million metric tons of CO_2 equivalent (mmtCO_2e) when considering carbon sinks (or 5,223–5,368 mmtCO_2e on a gross basis).[c] If the United States follows a straight-line trajectory from its 2025 pledge to its long-term 2050 target,[49] its emissions in 2030 would be 3,833–3,933 mmtCO_2e when considering carbon sinks and 4,468–4,584 mmtCO_2e on a gross basis.

As noted previously, the historical and projected GHG emissions we use in this analysis differ in magnitude with EPA's historical data in its 2014 GHG inventory and projections used by the Administration in the *U.S. Climate Action Report* due to differences in CH_4 and HFC methodologies. For example, we find that 2005 emission levels to be at 7,568 mmtCO_2e while EPA's 2014 national inventory reports 2005 emission levels at 7,254 mmtoCO_2e (these estimates reflect economy-wide GHG emissions before taking into account sequestration from land-use, land-change, and forestry). However, we believe our estimates of percent emission reductions can legitimately be compared to the Administration's targets because the methods we use to develop emission projections are consistent with the construction of our historical inventory. See our discussion throughout Chapter 2, as well as the Appendix, for more information on how we constructed our emission estimates.

Key Contextual Factors in Examining U.S. Emission Targets

In reviewing the substance of the U.S. INDC or any emission scenario for the United States, one needs to understand the terms and the context of the commitment the United States made in 2009 at the Copenhagen COP. The United States announced a target to reduce emissions in 2020 "in the range of 17 percent (below 2005 levels), in conformity with anticipated U.S. energy and climate legislation…"[50] The U.S. submission also noted that the ultimate goal of the legislation was to reduce emissions by 83 percent below 2005 levels by 2050. A straight-line interpolation of those two targets would result in a 28 percent reduction below 2005 levels in 2025.

Two factors make near-term emission targets for 2020 or 2025 difficult to achieve. First, the cap-and-trade legislation that passed the House of Representatives in 2009 did not pass the Senate, and therefore did not become U.S. law. The Obama Administration has had to rely on administrative powers to move forward on climate mitigation. Second, the 2009 legislation would have allowed for generous use of international offsets to meet the U.S. target. Use of such offsets is no longer under consideration in the current context (since, for example, offsets cannot be used under Clean Air Act obligations), so the emission reduction targets now being discussed are based entirely on reductions from within the U.S. economy.

Despite these two factors, the United States has made significant progress toward the 17 percent reduction promised for 2020. Lower emissions are due in part to the economic recession that began in 2008, but other contributors have included new and expanded federal and state policies, as well as recent market trends in natural gas and renewable energy, cleaner and more fuel-efficient vehicles, and slower electricity demand growth. These latter factors could make it easier for the United States to reduce its GHG emissions with net benefits to the economy. Below, we discuss recent emission trends in more detail by major sector or emission source. We describe contributors to recent trends, as well as how current policies, proposed actions under the Climate Action Plan, and other factors are likely to impact these trends going forward.

Key Influences on the U.S. GHG Emission Trajectory

Producing Cleaner Electricity

The power sector is shifting from coal-fired generation toward lower-carbon sources, including natural gas-fired and renewable generation. Coal generation fell 21 percent between 2005 and 2013, while natural gas and renewable generation grew 49 and 51 percent, respectively.[51]

Recent low prices for natural gas have resulted in a surge in gas-fired generation and a corresponding decline in coal generation. Low natural gas prices are also helping to drive an ongoing reduction of industrial coal use as fuel

[c] According to EPA's 2014 GHG Inventory, which was used for this analysis. Using emission estimates from EPA's 2015 GHG inventory (which were not available at the time of our analysis), if the United States meets its INDC pledge, its 2025 emissions will be 4,636–4,764 million metric tons of CO_2 equivalent (mmtCO_2e) when considering carbon sinks (or 5,292–5,439 mmtCO_2e on a gross basis). If the United States follows a straight-line trajectory from its 2025 pledge to its long-term 2050 target, its emissions in 2030 would be 3,966–4,069 mmtCO_2e when considering carbon sinks and 4,528–4,645 mmtCO_2e on a gross basis. See: U.S. Environmental Protection Agency. 2015. "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2013." Accessible at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

and feedstock.[52] Looking forward, natural gas prices are expected to slowly rise from current levels, which could reverse this trend. However, gas still emits less CO_2 than coal, and it could play a key role in a low-carbon power grid to help integrate variable renewable generation sources, if upstream methane emissions from natural gas production and transport are properly managed.

Meanwhile, wind generation is now cheaper (on a megawatt-hour basis) than new coal and natural gas plants in a growing number of markets, while some new solar photovoltaic projects are being chosen over new coal generation because of lower costs or larger net benefits.[53] States across the country are continually finding that renewable energy investments are driving energy bill savings, supporting new jobs, and providing other economic benefits.[54] Utilities may also see the value in using renewable energy (with zero fuel costs) as a hedge against the uncertainty surrounding future coal and natural gas prices.[55] As a result, the United States may find that growth in renewable generation exceeds projections.[56] Recent increases in transmission capacity and improvements in renewable energy forecasting and subhourly supply scheduling[57,58] have helped spur renewable growth in addition to declining costs.[59,60] As renewable generation penetration increases over the longer term, the country would benefit from continuing to expand transmission and increasing system flexibility (to help respond to the variability of renewable sources) by increasing the use of grid storage, distributed generation sources, and demand response.[61]

LOOKING AHEAD

The Climate Action Plan set two goals that aim to build on these trends, including cutting carbon pollution from power plants. To achieve this goal, President Obama directed EPA to set standards for both new and existing power plants. Standards for new plants were proposed in September 2013, and standards for existing plants—that is, the Clean Power Plan—were proposed in June 2014. Both sets of standards are expected to be finalized in summer 2015. The Climate Action Plan also aims to double renewable generation between 2012 and 2020 supported by accelerated clean energy permitting and modernization of the electric grid. The Clean Power Plan can encourage more widespread adoption of state renewable targets. However, EPA only took into account existing state renewable portfolio standards when developing its state targets rather than the full potential for development of new renewables. According to their modeling of the proposed rule, renewable generation increases 30 percent between 2012 and 2020. However, it is likely that states will use more renewable generation to comply with the rule than estimated by EPA, particularly as renewable technology costs continue to fall.

Increasing Efficiency

With less energy-intensive manufacturing, higher-efficiency appliances and buildings, and more fuel-efficient vehicles coming to market, the overall economy is becoming more energy efficient. While energy use is expected to begin growing again following a downturn during the economic recession, efficiency will offset growth in energy consumption as the economy recovers.[62] EIA projects that energy use per dollar of GDP will decline steadily at an average 2 percent per year through 2040, further signaling the decoupling of energy use from economic growth. While GDP is projected to grow at an average 2.4 percent per year through 2040, energy use is projected to grow at only 0.4 percent per year.[63]

Despite this progress, barriers still remain that inhibit the implementation of the full range of cost-effective energy efficiency measures. Smart and innovative policies are therefore needed to overcome these barriers and spur further investment into efficiency as well as promote the next wave of new technologies.

LOOKING AHEAD

The Climate Action Plan has set three goals to help overcome these barriers and capture more efficiency across the economy. This includes implementing new appliance and equipment efficiency standards. Specifically, the plan establishes a goal to set efficiency standards for appliances and federal buildings that will reduce carbon pollution by at least 3 billion metric tons cumulatively by 2030. Since 2009, DOE has issued new and strengthened appliance standards covering more than thirty products. According to the Appliance Standard Awareness Project, which tracks progress toward this goal, standards finalized since the start of the Administration will achieve cumulative reductions of 2.2 billion metric tons of CO_2 by 2030.[64]

In addition, the Climate Action Plan aims to reduce barriers to investment in energy efficiency by providing funds for upfront costs of energy efficiency upgrades, specifically through the U.S. Department of Agriculture and the U.S. Department of Housing and Urban Development. The plan also calls for expanding the president's Better Buildings Challenge, which helps commercial and industrial buildings become at least 20 percent more energy efficient by 2020. Strategies include adding multifamily buildings to the program and launching the Better Buildings Accelerators program, which will focus on state and local efforts to improve efficiency.

Increasing Vehicle Efficiency and Changing Preferences for Travel Demand

The transportation sector is becoming less carbon intensive, due in large part to the most recent federal GHG emission and fuel economy standards covering light-duty cars and trucks (model year 2012–25) as well as medium- and heavy-duty vehicles (model year 2014–18). These rules for passenger vehicles have led to a doubling of the number of sport utility vehicle models with a fuel economy of at least 25 miles per gallon (mpg) over the last five years, while the number of car models with a fuel economy of at least 40 mpg has increased sevenfold.[65] Since car manufacturers are adopting more fuel-efficient technology, analysis shows they are outperforming the current standards and are on track to meet the model year 2025 standards.[66] Although they account for only a modest percentage of total vehicle sales, the uptake of electric vehicles has been faster than the initial uptake of hybrid vehicles in the United States,[67] and several manufacturers are planning to commercialize hydrogen cars through 2017. If technological progress continues, it should be easier and more cost-effective to meet the 2025 standards, and may be possible to achieve deeper reductions after 2025 (as long as the electricity and hydrogen used to power these alternative vehicles are produced using low-carbon energy sources).

A declining growth rate in vehicle miles traveled (VMT) by passenger vehicles also has contributed to declining emissions from light-duty vehicles over the past decade. While the economic recession contributed to this trend, it has been supported by changing demographics, high costs of driving (including rising fuel prices until late 2014), and changing consumer preferences. It is uncertain whether these trends will continue or whether VMT growth will rebound due to continued recovery from the recession and other factors, including the recent decline in fuel prices.[68,69]

LOOKING AHEAD

The Climate Action Plan aims to develop and deploy advanced transportation technologies, calling for the Administration to continue leveraging public-private partnerships to deploy cleaner fuels, including advanced batteries and fuel cell technologies, and to work with state and local authorities to improve transportation options. However, additional policies and support, like increased access to alternative fuel stations, as well as federal and state mandates and incentives, will also be needed to help promising vehicle technologies realize their potential. Additionally, the president directed EPA and the National Highway Transportation Safety Administration (NHTSA) to increase fuel economy standards by developing post-2018 standards for heavy-duty vehicles. EPA and NHTSA, in collaboration with California's Air Resources Board, are expected to release proposed rules in the first half of 2015.

HFC Consumption on the Rise

HFCs are a small but rapidly growing component of U.S. (and global) GHG emissions. These gases, which are used as refrigerants, foam blowing agents, and aerosols, can have very high global warming potentials (GWPs); those with the highest GWPs trap thousands of times more heat than CO_2. Emissions of HFCs have been increasing due to the phaseout of chlorofluorocarbons (CFCs) and other ozone-depleting substances under the Montreal Protocol and Clean Air Act. This trend is expected to continue as the interim substitutes, hydrochlorofluorocarbons (HCFCs), are also phased out and replaced with HFCs.[70] However, many companies are already using alternatives to high-GWP HFCs, often resulting in lower energy consumption in addition to reduced GHG emissions associated with the refrigerants.[71] Some low-GWP replacements have relatively high upfront costs, require the replacement of old equipment, or equipment redesign.[72] Therefore, additional rules or other incentives are needed to spur the U.S. market to rapidly move to these alternatives.

LOOKING AHEAD

In the absence of an agreement to an international phasedown through the Montreal Protocol, and as part of the U.S. Climate Action Plan, EPA has started to use its authority under the Clean Air Act to cut HFC emissions by driving the adoption of low-GWP HFCs as well as non-HFC alternatives. EPA has already started offering incentives and setting standards to phase out the use of high-GWP HFCs as part of its vehicle rules.[73,74] Additionally, in July 2014, EPA proposed rules under section 612 of the Clean Air Act—implemented through the Significant New Alternatives Policy (SNAP) program—to move some higher GWP HFCs out of the market for various applications.[75] In February 2015, EPA finalized rules to approve additional low-GWP alternatives for use.[76] EPA estimates that if these rules are finalized as proposed, HFC emissions will be reduced by 58 to 78 million metric tons of CO_2e in 2025 (a 15 to 21 percent reduction in projected business-as-usual HFC emissions).[77]

Increased Natural Gas Production Means More Methane Leaks

Natural gas production has increased by over 30 percent between 2005 and 2012[78] due to the rapid development of shale gas resources. Because leaks and vents of natural gas occur throughout the natural gas supply chain—from drilling through production, processing, transmission, distribution, and end use—increases in natural gas extraction lead to larger fugitive emissions from natural gas systems. EPA performance and emission standards, finalized in 2012, are expected to indirectly achieve a 9–21 percent reduction in methane emissions compared to projections without standards. These rules are expected to save the natural gas industry approximately $10 million per year once fully implemented in 2015, even without considering the benefits of reduced air pollution, because the value of the natural gas saved is greater than the cost of equipment to capture it.[79] However, methane emissions from natural gas systems are projected to grow slowly between 2013 and 2040, even though studies suggest that even more cost-effective leak reduction technologies and measures are readily available.

Despite the potential for saving money by reducing leaks, use of emission control technologies is not widespread because there are several market barriers inhibiting greater investment. First, principal-agent problems mean that often the companies investing in such technologies are not the ones receiving the benefits. Second, getting an accurate measurement of how much natural gas is leaking can be costly, so imperfect information acts as a barrier to investment. Lastly, there will always be opportunity costs and competing priorities for the money that would otherwise go toward reducing leaks and vents.[80] The presence of these barriers suggests that emission standards are ultimately necessary to spur this sector to make the types of investments that will reduce methane leaks.

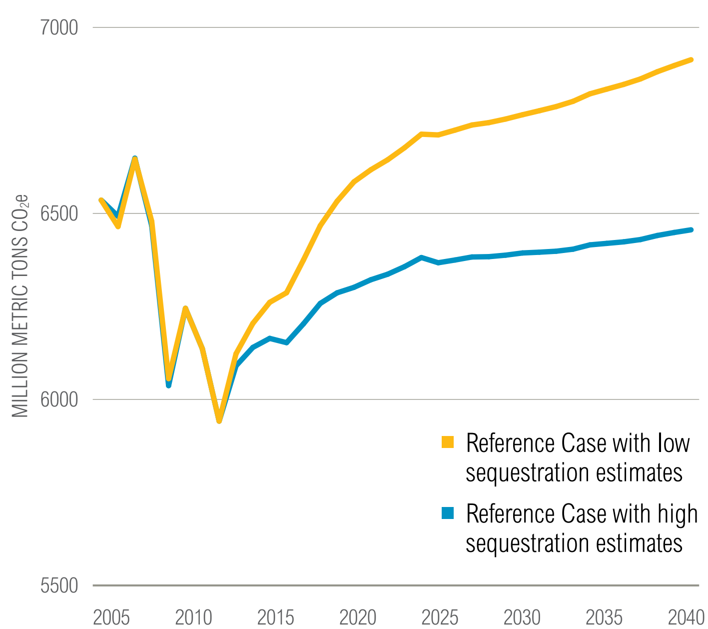
LOOKING AHEAD

In January 2015, the White House announced several new actions under the Climate Action Plan that will be taken by EPA, the Bureau of Land Management, the Department of Energy, and the Department of Transportation to reduce methane emissions from the oil and gas sector. The Obama Administration estimates these actions could reduce methane emissions by 40–45 percent from 2012 levels by 2025. EPA standards, which would only cover new equipment, are expected to be proposed sometime during the summer of 2015 and finalized in 2016. Standards are also in the works for landfills. However, both natural gas and landfill standards will only apply to new sources, missing the opportunity for abatement from existing sources.

U.S. Carbon Sinks

Annual estimates of carbon sequestration from land use, land use change, and forestry have fallen by 5 percent between 2005 and 2012. As illustrated in Figure 1.5, there is a lot of uncertainty regarding future sequestration levels. For example, Reference Case emission levels (considering only existing laws and state action) are projected to be 3 percent below 2005 levels in 2025, assuming the high end of the latest government estimates of U.S. carbon sinks. Reference Case emission projections increase to 3 percent above 2005 levels when considering the low end of the range.

Figure 1-5 | **Reference Case Greenhouse Gas Emissions Under a Range of Sequestration Estimates**



Sources: Historical emissions- U.S. Energy Information Administration, Monthly Energy Review; U.S. Environmental Protection Agency, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2012 (April 2014) and Benefits of Addressing HFCs under the Montreal Protocol; Projected emissions- WRI-NEMS; U.S State Department, 2014 *U.S. Climate Action Report*; U.S. Environmental Protection Agency, Benefits of Addressing HFCs under the Montreal Protocol; World Resources Institute, Clearing the Air.

LOOKING AHEAD

The Administration has set a goal to preserve the role of forests in mitigating climate change by exploring ways to protect and restore forests, grasslands, and wetlands to help sequester and store CO_2. However, ensuring that the U.S. carbon sinks sequester carbon in the upper range of current projections is critical to helping the nation meet its 2025 emission reduction target, so the U.S. government should develop a targeted plan to maintain and increase the nation's carbon sinks.

The United States Will Need to do More to Meet its Climate Goals

Recent economic and market trends and technological innovation—reinforced by state, federal, and local policies—have helped reduce U.S. GHG emissions since 2005. But in the absence of new policies and programs, emissions are not expected to continue a downward trend. Instead, they are expected to grow slowly from current levels to 5 percent below 2005 levels by 2020 and 4 percent by 2025, far from the U.S. emission reduction targets for these years.

The U.S. INDC did not provide a specific action plan for meeting the 2025 target, but it makes clear that the United States will rely on core aspects of the Climate Action Plan described above. The U.S. Climate Action Plan is poised to make significant contributions toward meeting these goals, particularly if finalized standards and strategies across all aspects of the plan are ambitious. However, to meet its climate goals, the United States will need to strengthen and expand on the actions within many of the sectors already identified in the plan, and take action on additional sectors not covered by the current plan.

We developed low-carbon pathways and an action plan that the United States can take to achieve its near-term emission reduction goals. These pathways can meet or exceed the U.S. 2025 emission target using existing federal authority and state action. The pathways, action plan, and underlying analysis are presented in Chapter Two.

ENDNOTES | INTRODUCTION AND CHAPTER 1

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28. The most recent version of the Annual Energy Outlook (AEO2015) was released after we completed our analysis. Total energy CO_2 emissions and key macroeconomic indicators are similar to AEO2014, although emissions, energy consumption, and other factors differ somewhat among subsectors. See Box A-2 in the Appendix for further discussion.
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36. For example, in Iowa, MidAmerican Energy just announced it will invest $1.9 billion in new wind power, bringing wind capacity up to 39 percent of its generation portfolio. The company estimates that when all the turbines are completed rates will go down by $10 million annually, while creating 460 construction jobs, 48 permanent jobs, and generating more than $360 million in new property tax revenue. (MidAmerican Energy. May 8, 2013. “MidAmerican Energy Announces $1.9 Billion Investment in Additional Wind Generation Capacity.” Accessible at: <http://www.midamericanenergy.com/wind_news_article.aspx?id=634>.) The Illinois Power Agency found that the state’s renewable energy standard enabled significant job creation and economic development opportunities; moreover, in 2011, the growth of wind energy reduced electricity rates by about 4 percent per megawatt hour of electricity generation, for total statewide savings of over $175 million. (Illinois Power Agency. 2012. “Annual Report: The Costs and Benefits of Renewable Resource Procurement in Illinois under the Illinois Power Agency and Illinois Public Utilities Acts.” Accessible at: <http://www2.illinois.gov/ipa/Documents/April-2012-Renewables-Report-3-26-AAJ-Final.pdf>.) Studies by the New York Independent System Operator (NY ISO), Synapse Energy Economics, and the National Renewable Energy Laboratory suggest that increased renewable energy generation has the potential to save American ratepayers tens of billions of dollars a year over the current mix of electric power options. (Josh Ryor and Letha Tawney. 2014. “Shifting to Renewable Energy Can Save U.S. Consumers Money.” Washington, DC: World Resources Institute. Accessible at: <http://www.wri.org/blog/2014/06/shifting-renewable-energy-can-save-us-consumers-money>.) In March 2015, DBL Investors found that the average retail electricity prices in states generating more of their electricity from renewable sources was often much lower than states that used fewer renewable sources, suggesting that state leaders on renewable development “have not experienced disproportionate electricity price growth.” (Nancy Pfund and Anand Chhabra, DBL Investors. 2015. “Renewables are Driving Up Electricity Prices: Wait, What?” Accessible at: <http://www.dblinvestors.com/wp-content/uploads/2015/03/Pfund-Chhabra-Renewables-Are-Driving-Up-Electricity-Prices-Wait-What.pdf>.)
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41. World Resources Institute. “What is an INDC?” Sccessible at: <http://www.wri.org/indc-definition>.
42. Starting in 2015 with its “Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990:2013,” the United States will be reporting emissions of nitrogen trifluoride (NF_3), a fluorinated gas emitted during semiconductor manufacturing. NF_3 emission data were not available at the time of this analysis (we relied on the 2014 inventory), but its overall impact on the inventory is relatively minor. In 2013, EPA estimates the United States emitted 0.6 million metric tons of CO_2e due to NF_3, representing less than 0.01 percent of total emissions.
43. The U.S. INDC specifies a “production approach” to account for harvested wood products, consistent with IPCC guidance. According to the IPCC, this includes estimating “changes in carbon stocks in the forest pool (and other wood producing lands) of the reporting country and the wood products pool containing products made from wood harvested in the reporting country. The wood products pool includes products made from domestic harvest that are be exported and stored in uses in other countries. This approach inventories carbon in wood products from domestically harvested wood only and does not provide a complete inventory of wood carbon in national stocks.” See: Intergovernmental Panel on Climate Change. 2006. IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4: Agriculture, Forestry and Other Land Use. “Chapter 12: Harvested Wood Products.” Accessible at: <http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_12_Ch12_HWP.pdf>.
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56. Our Reference Case projects that renewable generation will account for around 18 percent of total generation in 2030. However, while the variability of renewable generation creates some challenges for grid balancing authorities, several studies have shown that grids across the country can handle up to 35 percent generation from variable renewable resources with minimal cost. For example, PJM, National Renewable Energy Laboratory (NREL) for the Western United States, and the state of Michigan have all found that 30–35 percent of electricity could be generated using variable renewable resources with minimal cost. See GE Energy Consulting. “PJM Renewable Integration Study Executive Summary Report.” Revision 05, 2014. Accessible at: <http://pjm.com/~/media/committees-groups/task-forces/irtf/postings/pris-executive-summary.ashx>. GE Energy. 2010. “Western Wind and Solar Integration Study.” Prepared for National Renewable Energy Laboratory. Accessible at: http://www.nrel.gov/docs/fy10osti/47434.pdf. J.D. Quackenbush and S. Bakkal. 2013. “Readying Michigan to Make Good Energy Decisions: Renewable Energy. ” Michigan Public Service Commission, Licensing and Regulatory Affairs. Michigan Economic Development Corporation. Accessible at: <http://www.michigan.gov/documents/energy/renewable_final_438952_7.pdf>. For more information, see M. M. Hand, S. Baldwin, E. DeMeo, J. M. Reilly, T. Mai, D. Arent, G. Porro, M. Meshek, and D. Sandor (eds.). “Renewable Electricity Futures Study.” 4 vols. NREL/TP-6A20-52409. Golden, CO: National Renewable Energy Laboratory. Accessible at: <http://www.nrel.gov/analysis/re_futures/>. R. Wiser and M. Bolinger. “2013 Wind Technologies Market Report.” Lawrence Berkeley National Laboratory. Accessible at: <http://emp.lbl.gov/sites/all/files/2013_Wind_Technologies_Market_Report_Final3.pdf>.
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Chapter 2

PATHWAYS FOR THE UNITED STATES TO DELIVER ON ITS CLIMATE COMMITMENT

As noted in Chapter 1, federal and state policies, as well as technological innovation, have helped to reduce greenhouse gas (GHG) emissions by about 8 percent below 2005 levels in 2012. Yet, preliminary data show that total emissions rose by almost 2 percent between 2012 and 2013.[1] The actions already taken by the Obama Administration under the Climate Action Plan set an important foundation that will help drive cuts in future emissions, but additional action within the realm of executive authority will be needed for the United States to achieve its target of reducing emissions 26–28 percent below 2005 levels by 2025, as outlined in its Intended Nationally Determined Contribution (INDC).

In this chapter, we examine specific ways that the United States can build on the Climate Action Plan and make significant emission cuts in the near- to medium-term. We find that the United States can meet, and even surpass, its announced target to reduce GHG emissions using existing federal authorities and state actions. However, this will require a comprehensive, focused effort across all sectors of the economy, including extending and expanding regulations already in place as well as setting new standards for sources of emissions not yet addressed directly by the Climate Action Plan, but achievable using existing authorities.[2]

UNDERSTANDING THE LOW-CARBON PATHWAYS

To examine how the United States could achieve significant reductions in the near- to medium-term, we developed three low-carbon pathways, described below, that include mitigation opportunities and policy tools that can be pursued using current federal authorities, as well as additional state action. All three pathways require ambitious action. In this paper, we use the term "ambitious" to reflect measures that: (1) are technically achievable; (2) take advantage of and reinforce recent low-carbon technology and market trends; and (3) are necessary to capture the full scope of emission reduction opportunities in a given sector. The three pathways serve as illustrative examples of different combinations of policies and measures that the United States can take to achieve significant emission reductions (Table 2.1).

1. **Core Ambition.** Our Core Ambition pathway assumes that the U.S. Environmental Protection Agency's (EPA) Clean Power Plan is finalized as proposed, and actions are taken to harness low-carbon opportunities across most other sectors of the economy.[3] These actions include new and strengthened federal appliance efficiency standards, improved GHG and fuel efficiency standards for passenger vehicles and heavy-duty trucks, emission standards for natural gas systems, reduced hydrofluorocarbon (HFC) consumption, and others. Under this pathway, power sector carbon dioxide (CO_2) emissions fall 40 percent below 2005 levels by 2030 as a result of both the Clean Power Plan as proposed and additional reductions in electricity demand from federal efficiency measures.[a] Roughly 70–75 percent of the potential abatement we identified under this pathway is in sectors in which the Obama Administration has already begun to act, although many of these existing and proposed measures covering these emission sources will need to be strengthened. The United States can capture the remaining abatement potential by taking new action across emission sources not yet addressed, but where executive authority exists.

Because the largest source of potential emission abatement for the United States is found in the power sector, the stringency of efforts in this sector affects how much additional action is needed across other sectors to achieve deeper economy-wide reductions. Our next two pathways

[a] We assume that EPA sets separate standards for industry, and the U.S. Department of Energy establishes new and strengthened appliance and equipment standards (we do not assume implementation of any state appliance standards). We assume that CO_2 reductions resulting from these measures are additional to the CO_2 reductions resulting from EPA's proposed Clean Power Plan. Under this assumption, states would take credit only for efficiency measures that go beyond a baseline adjusted for these new federal measures. As the rule is implemented, it may be possible for states to receive credit for measures related to industrial efficiency and appliances regulated by federal standards, but EPA has not yet released guidance on these issues.

Table 2-1 | **Key Elements of the Pathways**

	CORE AMBITION	POWER SECTOR PUSH	TARGETED SECTOR PUSH
POWER SECTOR	■	●	■
OTHER ENERGY EMISSION SOURCES	▲	▲	●
NON-CO_2 EMISSION SOURCES	▲	▲	▲

■ Clean Power Plan as proposed combined with federal appliance and industrial efficiency standards (leading to power-sector emission reductions in the range of 36 percent below 2005 levels in 2025 and 40 percent in 2030).

● Low carbon trends are accelerated through the 2020s either in the power sector via greater deployment of renewables and energy efficiency (leading to power-sector emissions reductions in the range of 45 percent below 2005 levels in 2025 and 52 percent in 2030) or across four other key sectors (passenger vehicle CAFE standards, passenger vehicle travel demand, industrial energy efficiency, residential and commercial natural gas demand).

▲ Ambitious measures across all other emission sources analyzed in this study.

were designed to achieve very similar levels of emission reductions, illustrating alternative ways to go beyond our Core Ambition pathway, either through increased action in the power sector or outside the power sector.

2. **Power Sector Push.** Our Power Sector Push pathway assumes that EPA strengthens the proposed standards for existing power plants under its Clean Power Plan and renewable energy technology costs continue their rapid decline. This allows states and utilities to deploy more renewable energy and energy efficiency, leading to power-sector CO_2 emission reductions of 45 percent below 2005 levels by 2025 and 52 percent by 2030. The Power Sector Push pathway also includes policies that drive further reductions in residential and commercial buildings, industry, transportation, natural gas systems, and various industrial gases similar to the Core Ambition pathway.

3. **Targeted Sector Push.** The Targeted Sector Push pathway explores how to achieve deeper economy-wide reductions if the power sector is limited to reductions consistent with the proposed Clean Power Plan and our Core Ambition pathway. This pathway pushes the envelope in four key areas: passenger vehicle efficiency, travel demand, industrial energy use, and natural gas demand in buildings.

   This would require even more accelerated deployment of next generation vehicle technologies than has occurred in recent years, allowing GHG and CAFE standards for light-duty vehicles to be reached five years earlier than the Core Ambition pathway. In addition, this pathway reflects an acceleration of recent trends toward lower growth in personal travel demand facilitated by supportive policies, including compact development and improved public transportation. In the industrial sector, larger emission reductions are achieved by more fully capturing efficiency opportunities and increasing use of lower-carbon fuel sources. This pathway also captures much greater natural gas savings in homes and commercial buildings through accelerated adoption of state efficiency savings targets.

While these pathways are based on existing federal authorities and action at the state level, the application of certain policy tools, especially those that would require more ambitious reductions (like those in our Power Sector Push and Targeted Sector Push pathways), would be enhanced by supportive congressional actions (e.g., periodic transportation reauthorization bills that help promote reduced travel demand, new or reauthorized tax provisions promoting renewable energy and energy efficiency, and others). At a minimum, we assume the absence of congressional barriers to executive branch actions using existing authorities.

MODELING OUR REFERENCE CASE AND LOW-CARBON PATHWAYS

We used WRI's Greenhouse Gas Abatement Model (WRI-GAM), a bottom-up, sector- by-sector, Excel-based model to estimate the emission reductions resulting from the policies we analyzed. WRI-GAM utilizes publicly available detailed emission reports, as well as outputs from a publicly available off-the-shelf transportation model (Argonne National Laboratory's VISION model). Unless otherwise noted, "Reference Case" here always refers to the one constructed for this analysis, and not to any official EIA or EPA projections or reference cases. Our Reference Case for energy-related projections (such as electricity demand growth, industrial energy use, energy CO_2 emissions, and others) utilized outputs from the version of the Energy Information Administration (EIA) National Energy Modeling System maintained by Duke University's Nicholas Institute for Environmental Policy Solutions (DUKE-NEMS), which collaborated with WRI in this study. We made minor modifications to these projections, described in more detail in the Appendix, to better reflect recent market trends. For example, we used elements of the AEO2014 Low Renewable Technology Cost side case for the power sector in order to better capture declining renewable technology costs, which are not captured well by the AEO 2014 Reference Case.[4]

For most non-energy CO_2 and non-CO_2 gases, WRI-GAM uses EPA projections contained in the U.S. State Department's 2014 *U.S. Climate Action Report*.[5] For HFCs, WRI-GAM relies on projections of HFC consumption estimated by EPA in *Benefits of Addressing HFCs under the Montreal Protocol* instead of HFC emission estimates from EPA's inventory.[6] WRI-GAM also uses projections of methane emissions from natural gas systems based on an update of analysis initially conducted for WRI's *Clearing the Air*, which we believe better captures the current methane leakage rate.[7,8]

WRI-GAM tracks emission abatement from different policies across the six main greenhouse gases while taking into account some cross-sector effects. We account for changes in electric demand through a module that calculates the CO_2 benefit of the net electric demand adjustment. We also account for changes in emissions from refineries and natural gas systems due to changes in demand for petroleum products and natural gas, respectively. However, most sectoral analyses were independent and did not interact with each other; for example, reductions in coal or natural gas demand from one set of policies did not affect utilization of those fuels in another sector. While WRI-GAM is able to model top-down policy measures (e.g., state energy efficiency savings targets), it is unable to model efficiency improvements to specific types of equipment and appliances or power and industrial units. WRI-GAM is also not an economic model, so we are not able to analyze the economic effects of the policies we assume under our Core Ambition, Targeted Sector Push, and Power Sector Push pathways. We considered using DUKE-NEMS to model the three pathways based on existing federal authorities and state action, which would have brought the capability to model economic impacts of these pathways. However, the Clean Power Plan is central to these pathways, and modeling the details and complexities of the Clean Power Plan in DUKE-NEMS proved difficult and was beyond the scope of this analysis.[9]

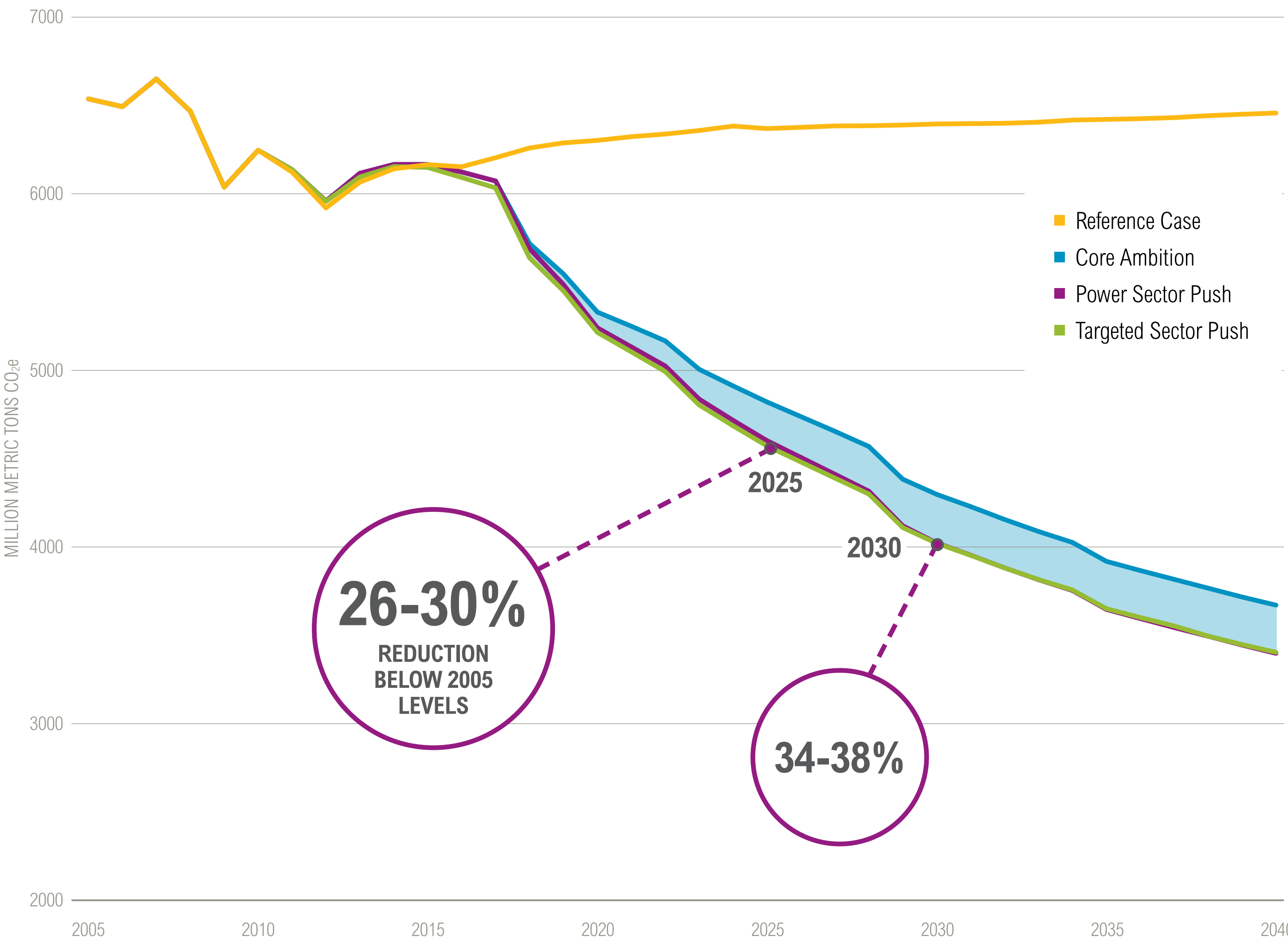
A more detailed discussion of our data sources, methods, and assumptions for these three pathways is provided in the Appendix. Box 1.1 in Chapter 1 lists major policy developments included in our Reference Case.

KEY FINDINGS

Our analysis indicates that the United States can build on the progress it has made so far and make significant emission reductions over the next several decades by establishing policies that stimulate innovation and investment in a low-carbon future. As noted in Chapter 1, the U.S. INDC did not provide a specific action plan for meeting its 2025 target to reduce GHG emissions by 26–28 percent below 2005 levels. However, we find that the United States can meet, and even surpass, this target, and that this can be achieved through several different pathways. The potential economy-wide GHG reductions resulting from these pathways rely strongly on how far the power sector is pushed, which is illustrated by our key findings:

- **The United States can reduce its total GHG emissions by 26 percent below 2005 levels in 2025 and by 34 percent in 2030 using existing federal authorities and expanded state actions** (Figure 2.1). These reductions can be achieved by implementing EPA's Clean Power Plan as proposed and extending or expanding current measures while also taking new, ambitious action across other sectors of the economy. This includes policies affecting residential, commercial, and industrial energy use, transportation, natural gas systems, and various industrial gases.

Figure 2-1 | **Net U.S. Greenhouse Gas Emissions: Reference Case and Low-Carbon Pathways Using Existing Federal Authorities and Additional State Action**



Note: This figure depicts net GHG emissions under three low-carbon pathways we modeled in our analysis that could be pursued using existing federal laws and additional state action. Core Ambition reflects the U.S. Environmental Protection Agency's (EPA) proposed Clean Power Plan (CPP), in addition to emission abatement opportunities across other sectors of the economy. Power Sector Push builds on Core Ambition by assuming that states and utilities go beyond the CPP as proposed, or that EPA strengthens the proposal to take advantage of cost-effective energy efficiency resources and continued decreases in renewable energy costs. Targeted Sector Push assumes that the CPP is finalized as proposed, but pushes the envelope in a few key areas outside the power sector to achieve economy-wide reductions similar to Power Sector Push. Both of these pathways were designed to achieve very similar levels of emission reductions, illustrating alternative ways to go beyond a 26 percent reduction across the economy, either through increased action in the power sector or outside the power sector. The shaded area between the pathways indicates that reductions anywhere in this range are possible given mixtures of policies that blend these three pathways. See text for more details on these pathways and the Reference Case.

Figure 2-2 | **U.S. Emissions by Sector in Reference Case and Low-Carbon Pathways in 2025**

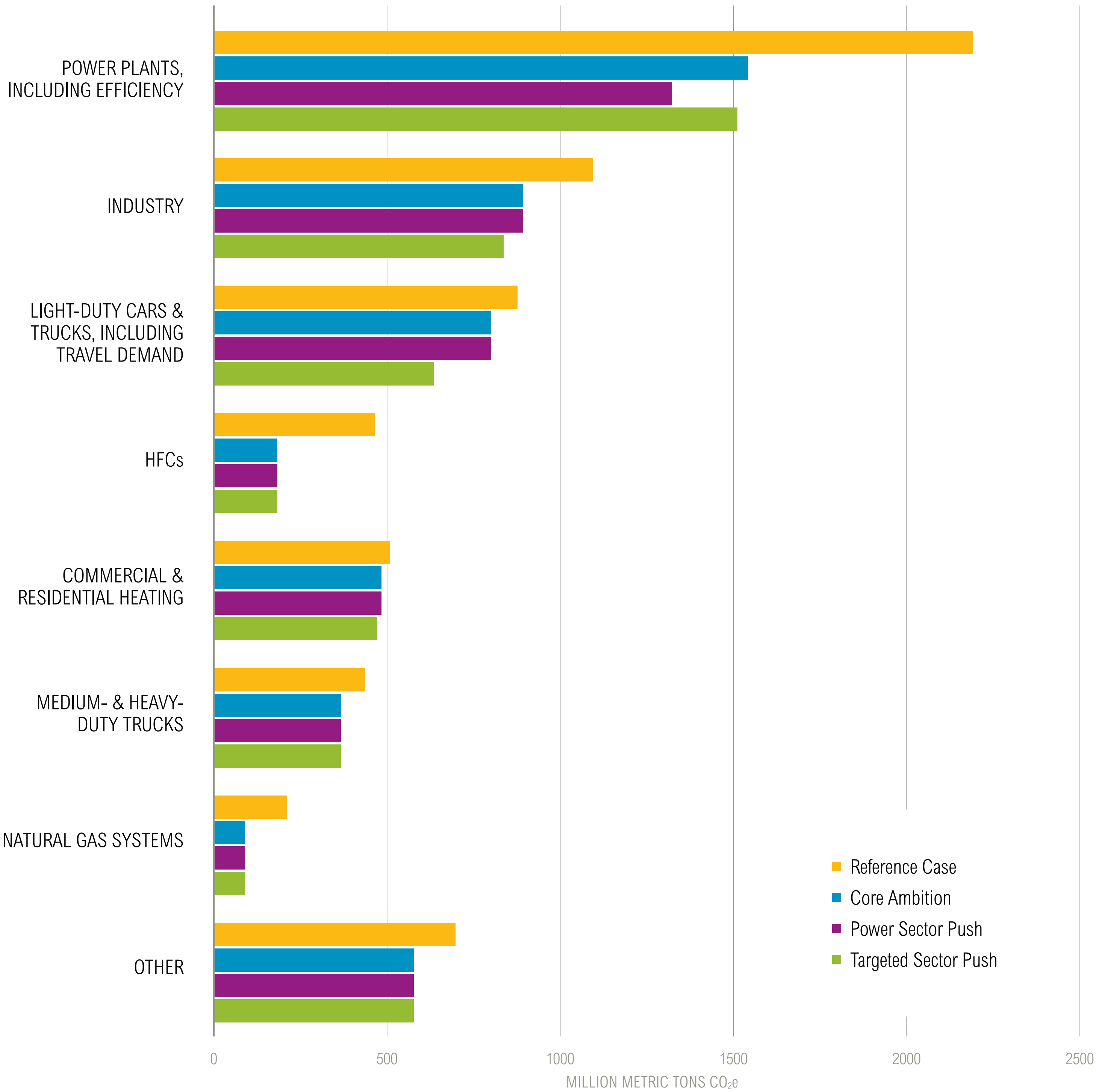
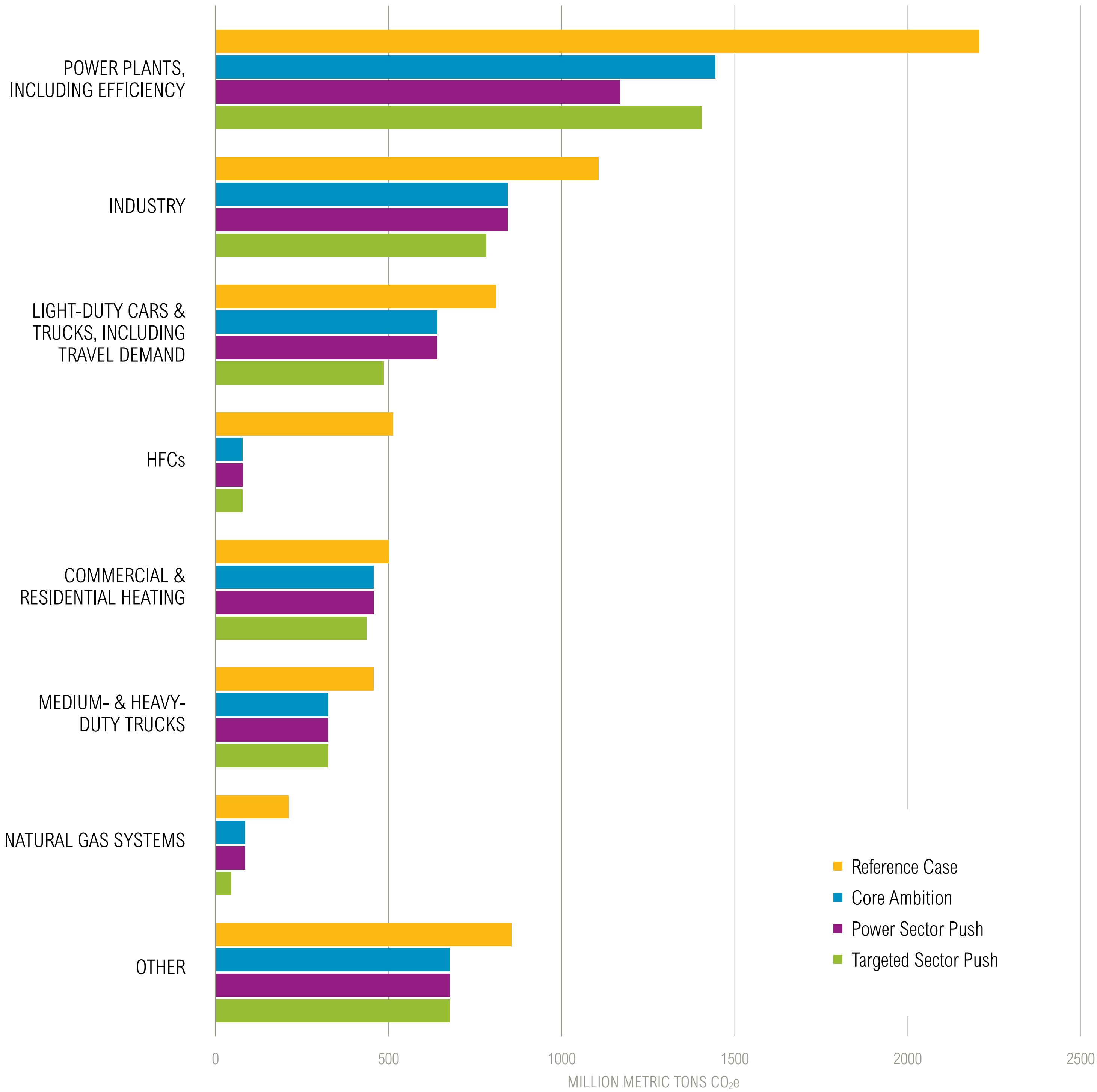


Figure 2-3 | **U.S. Emissions by Sector in Reference Case and Low-Carbon Pathways in 2030**



- **The United States can reduce its GHG emissions by 30 percent below 2005 levels in 2025 and by 38 percent in 2030 by deploying even more renewable energy and energy efficiency sources beyond what's required under the proposed Clean Power Plan.**

- **The United States can achieve similar levels of abatement (30 percent below 2005 levels in 2025 and by 38 percent in 2030) by focusing on non-power sectors** and further accelerating next-generation technological deployment and changes in consumer behavior related to passenger vehicle efficiency and travel demand, industrial energy efficiency, and decreasing natural gas use in the residential and commercial sector.

Figures 2.2 and 2.3 show GHG emissions by sector under our low-carbon pathways compared to the Reference Case. The power sector is the largest opportunity for GHG emission abatement across all our pathways, where cleaner generation combined with more efficient electricity use could reduce power sector carbon dioxide (CO_2) emissions 45 percent below 2005 levels by 2025 and 52 percent by 2030. Hydrofluorocarbons (HFCs), industry,[10] vehicles and reduced transport demand, and natural gas systems also offer important abatement opportunities in the 2025–30 time frame.

PATHWAY ASSUMPTIONS

The following section provides additional details about the policy assumptions we used for our Core Ambition, Power Sector Push, and Targeted Sector Push pathways. See the Appendix for additional details.

Electric Power

Electric power generation is the largest source of GHG emissions in the United States. In 2012, it accounted for almost 30 percent of total emissions and about 40 percent of all CO_2 emissions from fossil fuel combustion. This sector presents large and relatively low-cost opportunities for emission reductions on both the supply and demand sides. Our policy scenarios for the power sector are summarized in Tables 2.2 and 2.3, and described in the sections that follow.

New and Existing Power Plants

Under section 111 of the Clean Air Act, EPA may prescribe emission limitations based on the "best system of emission reduction" for new and modified existing sources within source categories EPA determines cause or contribute significantly to air pollution that may reasonably be anticipated to endanger human health or welfare.[11] The agency used this power to propose carbon pollution standards

Table 2-2 | **Electric Power Generation Assumptions**

	CORE AMBITION	POWER SECTOR PUSH	TARGETED SECTOR PUSH
STANDARDS FOR NEW PLANTS	EPA finalizes New Source Performance Standards (NSPS) as proposed, which set a standard between 1,000–1,100 pounds of CO_2 per megawatt-hour of output until 2030 (depending on unit size and fuel consumed), at which time they establish new standards equivalent to carbon capture and sequestration (CCS) with a 90 percent capture rate for coal plants and partial CCS for natural gas plants.		
STANDARDS FOR EXISTING PLANTS	EPA's Clean Power Plan is finalized as proposed for existing fossil power plants (26 percent reduction in power sector CO_2 emission levels compared to 2005 levels by 2025 and 30 percent reduction by 2030). Efficiency gains from updated and new federal appliance standards and industry lead to additional CO_2 reductions: 36 percent below 2005 levels in 2025 and 40 percent in 2030.	Renewable energy technology costs continue their rapid decline and EPA strengthens its proposed Clean Power Plan so that more cost-effective renewable energy and energy efficiency is deployed. Additional efficiency gains from updated and new federal appliance standards and industry lead to GHG emission reductions in the range of 45 percent below 2005 levels by 2025 and 52 percent by 2030.	Similar to Core Ambition, EPA's Clean Power Plan is finalized as proposed for existing fossil power plants (26 percent reduction in power sector CO_2 emission levels compared to 2005 levels by 2025 and 30 percent reduction by 2030). Efficiency gains from updated and new federal appliance standards and more ambitious standards on industry lead to additional CO_2 reductions: 37 percent below 2005 levels in 2025 and 42 percent in 2030.
RENEWABLE GENERATION	No additional renewable generation beyond what is captured in the power plant scenario reflecting EPA's Clean Power Plan proposal.		Same as Core Ambition

Table 2-3 | **Electricity Demand Assumptions**

	CORE AMBITION	POWER SECTOR PUSH	TARGETED SECTOR PUSH
FEDERAL APPLIANCE STANDARDS	259 TWh savings in 2025 and 375 TWh savings in 2030 from the residential and commercial sectors.		
STATE ENERGY EFFICIENCY SAVINGS TARGETS	No additional efficiency beyond what is captured in the power plant scenario reflecting EPA's Clean Power Plan proposal.	EPA strengthens its proposed Clean Power Plan, leading to greater deployment of renewable energy and energy efficiency resources.	Same as Core Ambition
STATE BUILDING CODES			

for new power plants in September 2013—1,000 pounds of CO_2 per megawatt-hour of output (lbs. per MWh) for larger natural gas units, 1,100 lbs. per MWh for smaller natural gas units, and 1,100 lbs. per MWh for coal units not using carbon capture or storage, and proposed the Clean Power Plan (CPP) for existing plants in June 2014.

The proposed CPP gives each state an emission goal that it must meet on average between 2020 and 2029, and a final goal that a state must meet in 2030. States can apply several measures to lower the carbon intensity of their power generation mix (fuel switching, increased dispatch of low-carbon plants, increased renewable generation, and energy efficiency, among others). EPA's modeling of the proposed rule indicates that the CPP would reduce U.S. power sector emissions by roughly 26 percent in 2025 and 30 percent in 2030 (below 2005 levels). Our Core Ambition and Targeted Sector Push pathways both assume the same levels of emission reductions. Those two scenarios also assume that EPA's proposed standards for new plants are finalized as proposed, and that EPA updates these standards in 2030 so that new plants would need to meet an emission rate equivalent to CCS with a 90 percent capture rate for coal plants and partial CCS for natural gas plants.

We did not model any additional state renewable development or energy efficiency gains through new or expanded renewable portfolio standards (RPS) or energy efficiency programs under our Core Ambition and Targeted Sector Push pathways. Instead, we assumed that these programs would be used to achieve the reductions required by the CPP. In contrast, we assume reduced demand resulting from ambitious federal appliance standards and industry efficiency gains are additional to the CPP. Federal appliance standards and standards for industry could drive significant electricity savings and emission reductions (see the following sections for more detail).

Our Power Sector Push pathway assumes an acceleration of recent clean energy trends—including rapidly declining renewable costs and greater deployment of energy efficiency—leading to power sector GHG reductions in the range of 45 percent below 2005 levels by 2025 and 52 percent by 2030. To achieve this level of abatement, EPA could strengthen its proposed Clean Power Plan so that it takes advantage of cost-effective renewable energy sources and energy efficiency, which is often the least-cost new resource option for utilities. It would also require continued technological innovation and investment so that renewable energy technology costs continue their rapid decline. This scenario also assumes that EPA's proposed standards for new plants are finalized as proposed, and that EPA updates these standards in 2030 so that new plants would need to meet an emission rate equivalent to CCS with a 90 percent capture rate for coal plants and partial CCS for natural gas plants.

Renewable Generation

Renewable electricity generation in the United States grew by almost 6 percent per year on average over the five-year period from 2009 to 2013 and accounted for 12.5 percent of total generation in 2013.[12,13] Growth in renewable energy has been aided by widespread implementation of state renewable generation programs, federal tax incentives for renewable technologies, voluntary renewable energy markets, new transmission and distribution, and rapidly declining prices for renewable resources.[14] As a result, new wind projects are cheaper than new coal and natural gas plants in a growing number of markets (comparing levelized generation costs), and some new solar photovoltaic projects are being chosen over new coal generation because of lower costs or larger net benefits.[15] In fact, renewable energy investments made in states across the country are driving energy bill savings, supporting new jobs, and providing other economic benefits in several states.[16] In sufficient quantities, renewables could help electricity penetrate beyond its traditional end uses and capture a growing share of applications in transportation (such as electric vehicles) as well as buildings and industry (such as distributed solar or wind).

Renewables are likely to play a significant role in U.S. power generation going forward as a result of low prices and policy signals, including EPA's Clean Power Plan. As noted above, our Core Ambition and Targeted Sector Push pathways do not include incremental emission reductions from renewable energy, assuming that all new renewable generation is counted for compliance with EPA's standards. Our Power Sector Push pathway does not prescribe a specific pathway to deeper cuts in power sector emissions than the Clean Power Plan as proposed, but the potential for greater deployment of renewable energy has been documented. For example, the Natural Resources Defense Council found that the renewable energy technology costs EPA relied on to develop their state targets are 46 percent above current average costs for wind and solar energy. They found that when these current costs are taken into account, between 65 and 86 percent more renewable energy can technically and economically be developed than what was originally considered in the state targets under the proposed Clean Power Plan.[17] Over the longer term, a deep decarbonization of the power sector would require expanding transmission and integration as well as increasing system flexibility (to help respond to the variability of renewable sources) by increasing the use of grid storage, distributed generation sources, demand response, and flexible back-up generation (like natural gas plants).[18,19]

Residential and Commercial Electricity Demand

Homes and commercial buildings account for 74 percent of electricity demand in the United States, and are thus a critical component of a pathway to a low-carbon economy.[20] Energy efficiency policies put into place over the past few decades—including federal appliance standards, state energy efficiency savings targets, state building energy codes, federally supported research and development, and others—have helped offset rising demand for electricity and saved billions of dollars for homes and businesses.[21] Even as new construction and use of appliances and electronics has increased, total electricity demand growth has been on the decline, from over 6 percent per year in the early 1970s to only 1 percent per year from 2004 through 2013.[22] Even without new policies to promote efficiency improvements, EIA projects that electricity demand growth will remain steady at an average of 0.9 percent per year through 2040, while GDP grows at 2.4 percent per year.[23]

However, research suggests that the United States still has a large array of greater energy efficiency opportunities available due to the persistence of market barriers.[24] Split incentives between actors who make investment decisions and those who receive the benefits (e.g., landlords and tenants, building managers and financial officers of a business) can prevent the adoption of the most efficient technologies or processes in buildings. Other barriers include lack of knowledge or uncertainty about the long-term benefits of efficient technology choices, limited access to capital for upfront costs, and factors of consumer decision making that go beyond a simple assessment of costs and benefits (e.g., convenience, product appearance, and features). Targeted policies can help overcome these barriers by driving the development and uptake of efficient products and improving the efficiency of new and existing buildings.

Our pathways included three policies that reduce residential and commercial electricity demand, described in more detail below: (1) federal appliance standards, (2) state energy efficiency savings targets, and (3) state building energy codes. We also included actions that reduce electricity demand from industry (the section on industry discusses these in more detail). In our Core Ambition, Power Sector Push, and Targeted Sector Push pathways, all energy efficiency from state policies was counted toward compliance with the existing power plant standards as proposed, while electricity savings from federal appliance standards (we do not assume implementation of any state appliance standards) and industrial efficiency gains were additional. Under this assumption, states would take credit only for efficiency measures that go beyond a baseline adjusted for these new federal measures. As the rule is implemented, it may be possible for states to receive credit for measures related to industrial efficiency and appliances regulated by federal standards, but EPA has not yet released guidance on these issues.

FEDERAL APPLIANCE STANDARDS

Federal appliance and equipment efficiency standards have a long history of saving energy and money for American homes and businesses. Standards put into place over the past twenty-five years cover more than fifty products used in homes, commercial buildings, and industry, and have generated $370 billion in cumulative utility bill savings (electricity and heating fuel) for consumers. Without these standards, total electricity demand would have been 8 percent higher than it was in 2012.[25]

Continued development of new and updated standards has the potential to deliver greater savings going forward. Since 2009, DOE has issued new or updated standards covering more than thirty products.[26] These standards could save consumers nearly $450 billion in lower electricity bills between now and 2030[27] and reduce total electricity consumption by 400 terawatt hours, 9 percent below future projections.[28]

We reflect the potential for continued development of new and strengthened efficiency standards in all our pathways. We based the electricity demand reductions from these standards on the Institute for Electric Innovation (IEI) study, *Factors Affecting Electricity Consumption in the United States*,[29] which calculates the electricity savings possible by expanding and strengthening standards across most major household and commercial building appliance and equipment categories. We relied on the "aggressive" scenario from this study, which resulted in electricity savings of 259 TWh in 2025 and 375 TWh in 2030. In the IEI scenario, some appliance and equipment classes are pushed to their engineering limits by 2035. Particular technologies may evolve differently over the next several years and deliver different savings than anticipated by the IEI study. However, the magnitude of projected reductions is reasonable given the success of past appliance standards as well as DOE's demonstrated commitment to setting new and strengthened appliance standards over the past several years.

Many equipment categories offer greater potential for electricity savings through expanded or strengthened standards, including commercial air conditioners and heat pumps, commercial water heaters, residential furnaces and air conditioners, and indoor and outdoor lighting. DOE already has over twenty additional standards under development covering many of these areas.[30] For example, DOE's recently proposed standards for commercial rooftop air conditioners could save nearly 12 quads of energy and $17 billion to $51 billion in energy bills for businesses over the lifetime of units sold in the thirty-year period after the standards take effect.[31] And recently finalized standards for general service fluorescent lamps are projected to reduce electricity use in homes and businesses by a cumulative 250 TWh over a thirty-year period, saving consumers $2 billion to $6 billion, after taking product costs into account.[32]

STATE ENERGY EFFICIENCY SAVINGS TARGETS

Currently, nearly half of all states have some kind of mandatory electric savings targets in place (including energy efficiency resource standards, combined renewable standards and efficiency standards, or policies requiring the capture of all cost-effective electric efficiency). To meet these targets, utilities typically offer a portfolio of efficiency programs to homes and businesses, including weatherization assistance, rebates or tax incentives for efficient appliances or home upgrades, subsidized building retrofits, energy auditing, and many others. Most states with targets in place aim to save over 1 percent of annual electricity sales once programs are fully ramped up, and several states have gone further, requiring annual savings of 2 percent or more. According to reports by public utility commissions, utilities, program administrators, and others, these programs have typically proven cost-effective, saving customers at least $2 for every $1 invested.[33]

In our Core Ambition and Targeted Sector Push pathways, we assumed that all savings from state energy efficiency targets would be counted toward compliance with existing power plant standards. In our Power Sector Push pathway, we did not prescribe the specific measures that would drive greater power sector reductions than achieved in the Core Ambition pathway, but it is likely that greater deployment of energy efficiency via new or expanded state energy efficiency targets would be necessary.

STATE BUILDING CODES

Building codes save energy by ensuring that new construction and existing buildings that undergo major renovations or repairs meet minimum efficiency requirements. Model codes are always evolving to reflect the latest developments in technology and design, but the stringency and enforcement of codes varies nationwide. In our Core Ambition and Targeted Sector Push pathways, we assumed that all savings from state building codes would be part of state compliance with existing power plant standards. In our Power Sector Push pathway, we did not prescribe the specific measures that lead to deeper reductions than Core Ambition, but more widespread adoption and enforcement of building codes than current levels could help achieve these reductions.

Transportation

Opportunities to reduce GHG emissions abound in the transport sector (Table 2.4). New standards for light-duty vehicles (LDVs) enacted in 2012 will approximately double the fuel economy of model year (MY) 2025 vehicles, delivering fuel savings to consumers.[34] Further progress is possible, especially with advances in conventional vehicle technologies and battery and fuel cell technologies. Targeted transportation policies can also reduce vehicle miles traveled (VMT), thus lowering emissions. VMT for passenger vehicles is already growing more slowly now than in past decades, and strategies such as support for public transit and compact, connected cities that offer safe options for walking and bicycling can reinforce this trend while increasing the quality of life. EPA and DOT are developing phase II standards for medium- and heavy-duty trucks after phase I ends in 2018. Analysis shows that fuel consumption rates could be reduced an average of 40 percent below 2010 levels by 2025 using technologies that are currently available and would have an average payback period of less than two years.[35] Opportunities also exist to reduce fuel consumption and GHG emissions from aircraft and off-highway vehicles via standards and/or operational improvement.

Light-Duty Vehicles

The GHG emission standards and CAFE standards for LDVs finalized in 2012 will result in CAFE standard-equivalent of 49.7 miles-per-gallon (mpg) for model year 2025. Because of the improved efficiency of these vehicles, their owners will save on average a net $3,400 to $5,000 over the life of their 2025 vehicle compared with a vehicle meeting the model year 2016 standards.[36] Recent data from EPA shows that car manufacturers have outperformed the current GHG standards for two years in

Table 2-4 | **Transportation Assumptions**

<table>
<tr><th></th><th>CORE AMBITION</th><th>POWER SECTOR PUSH</th><th>TARGETED SECTOR PUSH</th></tr>
<tr><td>LIGHT-DUTY VEHICLE STANDARDS</td><td colspan="2">Emission standards are extended and nearly halved from 2025 to 2040 through a 5 percent annual improvement rate in GHG emission standards. This results in a 126 grams per mile or a 63 mpg CAFE standard in 2030 (76 grams per mile or 103 mpg CAFE standard in 2040).

In WRI-GAM, we assume alternative vehicles are on a pathway so that in 2050 70 percent of new car sales are alternative vehicles (consistent with findings from National Academy of Sciences optimistic scenarios). This equates to the following penetration rates in 2030/2040:

PHEVs: 5% / 7%
EVs: 10% / 15%
FCEVs: 10% / 28%

Because of the high alternative vehicle penetration levels assumed, and because the U.S. power system is also decarbonizing, conventional vehicles achieve an on-road fuel economy of 43 mpg in 2030.</td><td>Car manufacturers achieve the current MY2025 emission standard in 2021 due to higher uptake of new technologies for conventional vehicles as well as EVs, PHEVs, and hydrogen vehicles. This could be achieved by overcompliance with the current GHG and CAFE standards, or by strengthening the MY2021–25 standards during the mid-program review. GHG and CAFE standards continue to increase by 5 percent per year to achieve approximately 103 grams per mile in 2030 or a 77 mpg CAFE standard in 2030 (62 grams per mile or 125 mpg CAFE standard in 2040).

Because of the high alternative vehicle penetration levels assumed, and because the U.S. power system is also decarbonizing, conventional vehicles achieve an on-road fuel economy of 54 mpg in 2030.</td></tr>
<tr><td>LDV TRAVEL DEMAND</td><td colspan="2">Recent social and demographic light-duty VMT trends continue, supported by state, local, and federal policies. This leads to light-duty VMT reductions of 7 percent below Reference Case projections in 2025 and 12 percent in 2030.</td><td>Recent VMT trends accelerate, leading to reductions of 20 percent below Reference Case projections in 2025 and 25 percent in 2030.</td></tr>
<tr><td>MEDIUM- & HEAVY-DUTY VEHICLES</td><td colspan="3">By 2025, the medium- and heavy-duty fleet reduces its fuel consumption rate by an average 40 percent below 2010 levels. Standards continue to improve annually by 2.5 percent through 2040 on average, for all medium- and heavy-duty vehicle types.</td></tr>
<tr><td>OFF-HIGHWAY</td><td colspan="3">A 2.4 percent annual improvement in the emission rate for new equipment and engines from 2018 to 2040.</td></tr>
<tr><td>AVIATION</td><td colspan="3">A 1.4 percent annual operational improvement via FAA's NextGen program, plus a 2.3 percent annual improvement in the performance of new aircraft and engines. Both rates remain constant through 2040.</td></tr>
</table>

a row,[37] and Ford believes it is on track to achieve the 2025 standards, despite current low gasoline prices.[38]

The Reference Case assumes that fuel efficiency holds steady at that level out to 2040. Improvements in fuel efficiency and increased penetration of electric and fuel cell vehicles could allow EPA and NHTSA to increase standards after 2025. While the MY2017 to MY2025 standards improve roughly 4 percent per year, our approach to reducing LDV emissions in our Core Ambition and Power Sector Push pathways assumes that EPA and NHTSA continue to tighten standards in the 2025–40 period at a slightly higher rate of 5 percent per year, resulting in a CAFE standard equivalent of 63 mpg in 2030 and 103 mpg in 2040. Because the power grid is also decarbonizing under this pathway, electric vehicles are able to achieve increasingly higher equivalent fuel economies, allowing conventional vehicles to achieve a fuel economy well below the fleet-average CAFE standard. Because of this interplay, conventional vehicles achieve an on-road fuel economy of 43 mpg in 2030. For reference, the Ford Fusion hybrid achieves 44 mpg (city) and 41 mpg (highway).

To help achieve this high fleet-wide average fuel economy in our Core Ambition and Power Sector Push pathways, we also assume that alternative vehicles such as electric vehicles, plug-in electric hybrids, and hydrogen vehicles increase their penetration to reach 70 percent of new vehicle sales by 2050, which is consistent with results found by the National Research Council's *Transitions to Alternative Vehicles and Fuels*.[39] Electric vehicles and plug-in electric vehicles accounted for 1.4 percent of total car sales and 0.7 percent of total light-duty vehicle sales in 2014, which represents a five-fold increase over the last four years.[40] If the trends in alternative vehicle technology we are seeing today continue or accelerate, achieving these large improvements in fuel economy could be possible, with drivers seeing more and more fuel savings. For example, prices for electric vehicle batteries in 2014 have fallen by more than 40 percent since 2010,[41] and prices are likely to continue to decline. Tesla Motors plans to build facilities by 2017 that produce batteries 30 percent cheaper than today's batteries.[42] Because battery prices make up a large portion of total upfront costs for electric vehicles and plug-in hybrids, electric vehicle costs could fall dramatically as battery prices decrease; two car manufacturers (Tesla and Chevrolet) recently announced that they will be selling long-range electric vehicles (200+ mile range) at $30,000–$35,000 as soon as 2017 (including federal tax incentives).[43] Some states have also taken the lead in promoting the sale of zero-emission vehicles (ZEV) like electric vehicles and hydrogen fuel cell vehicles; eight states have a mandate to put at least 3.3 million ZEVs on the road by 2025.[44] Additionally, several large automakers continue to pursue hydrogen fuel-cell systems for light-duty vehicles, with early commercialization expected in the 2015–17 time frame.[45]

Our Targeted Sector Push pathway assumes that car manufacturers achieve the current MY2025 emission standard in 2021 due to higher uptake of new technologies for conventional vehicles as well as EVs, PHEVs, and hydrogen vehicles. This could be achieved by overcompliance with the current GHG and CAFE standards, or by strengthening the MY2021–25 standards during the mid-program review.[46] After 2021, this pathway assumes standards continue to improve at a rate of 5 percent per year, resulting in a CAFE standard equivalent of 77 mpg in 2030. Under this scenario, conventional vehicles achieve an on-road fuel economy of 54 mpg in 2030. For reference, the Toyota Prius-C achieves 53 mpg (city) and 46 mpg (highway). Notably, an eco-version of Toyota's model year 2016 Prius reportedly might achieve 60 mpg by potentially using a more efficient gasoline engine, new electronics, and a more efficient and light-weight battery, among other new technologies.[47]

Light-Duty Vehicle Travel Demand

Growth in personal travel demand has slowed significantly in recent years and this has been a factor in reducing LDV emissions. VMT growth fell from an average 3 percent per year from the 1970s to mid-2000s to an average 0.9 percent per year between 2004 and 2012.[48] Multiple factors are likely in play in this slowdown: the economic recession, changing demographics, high costs of driving (including rising fuel prices until late 2014), changing consumer preferences, as well as policy initiatives. Reference case projections from EIA assume VMT growth will rebound slightly and total VMT will rise steadily to 12 percent above 2012 levels by 2025 and 18 percent by 2030. However, other research suggests VMT growth could slow further, potentially even flattening through 2030, as demographics and preferences continue to shift.[49]

In our Core Ambition and Power Sector Push pathways, we assumed implementation of supportive policies that reinforce ongoing demographic trends and shifts in consumer preferences by allowing consumers mobility while reducing the need to drive a personal vehicle. Such policies include compact development that limits sprawl (i.e., smart growth), transit-oriented development, and improved and expanded public transportation, among many others.[50] While most of these options are directly implemented at the state and local levels, federal agencies—including DOT, EPA, DOE, HUD, and others—can encourage and support these efforts by expanding existing programs and implementing new strategies, including increased funding for public transit infrastructure, implementation of performance criteria for funding that reflects compact development and related strategies, research and development, tax policies that promote infill development (e.g., EPA's Brownfield Tax Incentive), and technical assistance.[51] We used the AEO2014 Low-VMT side case to represent this pathway, which assumes VMT reductions of 7 percent below Reference Case projections in 2025 and 12 percent in 2030.[52]

In our Targeted Sector Push pathway, we assumed that recent VMT trends accelerate, leading to VMT reductions of 20 percent below Reference Case levels in 2025 and 25 percent in 2030. Similar to our other two pathways, we do not model the specific policy actions that would lead to these reductions, but this would likely require much more widespread adoption of state and local measures previously described, encouraged by strong federal actions.

While we focus exclusively on light-duty travel demand, reductions in medium- and heavy-duty travel demand could also potentially contribute to a low-carbon shift in the transportation sector through policies that improve the efficiency of freight transportation operations. Potential policy options include increasing federal investment in freight rail infrastructure and service improvements and implementing tolls or other user fees to encourage mode shifts from truck to rail; however, research and data regarding the effectiveness of potential policies in this area are limited compared to light-duty travel demand.[53]

Medium- and Heavy-Duty Vehicles

In 2011, EPA and NHTSA issued a joint rulemaking that established the first-ever emission standards and fuel consumption standards for model years 2014–18 for medium- and heavy-duty vehicles, including combination tractors (used for freight transportation and usually pulling one or more trailers and emitting about two-thirds of medium- and heavy-duty CO_2 emissions), vocational vehicles (used for a wide range of purposes, including fire trucks, dump trucks, refuse trucks, and others), and heavy-duty pickup trucks and vans (used mainly for work purposes, as well as shuttle vehicles). Several studies indicate that further improvements are technically achievable at reasonable cost.[54] All our pathways assume the fuel consumption standards improve by around 40 percent by 2025 across all vehicle categories compared to 2010 vehicles. This magnitude of improvement is likely only possible if EPA regulates trailers, which are not covered by current standards. We assume that emission standards increase by 7.5 percent every three years (2.5 percent annually) thereafter. This would lead to an average fuel economy of 14 mpg (728 grams CO_2 per mile) across all medium- and heavy-duty vehicles in 2025 and 20 mpg (487 grams CO_2 per mile) in 2040. As a result of the standards, medium- and heavy-duty vehicles sold in 2040 will consume 59 percent less fuel than vehicles sold in 2010.

This pathway for medium- and heavy-duty vehicles was derived from an analysis completed by the American Council for an Energy Efficient Economy, Environmental Defense Fund, Natural Resources Defense Council, Sierra Club, and Union of Concerned Scientists,[55] which found that new trucks can reduce fuel consumption by at least 40 percent compared to 2010 levels by 2025 using technologies that are currently available and would have an average payback period of less than two years.[56]

Off-Highway

EPA may also regulate off-highway sources of global warming pollution under Title II of the Clean Air Act. Off-highway mobile sources include engines and equipment used for agriculture, construction, mining, lawn and garden purposes, among other uses. Because there is no specific off-highway category in the AEO, we utilized business-as-usual projections and abatement potential from the *EPA Analysis of the Transportation Sector: Greenhouse Gas and Oil Reduction Scenarios*. For all pathways, we assumed that EPA set standards achieving an additional 2.4 percent annual improvement in the emission rate for new equipment and engines from 2020 to 2040.

Aircraft

EPA has statutory authority under Title II of the Clean Air Act to promulgate standards to reduce emissions from new and existing aircraft engines.[57] The Reference Case for this sector reflects some improvements in fuel efficiency, but emissions continue to grow through 2040. Multiple studies indicate that improved engines, lower weight, and reduced drag can bring about major improvements in aircraft fuel efficiency on the order of 20 to 30 percent or more in the 2025–30 time frame. The Federal Aviation Administration (FAA) can also reduce GHG emissions from aircraft by enhancing the way that air travel is managed in the United

States. Through its Next Generation Air Transport Systems (NextGen), FAA is proactively managing aviation environmental issues with several programs and initiatives.[58] All our policy pathways assume that the FAA achieves a 1.4 percent annual operation improvement, and that EPA requires 2.3 percent annual improvement in the fuel efficiency of new aircraft through 2040, based on Scenario B from the EPA analysis of the transportation sector.[59]

It is worth noting that there may be other paths forward to achieve these improvements in new aircraft standards. The International Civil Aviation Organization's (ICAO) Committee on Aviation Environmental Protection is in the process of developing a new international standard for aircraft carbon dioxide emission levels. The United States anticipates that ICAO will adopt an aircraft CO_2 emission standard in February 2016, and acknowledges that to adopt standards equivalent to ICAO's standards, EPA would need to "first propose and finalize endangerment and cause or contribute findings for aircraft GHG emissions."[60] EPA expects to release an advanced notice of proposed rulemaking in late April 2015 and subsequently finalize its findings in 2016.[61]

Residential and Commercial Heating

Heating fuel is responsible for about one-quarter of total emissions in residential and commercial buildings.[62] We focus exclusively on natural gas consumption, which accounts for the majority of onsite fuel consumption for residential and commercial buildings.[63] Continued efficiency improvements are expected to offset some of the energy demand growth from an increased number of homes and commercial buildings as energy intensity decreases in both the residential and commercial sectors. Yet, overall natural gas consumption in this sector is expected to rise 8 percent between 2012 and 2025 and remain relatively flat through 2040 unless new policies are enacted.

The efficiency policies we examined in our electricity demand reduction pathways (i.e., federal appliance standards, state energy efficiency savings targets, and state building energy codes) also reduce natural gas use. For federal appliance standards and building codes, we assume the same level of natural gas savings across our Core Ambition, Power Sector Push, and Targeted Sector Push pathways (see Table 2.5). We based the natural gas savings from appliance standards on the American Council for an Energy-Efficient Economy study entitled *The Efficiency Boom: Cashing In on the Savings from Appliance Standards*,[64] which quantified the benefits from potential new or updated standards for thirty-four product categories that could be adopted within the next several years. We based the savings from building codes on the AEO2011 Expanded Standards and Codes Case, the most recent version of the AEO that provides fuel savings due to building codes and appliance standards separately.[65]

For state energy efficiency targets, we assume more widespread adoption of natural gas efficiency targets or similar policies. In our Core Ambition and Power Sector Push pathways, we assume that some states with targets currently in place achieve greater savings than required, and some states without targets in place adopt new policies to reduce natural gas use. In our Targeted Sector Push pathway, we assume ambitious savings of 1.5 percent per year of natural gas sales nationwide. Savings of this magnitude would most likely need to be encouraged by strong federal policy signals including new legislation.

Together, all efficiency measures reduced residential and commercial natural gas demand by 6–9 percent in 2025 and 11–16 percent in 2030 below Reference Case projections.

Table 2-5 | **Commercial and Residential Heating**

	CORE AMBITION	POWER SECTOR PUSH	TARGETED SECTOR PUSH
FEDERAL APPLIANCE STANDARDS	New and strengthened appliance standards reduce natural gas demand by 123 Tbtu in 2025 and 179 Tbtu in 2030.		
BUILDING CODES	Building code adoption reduces natural gas demand by 50 Tbtu in 2025 and 117 Tbtu in 2030.		
NATURAL GAS EFFICIENCY SAVINGS TARGETS	Fifty percent of states without a target achieve natural gas savings of 1.5 percent per year from 2020 through 2030. Seventy-five percent of states with a target achieve natural gas savings of 1.5 percent per year from 2020 through 2030.		Nationwide natural gas savings of 1.5 percent per year from 2020 through 2030.

Industry

The challenge of industrial sector GHG emissions is to offset ongoing demand growth with accelerated efficiency improvements and fuel switching. While the United States saw a significant decrease in industrial activity during the 2008 economic crisis, the EIA Reference Case projects that industrial sector demand (as measured in value of shipments, constant dollars) will grow to 43 percent above 2012 levels in 2025 and 86 percent above 2012 levels by 2040. Over the same period, the emission intensiveness of industrial activity is expected to decline, with total sector GHG emissions peaking at 19 percent above 2012 levels in 2028 and leveling off through 2040, at which point total emissions are expected to be 18 percent above 2012 levels. Beyond the Reference Case, industrial sector growth creates investment opportunities to reduce emission intensity of production, especially in combination with targeted policies.

Table 2.6 summarizes the opportunities we modeled to achieve industrial sector GHG emission reductions by 2040.

Numerous state and federal policies have been enacted to accelerate industrial sector efficiency improvements. These include regulations for equipment via emission performance standards under Boiler Maximum Achievable Control Technology (MACT); EPA's NSPS; market and rate design that helps to reduce industry sector GHG emissions by promoting clean distributed generation; tax credits, exemptions and/or deductions; technical assistance from federal government agencies such as DOE's Better Buildings, Better Plants Program;[67] and research grants such as Advanced Research Projects Agency-Energy[68] and DOE's Advanced Manufacturing Office[69] programs.

The effectiveness of the policy options described above varies by subsector and state—there is no single optimal solution for the entire industrial sector across the United States. Rather, the combination of policy options and scenarios described here indicate that there are multiple pathways for achieving lower-carbon industrial sector growth. For our analysis, we assume under our Core Ambition and Power Sector Push pathways that EPA sets GHG emission standards for the industrial sector that achieve an 18 percent efficiency improvement beyond the Reference Case by 2025. This is the mid-point of the 14 to 22 percent estimate of cost-effective energy efficiency improvement potential for the U.S. industrial sector by 2020 documented in a 2010 National Academy of Sciences study.[70] The aggregate 18 percent energy efficiency improvement by 2025 translates to an annual 2.7 percent reduction of U.S. industrial energy intensity of value-added between 2012 and 2025. From 2025 to 2040, energy intensity of industrial activity continues to decline at an average annual rate of 1.9 percent, which is the historical U.S. average annual energy intensity of industrial value-added decline rate between 1997 and 2013.[71]

Our Targeted Sector Push pathway builds on the previous scenario with additional efficiency improvements and fuel switching via more ambitious GHG standards.[72] In addition, technical innovation, voluntary cost-effective

Table 2-6 | **Industrial Sector Emission Mitigation**

	CORE AMBITION	POWER SECTOR PUSH	TARGETED SECTOR PUSH
ACCELERATED EFFICIENCY IMPROVEMENTS	EPA sets GHG standards that achieve an 18 percent improvement[a] below Reference Case levels by 2025 with continued historical improvement rate to 2040.		EPA sets GHG standards that achieve a 22 percent improvement below Reference Case levels by 2025 with continued annual improvement rate to 2040.
FUEL SWITCHING	No fuel switching beyond Reference Case projections.		Additional fuel switching is modeled with a 25 percent reduction in coal use, a 10 percent reduction of distillate fuel oil use, and a 30 percent reduction in residual fuel oil use in 2025 beyond Reference Case projections; these reductions are offset with increased natural gas use.[66]
REFINERIES	Emission reductions consistent with a 10 percent improvement in efficiency. Decreased demand for petroleum products due to transportation measures lead to total CO_2 reductions from refineries in the range of 23–25 percent below Reference Case projections in 2030.		

Notes:

[a] This is midway between the 14–22 percent industrial sector efficiency potential estimate published in National Academy of Sciences (NAS). 2010. "Real Prospects for Energy Efficiency in the United States."

efficiency improvements, and state regulation can complement these federal standards. Specifically, we model a 22 percent reduction of energy intensity of production below 2025 levels, with linear interpolation to 2025 and a continued average annual improvement rate to 2040 of 3.1 percent per year. Given the total sector energy demand numbers based on these efficiency improvements, additional fuel switching is modeled with a 25 percent reduction in coal use, a 10 percent reduction of distillate fuel oil use, and a 30 percent reduction in residual fuel oil use in 2025.[73] These reductions in coal and oil use are completely offset by an increase in industrial sector natural gas use.

In addition, given that electricity and natural gas use account for two-thirds of industrial sector CO_2 emissions, future standards for new and existing power plants, as well as natural gas production with less methane leakage, play an important role in reducing indirect and upstream emissions from the industrial sector.

Petroleum Refineries

Refineries accounted for 15 percent of total industrial sector energy use in 2012. In our analysis, petroleum refineries are modeled independently of the rest of the industrial sector to account for changes in liquid fuel demand and policy developments.

In December 2010, EPA announced its intent to establish GHG performance standards for new and existing refineries using their authority under section 111 of the Clean Air Act, though it has not met the deadlines it announced at the time.[74] In the Advanced Notice of Proposed Rulemaking, EPA concludes that benchmarking data suggests that most existing refineries could economically improve energy efficiency by 10–20 percent, and that new refineries could be designed to be at least 20 percent more efficient than existing refineries.[75] We assume in our Core Ambition, Targeted Sector Push, and Power Sector Push pathways that emissions from refineries are reduced by the establishment of performance standards for new and existing units that improve efficiency by 10 percent.[76] Combined with decreased demand for petroleum products due to transportation measures, this leads to total CO_2 reductions from refineries in the range of 23–25 percent below Reference Case projections in 2030.

Methane Sources

Methane sources accounted for 11 percent of total U.S. emissions in 2012. Addressing methane leaks from natural gas systems offers one of the largest and most cost-effective opportunities to address this greenhouse gas. Coal mines and landfills also offer abatement opportunities (Table 2.7).

Natural Gas Systems

Methane, the primary component of natural gas, is a potent greenhouse gas, with at least thirty-four times the global warming potential of carbon dioxide.[77] Natural gas leaks occur throughout the natural gas supply chain, from drilling through production, processing, transmission, distribution, and end use. The exact scale of methane leakage is not known. EPA's 2014 Greenhouse Gas Inventory

Table 2-7 | **Methane Sources**

	CORE AMBITION	POWER SECTOR PUSH	TARGETED SECTOR PUSH
NATURAL GAS SYSTEMS	EPA sets standards for new and existing emission sources across the supply chain that achieves methane emission reductions of 67 percent from Reference Case starting in 2019. Assumes phased implementation of the following measures beginning in 2017, with full implementation in 2019: plunger lift systems to reduce emissions from liquids unloading at new and existing wells; leak monitoring and repair to reduce fugitive emissions from production, processing, and compressor stations; conversion of existing high-bleed pneumatic controllers to low-bleed or no-bleed controllers to reduce emissions from production, processing, and transmission; desiccant dehydrators to reduce emissions during dehydration of wet gas; improved compressor maintenance to reduce emissions during processing; hot taps in maintenance of pipelines during transmission; and vapor recovery units to reduce emissions during storage. These gains are in addition to emission reductions expected as a result of EPA's 2012 emission standards for hazardous air pollutants, and likely include all of the proposed standards for new equipment expected in the fall of 2015.		
COAL MINES	EPA sets standards that achieve total emission reductions of 36 percent from Reference Case projections starting in 2020.		
LANDFILLS	EPA sets standards that achieve total emission reductions of 9 percent from Reference Case projections starting in 2020 and 11 percent starting in 2030.		

estimates that the natural gas system's methane leakage rate was about 1.2 percent in 2012, but many recent studies suggest that it may be much greater, perhaps in the range of 3 percent to as high as 10 percent.[78] These leaks are not only bad for the climate, but many are also bad for industry because the lost revenue from leaking gas exceeds the cost of addressing those leaks. More information on the barriers to investment can be found in Chapter 1.

In 2012, EPA finalized New Source Performance Standards (NSPS)[79] for volatile organic compound (VOC) emissions and National Emissions Standards for Hazardous Air Pollutants (HAP) from U.S. natural gas systems.[80] While not explicitly addressing GHGs, the NSPS will reduce methane emissions from natural gas systems by requiring "green completions" that capture gases leaked from wells.[81] And in January 2015, the Obama Administration announced its intention to propose standards for new oil and gas infrastructure, which they estimate will reduce methane emissions from oil and gas systems by 40–45 percent below 2012 levels by 2025. However, these standards do not address emissions from existing sources, and studies suggest that even greater reductions can be achieved from new and existing sources with technologies that are both technically feasible and profitable, with a potential payback period of less than three years.[82] Assuming use of these cost-effective technologies, we project that industry could achieve a 67 percent reduction in methane emissions from Reference Case projections. For all our pathways, we assume that EPA uses its authority under the Clean Air Act to set standards that achieve these levels of reductions starting in 2019, after a two year phase-in beginning in 2017.

Coal Mines

EPA has authority to regulate coal mines as a source category under section 111 of the Clean Air Act. As discussed above for power plants, this would entail EPA issuing performance standards for new and existing coal mines and regulations to guide states in their regulation of existing coal mines. For all our pathways, we project emission reductions of 36 percent below our Reference Case projections starting in 2020, using the reductions achievable at a cost of $61 per ton of CO_2e (2012$). We chose this benchmark as representing the upper end of the range of estimates for the social cost of carbon for 2015, based on the 2013 update by the Interagency Working Group (IWG) on the Social Cost of Carbon.[83] We used the same benchmark for landfills, PFCs, SF_6, and nitric and adipic acid.

The social cost of carbon is meant to provide an estimate of the monetized damages associated with the incremental emission of greenhouse gases. The estimates contained in the IWG report are intended to provide guidance to agencies as they incorporate the benefits of reducing greenhouse gas emissions into the cost-benefit analyses associated with future regulatory actions. The reported range was $12–$61 for 2015 and $17–$80 for 2030.

Landfills

EPA already regulates emission of volatile organic compounds from landfills under section 111 of the Clean Air Act.[84] These standards provide the co-benefit of reducing methane emissions, and EPA could either strengthen those standards or establish new standards for GHG emissions. For all our pathways, we projected reductions of 9 percent below our Reference Case projections starting in 2020 and 11 percent starting in 2030, consistent with the cost-effective reductions identified in EPA's marginal abatement cost curves (see our section on coal mines for a discussion of the choice of $61 per ton). Updates to EPA's air standards for new municipal solid waste (MSW) landfills, proposed in July 2014, were not included in the Reference Case since this new rule has yet to be finalized. This proposal would require new MSW landfills subject to the rule to begin controlling landfill gas at a lower emission threshold than currently required. EPA estimates that under the proposal, landfills would capture two-thirds of their methane and air toxics emissions by 2023, which is 13 percent more than required under current rules.[85] EPA also requested public input on whether and how to further reduce emissions at existing landfills through updating current emission guidelines, which have not been updated since 1996.

Fluorinated Gases

Fluorinated greenhouse gases have no natural sources and are used in (and emitted from) a variety of industrial, commercial, and residential applications.[86] They also have very high global warming potentials, ranging from the 100s to 20,000s, and can have very long lifetimes. Therefore, this is an important category of greenhouse gases to address (Table 2.8). However, manufacturers have already developed many alternatives to these high-GWP gases, with some users finding net energy savings.

Table 2-8 | **Fluorinated Gases**

	CORE AMBITION	POWER SECTOR PUSH	TARGETED SECTOR PUSH
HYDROFLUOROCARBONS	EPA sets standards that result in a 61 percent reduction in HFC consumption by 2025 below Reference Case levels and an 85 percent reduction by 2030, which is consistent with the non-Article 5 country schedule as laid out in the 2014 North American amendment proposal to the Montreal Protocol and also extends the servicing and disposal of air conditioning and refrigeration equipment requirements for HCFCs and CFCs to HFCs.		
PERFLUOROCARBONS	EPA establishes performance standards for aluminum and semiconductor emission sources resulting in 22 percent emission reductions from Reference Case projections starting in 2020 (on average, across PFC emission sources) and 17 percent in 2030.		
SULFUR HEXAFLUORIDE	EPA establishes performance standards for electrical transmission and distribution systems, as well as magnesium and semiconductor production emission sources, resulting in 47 percent reductions from Reference Case projections starting in 2020 (on average, across SF_6 emission sources) and 46 percent in 2030.		

Hydrofluorocarbons

Use and emission of HFCs, which are used primarily for refrigeration, air conditioning, and the production of insulating foams, have been increasing due to the phaseout of chlorofluorocarbons (CFCs) and substitution with hydrochlorofluorocarbons (HCFCs) under the Montreal Protocol and Clean Air Act.[87] The EPA's *Benefits of Addressing HFCs under the Montreal Protocol* projects that if current trends continue, HFC consumption will increase from roughly 335 mmtCO_2e in 2012 to about 513 mmtCO_2e in 2030 (due to modeling limitations, we relied on projections of HFC consumption instead of emissions).[88]

Even though alternatives with low and even zero global warming potential are increasingly available, with some offering performance benefits, adoption remains uneven. While converting to some low-GWP alternatives may offer net cost savings, some low-GWP replacements have relatively high upfront costs, require the replacement of old equipment, or require equipment redesign.[89] Thus there is little reason to believe that the U.S. market will rapidly move to these alternatives without new rules or other incentives. However, EPA can reduce the use of high-GWP HFCs under its Significant New Alternatives Program (SNAP), implementing section 612 of the Clean Air Act. Under the SNAP program, EPA may restrict or prohibit the use of unacceptable substances and classify substitutes as acceptable.[90]

EPA has already started offering incentives to phase out high-GWP HFC use in personal vehicles[91] and adopted standards to control HFC leakage from air conditioning systems in pickups, vans, and combination tractors.[92] In July 2014, EPA proposed rules through the SNAP program to approve low-GWP alternatives and move some higher-GWP HFCs out of the market for various applications.[93] EPA estimates that if these rules are finalized as proposed, HFC emissions will be reduced by 58 to 78 million metric tons of CO_2e in 2025 (a 15 to 21 percent reduction in projected business-as-usual HFC emissions).[94]

Proposed rules[95] to move some higher-GWP HFCs out of the market for various applications are anticipated to be finalized this year. Opportunities exist to make HFC reductions beyond those proposed by EPA. These opportunities include accelerating the proposed reduction of certain HFCs (e.g., transitioning from the current high-GWP HFC used for mobile air conditioning in vehicles to available low-GWP options starting in 2018 instead of 2021), or adding end uses not currently covered; for example, while not currently proposed, new and replacement chillers could use hydrofluoro-olefins (HFOs) as soon as 2019.[96] EPA has estimated that the United States can reduce HFC emissions by over 40 percent from what would otherwise be emitted in 2030 entirely through measures that have a negative or break-even price today,[97] and several companies have begun using these alternatives, with many saving money and energy while they reduce GHG emissions.[98]

Under all our pathways, we assume that EPA continues to reduce the use of HFCs either through an international agreement under the Montreal Protocol, or through the SNAP program, so that the United States reduces its HFC consumption by 85 percent below 2008–10 levels by 2035. This is consistent with the non-Article 5 country schedule as laid out in the 2014 North American amendment proposal to the Montreal Protocol.[99] This results in a 61 percent reduction in consumption in 2025 compared to the Reference Case projections in the same year, and an 85 percent reduction in 2030. Because approximately two-thirds of HFC emissions occur due to system leaks and service practices, EPA should also extend the servicing and disposal of air conditioning and refrigeration equipment requirements for HCFCs and CFCs (under section 608 of the Clean Air Act) to HFCs as well as increase initiatives for HFC reclamation and recycling to ensure that fewer virgin high-GWP HFC compounds are used until their consumption is significantly reduced.[100]

Perfluorocarbons

PFCs are chemicals commonly used and emitted during the fabrication of semiconductors and the aluminum smelting process and can have GWPs thousands of times more than CO_2. All our pathways assume that EPA establishes performance standards for aluminum and semiconductor emission sources in a manner that results in reductions 22 percent below our Reference Case projections starting in 2020 and 17 percent starting in 2030 (on average, across PFC emission sources), consistent with the cost-effective reductions identified in EPA's marginal abatement cost curves (see our section on coal mines for a discussion of the choice of $61 per ton). These standards could build off of progress already being made in EPA's existing voluntary programs, including the PFC Reduction/Climate Partnership for the Semiconductor Industry[101] and the Voluntary Aluminum Industrial Partnership (VAIP).[102] While the U.S. and World Semiconductor Council goals (to reduce PFC emissions 10 percent below their 1995 baselines) were achieved in 2010,[103] and VAIP (which represents 98 percent of U.S. production capacity) continues to reduce emissions, EPA's analysis suggests that further reductions can be made and highlights the need for additional policies.

Sulfur Hexafluoride

SF_6 is used and emitted from electrical transmission and distribution systems, as well as magnesium and semiconductor production and can trap thousands of times more heat than CO_2. All our pathways assume that EPA establishes performance standards for aluminum and semiconductor emission sources in a manner that results in reductions of 47 percent below our Reference Case projections starting in 2020 and 46 percent starting in 2030 (on average across SF_6 emission sources), consistent with the cost-effective reductions identified in EPA's marginal abatement cost curves (see our section on coal mines for a discussion of the choice of $61 per ton). These standards could build off of progress already being made in EPA's existing voluntary programs, including the SF_6 Emission Reduction Partnership for Electric Power Systems (EPS).[104] While this program (which represents 48 percent of the total U.S. transmission system) continues to reduce emissions, EPA's analysis suggests that further reductions can be made and highlights the need for additional policies.

Nitric and Adipic Acid

Nitric acid (HNO_3) is primarily used as a feedstock for synthetic fertilizer, though it is also used in the production of adipic acid and explosives. Adipic acid ($C_6H_{10}O_4$) is used in the production of nylon and as a flavor enhancer in certain foods. The manufacture of nitric and adipic acid generates nitrous oxide (N_2O) as a byproduct, which has a global warming potential 265 times that of carbon dioxide over a 100-year time frame.[105] For all pathways, we assumed that EPA establishes performance standards for new and existing nitric and adipic acid manufacturing plants, resulting in reductions of 72 percent below our Reference Case projections starting in 2020 (Table 2.9), consistent with the cost-effective reductions identified in EPA's marginal abatement cost curves (see our section on coal mines for a discussion of the choice of $61 per ton).[106]

Table 2-9 | **Nitric and Adipic Acid Manufacturing**

CORE AMBITION	POWER SECTOR PUSH	TARGETED SECTOR PUSH
EPA sets standards that achieve total emission reductions of 72 percent from Reference Case projections starting in 2020.		

Figure 2-4 | **Sector Contributions to Deep Greenhouse Gas Emissions Under the Power Sector Push Pathway in 2025**

Note: This chart represents the abatement opportunities we identified for each sector under our Power Sector Push pathway beyond those included in our Reference Case (including abatement from carbon sinks). Additional abatement opportunities are likely available across other emission sources (e.g., agriculture).

10-POINT ACTION PLAN TO MEET THE 2025 REDUCTION TARGET

Climate change poses an enormous economic, social, and public health risk to the global community. But taking action to combat climate change does not require sacrificing economic growth and can in fact have economic benefits, including new opportunities for businesses and manufacturing, creation of new clean energy jobs, direct financial savings for consumers, and more. By making concerted efforts across the economy, the United States can significantly reduce GHG emissions in the 2025 and 2030 time frame, while taking advantage of these economic opportunities and providing global leadership on climate action.

We find that the United States could meet, and even surpass, its 2025 emission reduction target under a number of different ambitious pathways. To do so, federal agencies and states must move forward with ambitious action. We developed a 10-point plan, outlined below, that details specific steps federal agencies and states can take to achieve the necessary reductions. This plan requires comprehensive action across the economy. While the Climate Action Plan provides a valuable starting point to achieve the necessary reductions, the United States will ultimately need to strengthen actions already identified in the plan and take action in areas not currently covered, using current federal authorities and state actions.

The level of emission reductions achieved in the power sector will affect in large part whether the United States can meet or exceed its 2025 climate goal. We find that the United States can reduce its GHG emissions by 26 percent below 2005 levels in 2025 and 34 percent in 2030 if it finalizes the Clean Power Plan as proposed and takes ambitious action across other key emission sources. If deeper reductions are made in the power sector (either via a strengthened Clean Power Plan and/or continued technological innovation and cost declines in lower and zero-emission sources), and multiple other opportunities across the economy are taken advantage of (illustrated in Figure 2.4), the country can reduce its GHG emissions 30 percent below 2005 levels in 2025 and 38 percent in 2030 and put itself on a pathway to even larger cuts in the longer term.

Complementary measures, via new congressional or state legislation, could make it easier to achieve reductions toward the upper range of potential abatement. The United States should also expand its research, development, and deployment programs to spur the adoption of next-generation technologies. This will help bring next generation technologies to market, drive costs down through learning-by-doing, and help overcome other barriers, while allowing the United States to remain a world leader of innovation.[107]

10-Point Action Plan for Achieving the 2025 U.S. Climate Goal:

1. **Strengthen the Clean Power Plan both in the near term and over time to fully reflect cost-effective renewable energy and energy efficiency potential.** Accounting for up to 49 percent of total reductions in 2025 and 44 percent in 2030, the power sector represents the largest source of potential near-term abatement opportunities. To achieve as much of this potential as possible, EPA should strengthen its proposed Clean Power Plan by ensuring that states take advantage of all the cost effective investments in renewable energy sources and energy efficiency when meeting their state-specific standard. States should also aim to extend and expand their renewable energy standards and energy efficiency savings targets. As technological innovation continues and renewable energy costs continue to decline going forward, EPA should revisit these targets periodically (as it is planning to do with its passenger vehicle standards) to ensure that each state's standard continues to reflect the full scope of opportunities in this sector.

2. **Scale up programs for residential and commercial energy efficiency.** A strengthened Clean Power Plan can encourage more ambitious state action, ensuring states take advantage of the significant potential for energy efficiency, which is often the cheapest resource for utilities. The United States should also continue to scale up its existing policies, which are already delivering benefits many times their costs. DOE should continue to create and strengthen appliance standards and update the protocols upon which standards are based, as well as enhance other efforts to develop and deploy new technology (e.g., research and development, partnerships with businesses, efficiency labeling). States should adopt or strengthen efficiency savings targets and building energy codes, as well as policies that provide incentive for utilities to pursue efficiency as a resource (e.g., energy efficiency in integrated resource planning, performance incentives for efficiency, decoupling of utility profits from electricity sales).

3. **Continue and expand programs to reduce HFC emissions.** Reducing the use of HFCs represents the second largest abatement opportunity—at least 16 percent in 2025 and 18 percent in 2030. Manufacturers are already developing low-GWP alternatives, some of which offer consumers net savings due to increased product efficiency. However, policies are needed to get a swift phasedown of these high global warming gases. Until an international agreement under the Montreal Protocol is made, EPA should finalize its currently proposed SNAP rules, which ban some high-GWP HFCs for certain applications, and approve low-GWP alternatives. EPA should continue to develop SNAP rules to capture opportunities for reducing high-GWP HFC use in additional end uses not covered in the current proposal. Because a large amount of HFC emissions occur due to system leaks and service practices, EPA should also extend the servicing and disposal of air conditioning and refrigeration equipment requirements for HCFCs and CFCs to HFCs in order to increase HFC reclamation and recycling.

4. **Encourage industrial energy efficiency.** Emission mitigation in the industrial sector represents the third largest near-term abatement opportunity modeled in this assessment. Industrial end-use efficiency and fuel switching account for at least 11 percent of abatement opportunities in 2025 and 2030, not including benefits from cleaner electricity generation and natural gas production. To achieve these emission reductions, EPA should combine ambitious minimum performance standards for equipment with voluntary benchmarking and labeling programs to encourage further industrial efficiency improvements.

5. **Reduce methane emissions from natural gas systems.** Natural gas systems account for at least 7 percent of the abatement opportunity in 2025 and 5 percent in 2030. Emissions from natural gas systems

are costing industry revenues, yet barriers remain that impair the ability of drillers and other service providers to update their equipment and practices to avoid these losses. Additional policies are needed to spur necessary investments in emission control technologies and practices. EPA should propose and finalize standards on both new and existing natural gas systems by 2017, and phase in implementation through 2020, to reduce methane leakage by 67 percent below Reference Case projections and save industry money, which can be done using existing technologies with a three-year payback or less.

6. **Extend and strengthen standards for passenger cars while reducing travel demand.** Passenger vehicles account for at least 4 percent of total reductions in 2025 and 7 percent in 2030, so EPA and the U.S. Department of Transportation (DOT) should continue to extend and strengthen existing standards for passenger vehicles. Specifically, when the current standards for light-duty vehicles end in 2025, EPA and DOT should aim for roughly a 63 mpg CAFE standard (126 grams per mile) by 2030. While this would require car manufacturers to innovate and the federal and state governments to expand alternative vehicle infrastructure across the country, American drivers would benefit from fuel savings at the pump. This sector would also benefit from continuing and even expanding federal and state mandates and incentives that promote the sale of alternative vehicles. Doing so would help accelerate the technology learning curve and bring lower-cost alternative vehicles to market faster. State and local policies—including those that increase compact development patterns, limit sprawl, and improve public transportation options—should also aim to reinforce recent trends of slower growth in personal driving.

7. **Extend and strengthen fuel efficiency standards for medium- and heavy-duty vehicles.** The heavy-duty truck sector accounts for at least 4 percent of abatement potential in 2025 and 6 percent in 2030. EPA and DOT have another big opportunity coming up when the current fuel consumption and GHG standards for medium- and heavy-duty vehicles end in 2018. Looking into the 2020s, these agencies should set standards that achieve a 40 percent reduction in fuel consumption compared to 2010 levels.

8. **Accelerate air travel management and establish standards for new aircraft.** Improving the existing aircraft fleet operations and making new aircraft more efficient represents at least 2 percent of the abatement opportunities we identified in 2025 and 2030. To achieve these reductions, the Federal Aviation Administration should continue to reduce GHG emissions from aircraft by expanding their programs and initiatives under the Next Generation Air Transport Systems, which enhance the way air travel is managed across the country. In anticipation of international adoption of aircraft CO_2 emission standards in 2016, EPA should stay on track to release an advanced notice of proposed rulemaking in 2015 and finalize its findings in 2016, and should aim to set standards that achieve a 2–3 percent annual improvement in the fuel efficiency of new aircraft.

9. **Reduce methane emissions from landfills, coal mines, and agriculture.** Taking action on additional methane sources represents at least 3 percent of the abatement opportunity in 2025 and 2 percent in 2030. EPA should finalize its proposed methane emission standards for new landfills, and set standards or develop other programs that reduce methane emissions from existing landfills. The EPA should also take additional action, either using its authority under the Clean Air Act to set emission standards, or through other measures, to reduce methane emissions from coal mines. Opportunities exist to reduce methane emissions from agricultural sources.[108] Quantifying these sources was beyond the scope of this analysis.

10. **Reduce emissions from other sources while increasing the U.S. carbon sink.** Other emission sources, like off-highway vehicles, nitric and adipic acid manufacturing, and PFC and SF_6 emission sources, represent 4 percent of the abatement opportunity in 2025 and 5 percent in 2030. To capture this abatement opportunity, the U.S. Administration should use its authority under existing laws to establish emission or efficiency standards, expand existing voluntary programs, and/or establish new programs or other measures. The United States should also develop a plan to maintain and even optimize the nation's carbon sinks, especially since there is a lot of uncertainty about current sequestration projections, and the latest data suggests that U.S. forests are likely to sequester carbon at a slower rate over the long term.

ENDNOTES | CHAPTER 2

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Chapter 3

DRIVING DEEPER REDUCTIONS BEYOND 2025 IN PARALLEL WITH ROBUST ECONOMIC GROWTH

As we illustrated in Chapter 2, the United States can meet, and even exceed, its near- and medium-term climate goals using existing federal laws and state action. Our 10-point action plan demonstrates how the country can accelerate recent market trends in renewable power sources, energy efficient technologies, alternative vehicles, and many other areas to reduce emissions 26–30 percent below 2005 levels by 2025. While these reductions are significant, U.S. efforts to combat climate change should not stop there. Even deeper greenhouse gas (GHG) emission reductions will be needed beyond 2025 to avoid the worst impacts of climate change. This chapter focuses on how the United States can achieve deeper reductions in the 2030–40 time frame.

The U.S. economy has already started to decarbonize, as illustrated by the decoupling of U.S. GHG emissions and economic growth; between 2005 and 2012, greenhouse gas emissions dropped by 8 percent while real GDP grew by 8 percent.[a,1] Projections from the U.S. Energy Information Administration (EIA) estimate that the intensity of energy use in the economy will continue to decline through 2040 even in the absence of new policies. In addition, state renewable targets, federal tax incentives, voluntary renewable energy markets, new transmission, and rapidly declining renewable energy technology costs are helping to drive increases in renewable generation. As a result, new wind energy is cheaper than new coal generation in many markets and cheaper than natural gas in a growing number of markets (on a per megawatt-hour basis).[2] Some new solar photovoltaic projects are being chosen over new coal and natural gas generation because of lower costs or larger net benefits. Energy efficiency programs are lowering utility bills for homes and businesses while driving GHG emission reductions. Low-cost shale gas has spurred fuel switching away from coal in power generation, reducing carbon dioxide (CO_2) emissions as well as other harmful air pollutants. Peer-reviewed research has demonstrated the technical feasibility of achieving deep decarbonization in the United States.[3]

Despite this progress, additional policies are likely needed to continue to unlock these types of opportunities, because market barriers hamper investment in what are otherwise beneficial activities.[4] A deep transition to a low-carbon economy will likely require new legislation to overcome market barriers and provide the long-term, consistent policy signals that provide confidence for investors in new technologies and infrastructure. While new legislation is unlikely in the near term—and thus was not included as a viable option to meet the 2025 emission reduction target—it could become an option if the political climate in Congress shifts over the next several years.

We developed two pathways that illustrate the emission reductions that could be achieved through new legislation. The first pathway would put a price on all energy-related CO_2 emissions (All-Energy Carbon Price), and the second would put a price on CO_2 emissions from the power sector only (Electricity-Only Carbon Price). Both pathways also include many complementary measures across nearly all other sectors of the economy, building off the steps the country is already taking to reduce emissions.

We find that the United States can make significant long-term emission reductions using legislative measures together with other policies that can be pursued using existing laws and state action. Through the implementation of a price on carbon at levels assumed in our pathways (described below), together with many other complementary measures across the economy, the country can reduce its GHG emissions 40-42 percent below 2005 levels in 2030 and 50-53 percent in 2040. Higher or lower carbon prices than those modeled here would achieve greater and smaller reductions, respectively.

A low-carbon transition of this magnitude does not require sacrificing the health of our economy. In fact, we find that these pathways could be pursued in parallel with robust economic growth and without any significant reduction in

[a] While a portion of the decoupling is likely due to the ongoing relative decline of the manufacturing sector as a portion of total GDP, quantifying that portion was outside the scope of this analysis.

overall employment. The pathways we developed include actions that cover a range of costs—from negative costs with net savings accruing to consumers, to positive costs. But our results show that the economy can continue to grow as the United States shifts to a lower-carbon future, with only relatively small changes from the expected economic trajectory in the absence of any new climate change policies. It's also likely that the United States would experience positive economic impacts related to associated public health benefits and longer-term climate-related benefits, which could partially or fully compensate for the costs of action, but such impacts are not reflected in our analysis.

UNDERSTANDING THE LEGISLATIVE PATHWAYS

We developed two pathways that illustrate what would be possible if Congress were to enact legislation that either puts a price broadly on all energy-related CO_2 emissions or solely on CO_2 emissions from the power sector, both with complementary measures across nearly all other sectors of the economy.

All-Energy Carbon Price

This pathway assumes that Congress establishes a price on CO_2 emissions across all energy sectors that begins in 2020. We modeled a carbon price as a tax (although it could also take the form of a cap-and-trade program) and explored two price trajectories: one based on the U.S. Energy Information Administration's $25 carbon fee scenario from the *Annual Energy Outlook 2014* (resulting in a 2020 CO_2 price starting at $32 per ton in constant 2012 dollars), and the second linked to the official government estimate of the Social Cost of Carbon (resulting in a 2020 CO_2 price starting at $46 per ton in constant 2012 dollars).[5] The modeling indicated that these two price trajectories would result in quite similar CO_2 reductions and economic impacts, and so we treat them as essentially one pathway. This pathway also includes complementary efficiency policies across the residential, commercial, and transportation sectors, as well as ambitious action across non-CO_2 emission sources that could be achieved using existing federal authorities and state action (similar to our Core Ambition pathway from Chapter 2).

Electricity-Only Carbon Price

This pathway assumes that Congress establishes a price on carbon applicable only to the power sector starting in 2020 (on the same trajectory as the $25/ton fee described above). Similar reductions could be achieved by establishing a cap-and-trade program in the power sector or a flexible clean energy standard. Similar to the All-Energy Carbon Price pathway, our Electricity-Only Carbon Price pathway also includes ambitious action across the residential, commercial, and transportation sectors, as well as other non-CO_2 emission sources across the economy that could be achieved using existing federal authorities and state action. However, unlike the All-Energy Carbon Price pathway, this pathway assumes targeted efficiency standards are implemented in the industrial sector.

Of course, these pathways are only illustrative of the reductions that could be achieved through legislative measures. The magnitude of reductions achieved by any new laws, including any form of carbon pricing, depends on how the laws are designed, their stringency and timelines, and whether other complementary policies are put into place. In our analysis, the Electricity-Only Price pathway results in slightly greater reductions than the All-Energy Carbon Price pathway, largely because we included targeted efficiency measures for industry under the Electricity-Only Price pathway, but not in the All-Energy Carbon Price pathway (in which the carbon price was the driver of reductions in the industrial sector). In addition, we modeled only two possible carbon price trajectories. Of course, deeper economy-wide emission reductions could be achieved through a higher carbon price.

OVERVIEW OF MODELS USED

To project the emission and economic impacts of our two legislative pathways, we used a version of the Energy Information Administration (EIA) National Energy Modeling System maintained by Duke University's Nicholas Institute for Environmental Policy Solutions (DUKE-NEMS), which collaborated with WRI in this study. We also worked with researchers at Georgia Tech University to develop an integrated high efficiency scenario for the industrial sector. Unlike WRI's Greenhouse Gas Abatement Model (WRI-GAM), NEMS has the capability to model a carbon price on all fossil fuel use, and to analyze the resulting emission and economic impacts. In general, NEMS is limited to modeling CO_2 from fossil fuel combustion, so we complemented these results with our modeling of ambitious action for non-energy CO_2 and non-CO_2

emission sources, in line with what was modeled in all other pathways using WRI-GAM. (As noted in Chapter 2, modeling the details and complexities of the Clean Power Plan in DUKE-NEMS proved difficult and was beyond the scope of this analysis. Thus we were unable to project economic impacts for the Core Ambition, Power Sector Push, and Targeted Sector Push pathways.)

Many of the policy and technological assumptions we used in this analysis were based on opportunities identified in two previous WRI reports—*Can The U.S. Get There From Here?* and *Seeing Is Believing*—and we supplemented them with additional opportunities in nearly all sectors of the U.S. economy. We used elements of EIA's Low Renewable Technology Cost side case for the power sector, where renewable technologies are 20 percent cheaper than the Reference Case, to better reflect more recent data on actual solar and wind project costs. However, there is reason to believe that even these estimates are higher than current costs in certain parts of the country, given the continuing dramatic reductions in costs of renewables (see the Appendix for further discussion). We assessed the economic impacts of policies and trends that address energy-related CO_2 under our All-Energy Carbon Price and Electricity-Only Carbon Price pathways using DUKE-NEMS. Summary results of the DUKE-NEMS modeling appear below and the Appendix contains additional information. We do not assess the economic impacts of the non-energy CO_2 and non-CO_2 measures included in these two legislative pathways because DUKE-NEMS does not model these gases.

We used the Macroeconomic Module of DUKE-NEMS to generate projections of GDP and unemployment, two common macroeconomic indicators. We also examined DUKE-NEMS projections of electricity prices and sales to analyze the impacts on electricity bills that would accompany major reductions in GHG emissions from the power sector. In the case of the carbon price scenarios, we ran DUKE-NEMS in a "revenue-neutral" mode, recycling all carbon price revenues back to households in lump-sum fashion.[b] No model is perfect, and the DUKE-NEMS model has strengths and weaknesses (not unique to DUKE-NEMS, but rather with NEMS in general). One of its key strengths is the richness in representation of end uses and technologies across all sectors. This allowed us to model

Box 3-1 | Limitations to Economic Modeling of GHG Emission Reductions

A number of different models can be used to project the impacts of low-carbon pathways, each with its own strengths and weaknesses. Despite their best efforts to simulate the real world, models often overestimate the costs of reducing GHG emissions. Some of this bias arises because most models are unable to capture the multiple benefits of reduced fossil fuel use, such as improved public health, reduced road congestion, and improved energy security. Bias also arises when models assume that the economy is in equilibrium prior to some policy intervention, with resources allocated efficiently and no market failures. Models also generally do a poor job capturing the dynamics of technological innovations. Examinations of ex post and ex ante cost estimation of environmental policies find that ex ante estimates are typically biased upward.

On the other hand, there are some biases that work in the opposite direction. Modeling of a cap-and-trade policy might assume a smooth, frictionless market for tradable permits, when this is unlikely to occur in reality. Modeling of a carbon tax might assume that some consumers and businesses respond perfectly rationally, and make energy and investment choices that reflect both current and future prices, but they may, in reality, exhibit "boundedly rational" behavior (that is, less than perfectly rational behavior in the real world). Modelers might also assume that a carbon tax applies to all emissions and has no enforcement problems. In reality, policymakers may carve out exceptions for favored sectors and/or face real-world enforcement problems that lead to greater emissions than the model might indicate.

Notes: See the literature review and original research in USEPA, National Center for Environmental Economics. 2012. Retrospective Study of the Costs of EPA Regulations: An Interim Report of Five Case Studies. Accessible at: <http://yosemite.epa.gov/sab/sabproduct.nsf/368203f97a15308a852574ba005bbd01/3A2CA322F56386FA852577BD0068C654/$File/Retrospective+Cost+Study+3-30-12.pdf>. See also general discussion in the Global Commission on the Economy and Climate. 2014. Better Growth, Better Climate, Chapter 5, "Economics of Change." Accessible at: <http://newclimateeconomy.report/>.

[b] Implicitly, if the carbon price took the form of a cap-and-trade system and all allowances were auctioned, the resulting revenues could be recycled as described here, on a lump-sum basis. Many options exist for recycling revenues, including reduction of tax rates, which can lead to net economic or employment impacts. For additional information, see: K. Kennedy, M. Obeiter, and N. Kaufman. 2015. "Putting a Price on Carbon: A Handbook for U.S. Policymakers." Working Paper. Washington, DC: World Resources Institute. Accessible at: <http://wri.org/carbonpricing>.

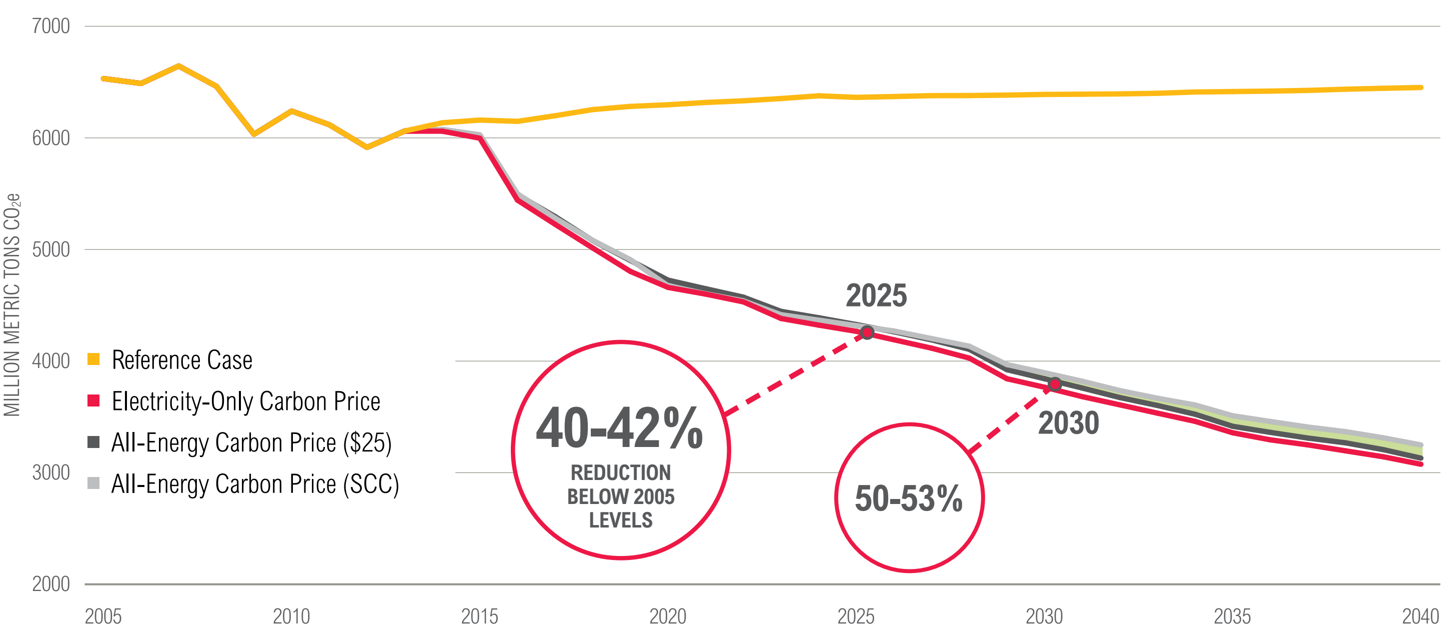
various policies tailored to those sectors. On the other hand, DUKE-NEMS assumes perfect foresight on energy prices in the power and refinery sectors, but very myopic behavior in all other sectors (that is, most energy consumers do not factor expected changes in future energy prices into their decisions). A more nuanced approach might be more realistic, especially when modeling carbon price scenarios, so that more energy consumers are assumed to respond to expectations of future higher energy prices in a manner that is somewhere between the extremes of perfect foresight and myopia. In addition, energy efficiency policy scenarios in DUKE-NEMS will reduce energy demand but also tend to reduce GDP. The more likely outcome is that greater efficiency in energy use would free up resources and lead to increases in GDP, all else being equal. Also, because the model generally does not allow us to implement certain types of top-down policies, it is possible that we are not capturing the full range of efficiency potential available to utilities or other sectors (see Box 3.1 for further discussion of these limitations).

KEY FINDINGS

The United States can make deep long-term emission cuts in the 2030–40 time frame by implementing new climate legislation together with complementary policies. Our modeling indicates that the low-carbon pathways requiring legislation, as described in this chapter, could reduce emissions by 40–42 percent below 2005 levels by 2030 and 50–53 percent by 2040 while still maintaining robust economic growth (Figure 3.1). Higher carbon prices in either pathway, of course, would result in deeper emission reductions.

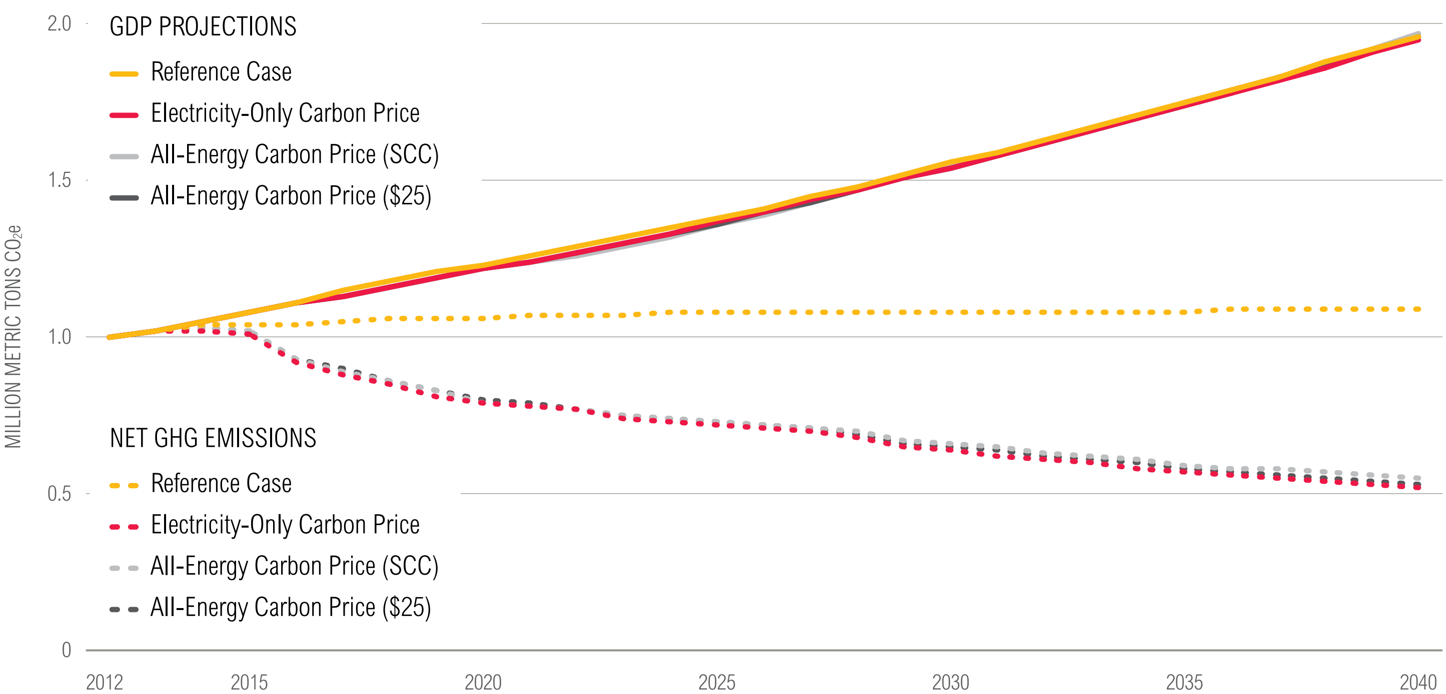
The Electricity-Only Carbon Price pathway achieves slightly greater emission reductions than the All-Energy Carbon Price pathway due largely to the fact that the industrial energy efficiency standards assumed under our Electricity-Only Carbon Price pathway achieved greater reductions than the carbon prices assumed under our All-Energy Carbon Price pathway, not because a carbon price focused on the power sector is inherently more effective in

Figure 3-1 | **Net GHG Emissions: Reference Case and Low-Carbon Pathways Assuming New Legislation and Other Supportive Measures**



Note: Both pathways assume complementary policies are enacted that address commercial, residential, and transport efficiency in addition to taking ambitious action across non-CO_2 sources. As noted above, we modeled two different carbon prices under the All-Energy Carbon Price pathway: (1) Social Cost of Carbon-based (upper bound in later years), and (2) $25/ton-based (lower bound in later years). Their impacts were quite similar in the early years, with the $25/ton-based price leading to a slightly lower level of emissions in the later years.

Figure 3-2 | **Net Greenhouse Gas Emissions and GDP Projections under Reference Case and Low-Carbon Pathways Indexed to 2012**



Note: Due to modeling limitations, we could not include the economic impacts of policies that address non-energy CO_2 and non-CO_2 emissions in our analysis (e.g., those that address HFCs, methane from natural gas systems, landfills, and coal mines, N_2O from nitric and adipic acid manufacturing, PFCs, SF_6, and carbon sinks from land use). The GDP effects displayed here only reflect policies that affect energy-CO_2 under our low-carbon pathways, which amounts to about 75 percent of total GHG emissions. These GDP effects also do not include the positive economic benefits (like improved public health) that would accrue as a result of some of these measures.

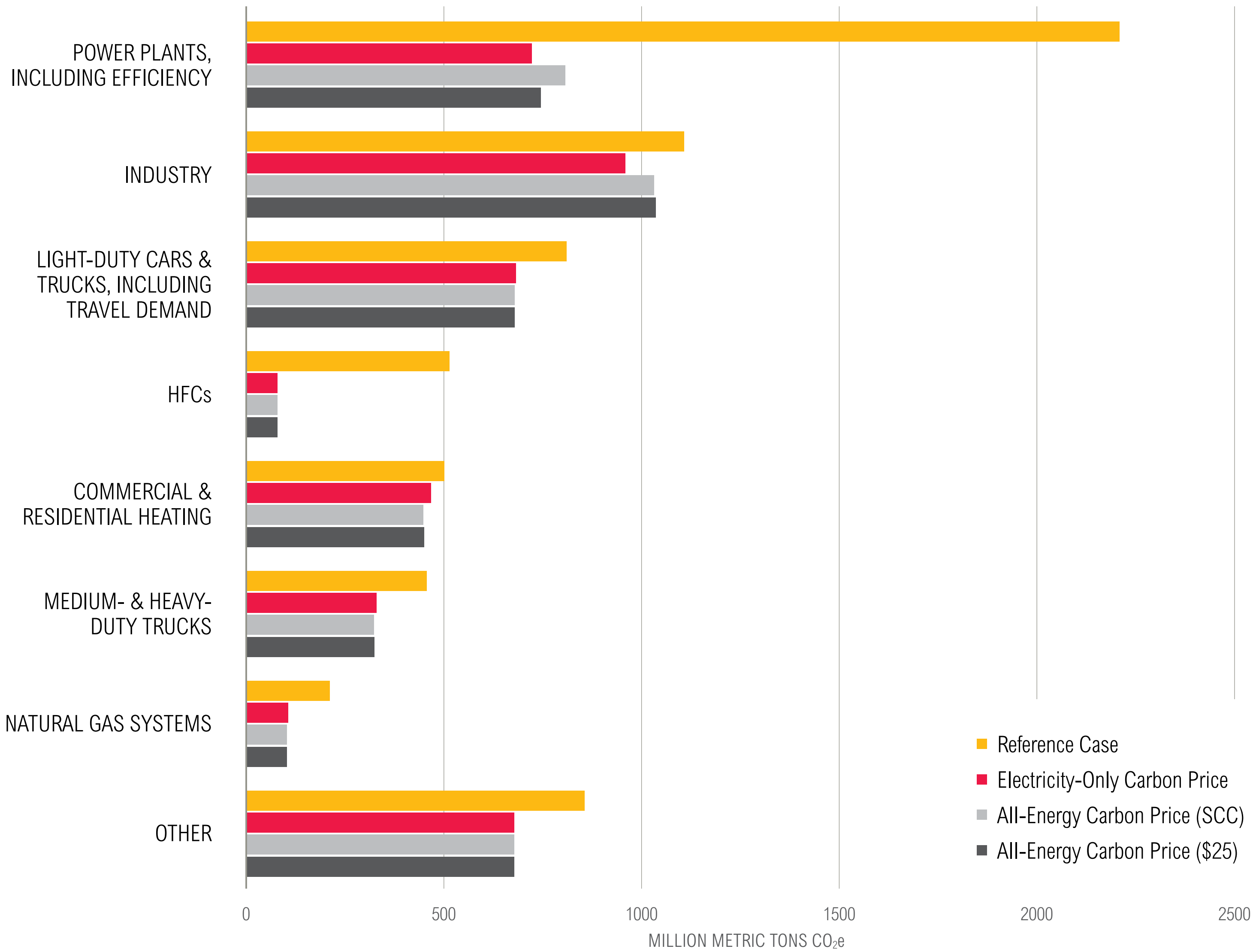
reducing emissions economy-wide. However, this may be a product of the DUKE-NEMS modeling assumption that the industrial sector generally behaves very myopically. In reality, industry may respond more directly to a price on carbon and achieve greater emission reductions than we modeled under our All-Energy Carbon Price pathway.

- **The United States can reduce emissions 40-41 percent below 2005 levels in 2030 and 50-52 percent in 2040 by setting a price on carbon on all energy-related CO2 emissions.** This would also require ambitious complementary strategies across other key sectors, including efficiency programs in the residential, commercial, and transport sectors, as well as measures targeting non-CO_2 gases. Additional abatement beyond the reductions identified here could be achieved by implementing standards or other programs that aim to increase industrial energy efficiency.

- **Deep reductions of similar magnitude (42 percent in 2030 and 53 percent in 2040) can be achieved by implementing a carbon price on the power sector and taking targeted action across other key areas of the economy.** The resulting price on carbon would spur the power sector to capture all available low-carbon opportunities, including more natural gas, nuclear, renewable energy, and energy efficiency sources. Deep reductions in the power sector would need to be complemented by targeted, ambitious action across other energy sectors (residential, commercial, industry, and transportation) and non-CO_2 emission sources.

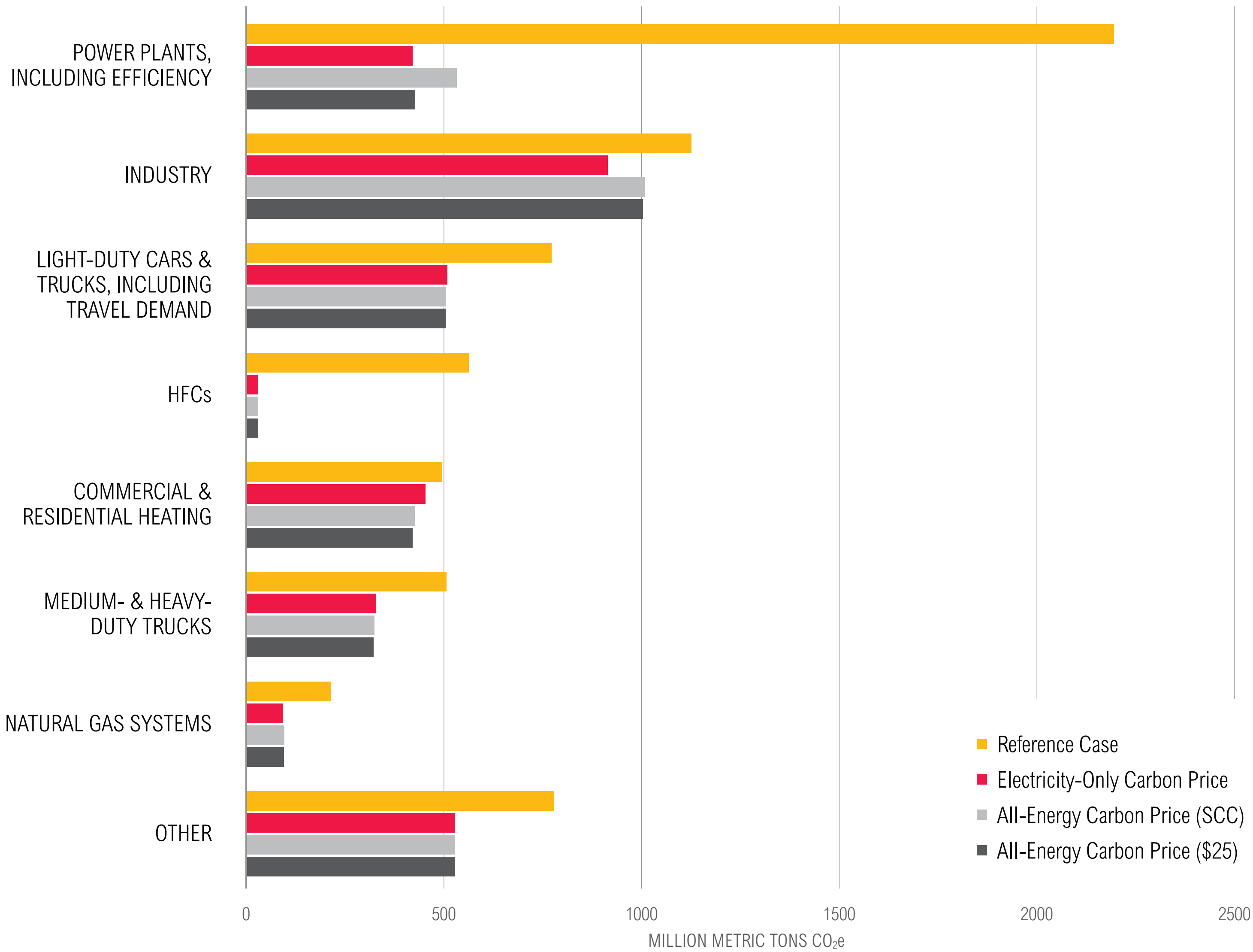
- **The United States can achieve these deep cuts in GHG emissions while maintaining robust economic growth and with little effect on net employment.** We also find that energy efficiency policies under these pathways can help reduce energy bills for some households, drivers, and businesses.

Figure 3-3 | **U.S. GHG Emissions By Sector under Reference Case and Low-Carbon Pathways in 2030**



While it is likely that the power sector will start transitioning to a cleaner energy power system before a price on carbon or other clean energy standard takes effect, this transition would probably occur more quickly under our two legislative pathways (illustrated in Figure 3.2). A combination of complementary energy efficiency measures beginning in 2015, along with the model's "perfect foresight" assumption that electric utilities plan and invest for the forthcoming carbon price, led to a significant amount of GHG abatement occurring before the carbon price starts in 2020. Additionally, our Electricity-Only Carbon Price pathway results in slightly more abatement than our All-Energy Carbon Price pathway. As noted above, our Electricity-Only Carbon Price pathway assumed that EPA would reduce industrial emissions by establishing GHG emission standards in five major industrial subsectors. However, in the All-Energy Carbon Price pathway, the price on carbon was the only measure to impact industrial emissions. Our results suggest that industrial GHG emissions are relatively inelastic with respect to carbon prices (see Figures 3.3 and 3.4 below), likely reflecting a default model assumption of relative myopia in the industrial sector with respect to future carbon prices.

Figure 3-4 | **U.S. GHG Emissions By Sector under Reference Case and Low-Carbon Pathways in 2040**



As shown in Figures 3.3 and 3.4, the power sector is the largest opportunity for GHG emission abatement in these pathways, where cleaner generation combined with more efficient electricity use could reduce power sector CO_2 emissions 70 percent below 2005 levels by 2030 and 83 percent by 2040. Hydrofluorocarbons (HFCs), industry,[6] vehicles and reduced transport demand, and natural gas systems also offer important abatement opportunities in the 2030–40 time frame.

None of the pathways we modeled were sufficient to put the United States on a trajectory to reach a long-term, science-based goal of reducing emissions 80 to 95 percent below 2005 levels by 2050. Reductions of this magnitude would likely require strong congressional action, such as a carbon price beyond what we considered in our analysis, and other complementary policies. The carbon prices we modeled are illustrative, and steeper reductions could be achieved with higher prices.

PATHWAY DETAILS

Both pathways contain a number of complementary policies in addition to new legislation. These policies, and our approaches to modeling them, are similar in the two legislative pathways, with the exception of the industrial sector. We assume that targeted industrial efficiency policies are implemented under the Electricity-Only Carbon Price pathway, but not the All-Energy Carbon Price pathway.

Most of the complementary policies we assume in the legislative pathways are also similar to those we assumed under the Core Ambition and Power Sector Push pathways from Chapter 2. However, the modeling approach differed between DUKE-NEMS and WRI-GAM in six areas, discussed in more detail in the sections that follow: electric power, residential and commercial electricity demand, residential and commercial heating, light-duty vehicles, medium- and heavy-duty vehicles, and industry. Our assumptions for these sectors are summarized in Tables 3.1–3.5.

Electric Power

In the power sector, we explore new legislative approaches that could drive much deeper reductions than the Clean Power Plan as proposed by establishing long-term policy signals that aim to accelerate recent rapid declines in renewable energy technology costs, stimulate investment in lower and zero-emission generating sources (like natural gas, nuclear, and renewables), and encourage the use of energy efficiency as a resource.

Under our Electricity-Only Carbon Price pathway, power sector emissions fell 70 percent below 2005 levels by 2030, just over twice the emission reductions under the Clean Power Plan as proposed, and 83 percent by 2040.

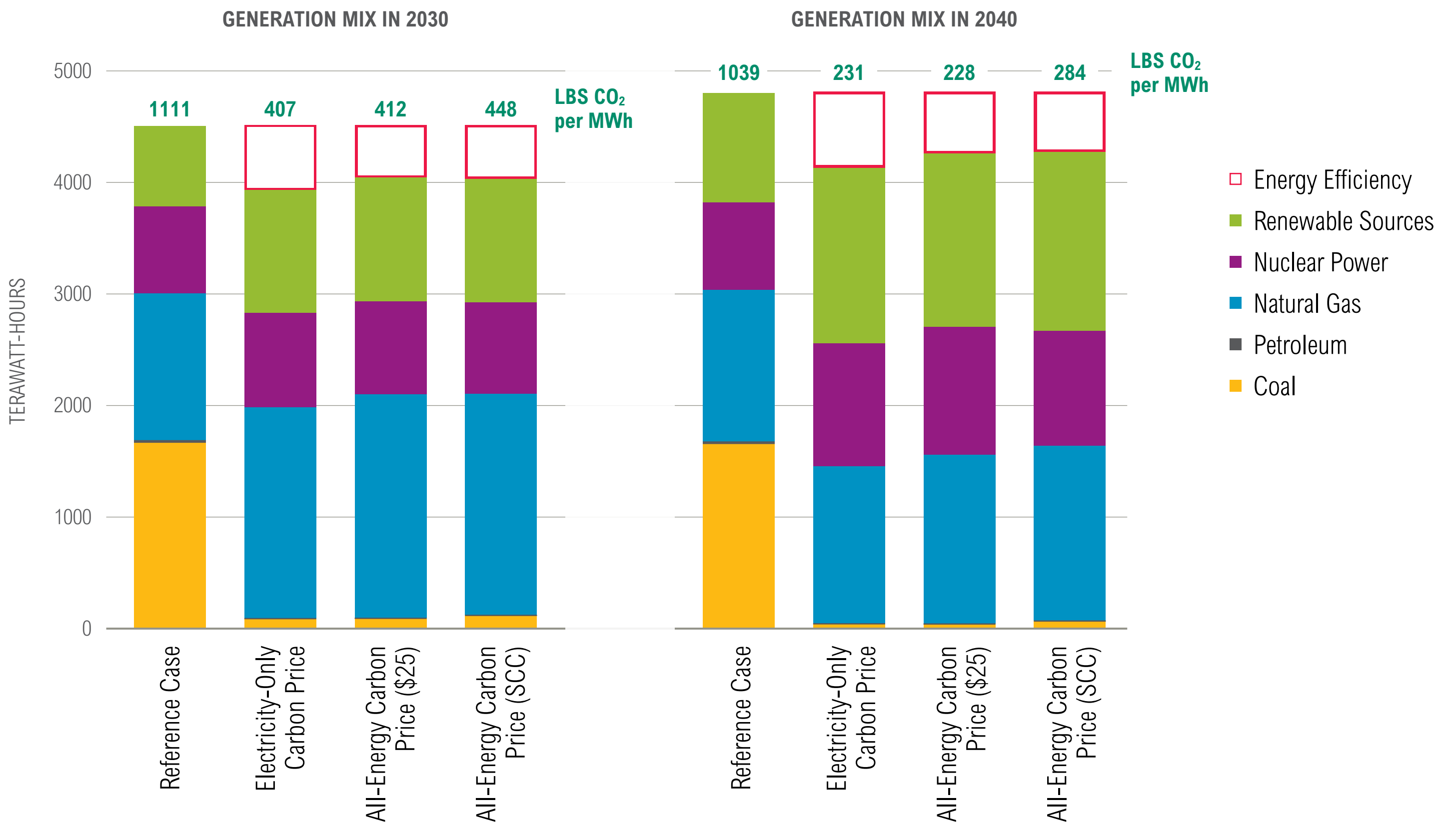
We examined the joint impact of several measures, all of which aim to reduce GHG emissions in the power sector through increased efficiency and use of natural gas, nuclear, and renewable energy sources to supply the lower electricity demand. We started with a side case from EIA's AEO2014 that implemented a $25 price on carbon starting in 2015. The price increases by 5 percent above inflation each year, reaching $41 per metric ton in 2025 and $52 per metric ton in 2030. We then layered on additional efficiency improvements based mostly on the AEO2014 Best Available Demand Technology side case, which limits appliance and equipment choices for consumers to the most efficient options available and also improves the efficiency of both new and existing building shells. Additional reductions in electricity demand resulted from the targeted industrial efficiency standards included in this pathway (see the Appendix for more details). Our All-Energy Carbon Price pathway achieved similar levels of CO_2 reductions—67 to 69 percent below 2005 levels in 2030 and 78 to 82 percent in 2040—as a result of the assumed price on carbon, state renewable targets, and additional efficiency measures across the residential and commercial sectors.

Both pathways led to greater use of low- and zero-carbon generation technologies over time (Figure 3.5). In 2012, renewable sources comprise about 12 percent of total electricity generation, while coal, natural gas, and nuclear comprised 39 percent, 29 percent, and 20 percent, respectively.[7] In the Electricity-Only Carbon Price pathway, renewable sources comprised approximately 28 percent of total generation by 2030 and 38 percent by 2040. Natural gas comprised nearly half of the generation mix in 2030, but decreased to 34 percent in 2040 as use of renewables increased. Nuclear power comprised 22 percent of total

Table 3-1 | **Power Sector Assumptions**

	ALL-ENERGY CARBON PRICE PATHWAY	ELECTRICITY-ONLY CARBON PRICE PATHWAY
EXISTING PLANTS	A carbon price, together with complementary energy efficiency policies in the residential and commercial sectors, leads to power sector emission reductions in the range of 67–69 percent below 2005 levels in 2030 and 78–82 percent in 2040.	A carbon price, together with complementary energy efficiency measures in the residential, commercial, and industrial sectors, leads to power sector emission reductions of 70 percent below 2005 levels in 2030 and 83 percent in 2040.
NEW PLANTS	Carbon price only	Carbon price only
RENEWABLE GENERATION	Due to the price on carbon and existing state renewable programs, renewable generation increases on a pathway to comprise about 27 percent of total generation in 2030 and 36–37 percent in 2040.	Due to the price on carbon and existing state renewable programs, renewable generation increases on a pathway to comprise 29 percent of total generation by 2030 and 38 percent in 2040.

Figure 3-5 | **Generation Mix Under Low-Carbon Legislative Pathways**



Note: This figure depicts net generation from the power sector by fuel type, including combined heat and power units. The energy efficiency category reflects electricity savings under each of our low-carbon pathways compared to the Reference Case. Values on each bar indicate the average emission intensity of power generation, measured in pounds of carbon dioxide emissions per megawatt hour of electricity generation.

generation in 2030 and 27 percent in 2040. Meanwhile, coal generation fell to 2 percent of the generation mix in 2030 and 1 percent in 2040. As a result of energy efficiency measures, total generation was 13 percent lower than projected levels in 2030 and 14 percent lower in 2040.

Our All-Energy Carbon Price pathway showed similar results, with renewables comprising about 27 percent of total generation in 2030 and 36-37 percent in 2040. Natural gas also comprised about half of total generation in 2030, falling to 35-37 percent in 2040. Nuclear power comprised 20-21 percent of total generation in 2030 and 24-27 percent in 2040. Coal generation fell to 2-3 percent of the generation mix in 2030 and 1-2 percent in 2040. While energy efficiency measures also reduced demand under the Carbon Price pathway, total savings were less than the Electricity-Only Carbon Price pathway because targeted industrial measures were not included. Under the All-Energy Carbon Price pathway, total generation was 10-11 percent below projected Reference Case levels in 2030 and 11 percent below projected levels in 2040.

A significant transition of this nature in the power sector would likely require complementary policies to accelerate technology development and further price reductions for renewable technologies (e.g., extended and stabilized federal tax credits for renewable sources, increased federal support for research and development of new technologies). Over the longer term, a deep decarbonization of the power sector would also require expanding transmission and integration as well as increasing system flexibility (to help respond to the variability of renewable sources) by increasing the use of grid storage, distributed generation sources, demand response, and flexible back-up generation (like natural gas plants).[8,9] However, several studies covering the Northeast, Midwest, and Western United States have shown that grids across the country can handle up to 35 percent generation from variable renewable resources with minimal cost.[10]

Residential and Commercial Electricity Demand

In our All-Energy Carbon Price and Electricity-Only Carbon Price pathways, we used EIA's Best Available Demand Technology side case as a proxy for all residential and commercial energy efficiency policies. In our All-Energy Carbon Price pathway, we assume that complementary efficiency policies are put into place to stimulate electricity demand reductions in the commercial and residential sectors beyond what would be achieved with a carbon price alone. We take a similar modeling approach in the Electricity-Only Carbon Price pathway, layering efficiency measures on top of a carbon price in the power sector. This approach is meant to capture the effects of strengthened federal appliance standards and more widespread adoption of state efficiency programs (e.g., building codes and energy efficiency savings targets), similar to the measures we describe under our first three pathways. However, we couldn't model these policies directly and determine the disaggregated impact of each policy in the same manner as we did with WRI-GAM. Instead, we were able to determine the total impact of all efficiency measures together, which reduced electricity sales to homes and commercial buildings by 23 percent in 2030 and 26–27 percent in 2040 below Reference Case projections.

Table 3-2 | **Residential and Commercial Electric Demand Assumptions**

RESIDENTIAL AND COMMERCIAL ELECTRICITY DEMAND	Appliance standards and state energy efficiency policies proxied through use of the AEO2014 Best Available Demand Technology side case. This reduces total electricity sales in these sectors by 23 percent in 2030 and 26–27 percent in 2040 below Reference Case projections.

Residential and Commercial Natural Gas Demand

The AEO2014 Best Available Demand Technology side case resulted in reduced natural gas demand through efficiency improvements to appliances and building shells. Together, all efficiency measures reduced residential and commercial natural gas demand by 8–12 percent in 2030 and 10–17 percent in 2040 below Reference Case projections.

Table 3-3 | **Residential and Commercial Natural Gas Assumptions**

RESIDENTIAL AND COMMERCIAL HEATING	Appliance standards and state energy efficiency policies proxied through use of the AEO2014 Best Available Demand Technology side case. This reduces residential and commercial natural gas demand by 8–12 percent in 2030 and 10–17 percent in 2040 below Reference Case projections.

Light-Duty Vehicles

Our Core Ambition and Power Sector Push pathways (Chapter 2) both assumed EPA and National Highway Traffic Safety Administration (NHTSA) continue to tighten standards from 2025–40 at a slightly higher rate of 5 percent per year, resulting in a CAFE standard equivalent of 103 mpg in 2040.

While our All-Energy Carbon Price and Electricity-Only Carbon Price pathways assumed similar improvement rates, we were not able to model full compliance with these extended and expanded standards, especially in the later years, due to limitations in DUKE-NEMS (e.g., under the Electricity-Only Carbon Price pathway, the compliance fuel economy for the entire light-duty vehicle fleet only reached 74 mpg in 2040). See the Appendix for further discussion.

Also, we did not assume a specific penetration rate of alternative fuel vehicles under our legislative pathways, unlike the Core Ambition and Power Sector Push pathways.

Table 3-4 | **Light-Duty Vehicle Assumptions**

LDV STANDARDS	CAFE standards similar to Core Ambition: CAFE standards improve by 5 percent per year between 2025 and 2040. No specific assumptions on alternative vehicle penetration.

Medium- and Heavy-Duty Vehicles

Our Core Ambition and Power Sector Push pathways (Chapter 2) both assumed that EPA and the National Highway Traffic Safety Administration (NHTSA) continue to tighten standards in the post-2018 time period so that these trucks reduce their fuel consumption rate by an average 40 percent below 2010 levels. Standards continue to improve annually by 2.5 percent through 2040 on average across all medium- and heavy-duty vehicles.

Similar to LDVs, DUKE-NEMS was not able to model full compliance with these standards in later years. For example, while we modeled a 59 percent reduction in fuel consumption by 2040 compared to 2010 levels, our modeling of these pathways in DUKE-NEMS results in only a 46 percent reduction in fuel consumption in 2040.

Table 3-5 | **Medium- and Heavy-Duty Vehicle Assumptions**

MHDV STANDARDS	By 2025, the medium- and heavy-duty fleet reduces its fuel consumption rate by an average 40 percent below 2010 levels. Standards continue to improve annually by 2.5 percent through 2040 on average across all medium- and heavy-duty vehicles.

Industry

While the U.S. industrial sector has opportunities for cost-effective GHG emission mitigation, these options are inhibited by persistent barriers and high investment costs.[11] Carbon pricing and targeted sector standards are two policy mechanisms that can facilitate GHG emission reductions. In order to assess the role of targeted policies and carbon prices in reducing industrial sector emissions, efficiency policy levers were included in the All-Energy Carbon Price pathway but excluded from the Electricity-Only Carbon Price pathway.

Our Energy Carbon Price pathway assumed that the price on carbon was used to spur CO_2 emission reductions throughout the industrial sector, including petroleum refineries.

Table 3-6 | **Industry Assumptions**

	ALL-ENERGY CARBON PRICE	ELECTRICITY-ONLY CARBON PRICE
INDUSTRY	Carbon price only. This is based on the U.S. Energy Information Administration's $25 carbon fee scenario from the *Annual Energy Outlook 2014* (resulting in a 2020 CO_2 price starting at $32 per ton in constant 2012 dollars).	EPA sets GHG emission standards for five manufacturing subsectors that lead to a reduction in energy consumption below Reference Case projections by 2030, ranging from 18 percent for bulk chemicals, 23 percent for cement and refining, 40 percent for pulp and paper, and 57 percent for iron and steel; industrial CHP promotion through extension of the investment tax credit.

The Power Carbon Price pathway includes additional efficiency assumptions related to combined heat and power (CHP), electric motors, biomass use, and technical efficiency improvements among five manufacturing subsectors. The scenario assumes 30 percent investment tax credits for CHP are extended through 2040, the rate of decline for CHP system costs is increased, the pulp and paper industry's supply of biomass is increased, and it enables EIA's "high-tech" assumptions, which includes triggering a high-tech flag that increases the speed of cost declines for CHP systems and improves electric motor efficiencies. It is further assumed that EPA sets GHG emission standards for five manufacturing subsectors that lead to a reduction in energy consumption below Reference Case projections by 2030, ranging from 18 percent for bulk chemicals, 23 percent for cement and refining, 40 percent for pulp and paper, and 57 percent for iron and steel.

All Other Emission Sources

The assumptions for all other sources were the same as our Core Ambition pathway (summarized in Table 3.7). See Chapter 2 and the Appendix for detailed descriptions.

Table 3-7 | **Assumptions for Other Sectors**

TRANSPORTATION	
LDV TRAVEL DEMAND	Light-duty VMT reductions of 7 percent below Reference Case projections in 2025 and 12 percent in 2030.
OFF-HIGHWAY VEHICLES	2.4 percent annual improvement in the emission rate for new equipment and engines from 2018 to 2040.
AVIATION	1.4 percent annual operational improvement via FAA's NextGen program, plus a 2.3 percent annual improvement in the performance of new aircraft and engines. Both rates remain constant through 2040.
METHANE SOURCES	
NATURAL GAS SYSTEMS	EPA sets standards that achieve methane emission reductions of 67 percent from Reference Case starting in 2019. Assumes phased implementation of the following measures beginning in 2017, with full implementation in 2019: plunger lift systems to reduce emissions from liquids unloading at new and existing wells; leak monitoring and repair to reduce fugitive emissions from production, processing, and compressor stations; conversion of existing high-bleed pneumatic controllers to low-bleed or no-bleed controllers to reduce emissions from production, processing, and transmission; desiccant dehydrators to reduce emissions during dehydration of wet gas; improved compressor maintenance to reduce emissions during processing; hot taps in maintenance of pipelines during transmission; and vapor recovery units to reduce emissions during storage. These gains are in addition to emission reductions expected as a result of EPA's 2012 emission standards for hazardous air pollutants, and likely include all of the proposed standards for new equipment expected in the fall of 2015.
COAL MINES	EPA sets standards that achieve total emission reductions of 36 percent from Reference Case projections starting in 2020.
LANDFILLS	EPA sets standards that achieve total emission reductions of 9 percent from Reference Case projections starting in 2020 and 11 percent starting in 2030.
FLUORINATED GASES	
HYDROFLUORO-CARBONS	EPA sets standards that result in a 61 percent reduction in HFC consumption by 2025 below Reference Case levels and an 85 percent reduction by 2030 (consistent with the non-Article 5 country schedule as laid out in the 2014 North American amendment proposal to the Montreal Protocol), and also extends the servicing and disposal of air conditioning and refrigeration equipment requirements for HCFCs and CFCs to HFCs.
PFCs	EPA establishes performance standards for aluminum and semiconductor emission sources resulting in 22 percent emission reductions from Reference Case projections starting in 2020 (on average, across PFC emission sources) and 17 percent in 2030.
SF_6	EPA establishes performance standards for electrical transmission and distribution systems, as well as magnesium and semiconductor production emission sources, resulting in 47 percent reductions from Reference Case projections starting in 2020 (on average, across SF_6 emission sources) and 46 percent in 2030.

ECONOMIC IMPACTS OF A LOW-CARBON TRANSITION

The transition to a low-carbon economy does not mean sacrificing economic growth. Deep reductions in GHG emissions could be achieved at a modest cost if the United States, via targeted policy signals, is able to continue or accelerate the trends in technological innovation we are seeing today. In fact, transitioning to a low-carbon economy could potentially lead to some positive economic impacts even in the short term because of the health benefits and energy cost savings that could accrue to businesses and consumers, and other co-benefits.

Experiences across the country have shown that policies to reduce GHG emissions can result in economic benefits, including direct savings for consumers and the creation of new jobs. These opportunities are arising across many sectors of the economy. For instance, the capital cost of renewable electricity sources like wind and solar continues a rapid downward trend.[12] Well-crafted energy efficiency programs are lowering utility bills while reducing energy demand, which indirectly reduces GHG emissions.[13] Increased production of low-cost shale gas, while raising concerns about methane emissions and other environmental impacts, has spurred fuel switching away from coal in power generation, reducing CO_2 emissions.[14] Technological progress on many fronts promises to create further opportunities, from creating alternatives to hydrofluorocarbons to breakthroughs in electric and fuel cell vehicles.[15]

Our analysis is consistent with many of these trends and finds that the United States can pursue a low-carbon pathway with little long-term impact on GDP or net employment. We also find that, in some cases, ambitious energy-efficiency policies can help lower customers' average energy bills in the residential, commercial, and transport sectors.

Our results do not include the significant health-related co-benefits associated with policies that reduce GHG emissions or the longer-term benefits of avoided climate-related damages. Policies that reduce fossil fuel use also reduce emissions of particulate matter and other air pollutants that can increase the prevalence of respiratory problems and other ailments. In addition to affecting quality of life, these ailments are costly and affect labor productivity. A low-carbon pathway could result in positive economic impacts if these co-benefits are included. It is also important to note that our results do not include any economic effects due to the policies we assume are put into place to reduce non-CO_2 emissions. Furthermore, some of these policies can be cost-effective; for example, large reductions in methane emissions from natural gas systems can be achieved with technologies that are technically feasible and profitable, each with a potential payback period of less than three years.[16]

Our findings are contrary to some conventional thinking, which holds that countries have to accept lower economic output and employment in the near-term in order to gain the benefits of reduced climate damages in the longer term. However, many of the models underpinning this thinking have serious shortcomings, as described in the 2014 report of the Global Commission on the Economy and Climate (*Better Growth, Better Climate*):

> The view that there is a rigid trade-off between low-carbon policy and growth is partly due to a misconception in many model-based assessments that economies are static, unchanging, and perfectly efficient.... Indeed, once market inefficiencies and the multiple benefits of reducing greenhouse gases, including the potential health benefits of reduced air pollution, are taken into consideration, the perceived net economic costs are reduced or eliminated.[17]

Better Growth, Better Climate also notes how economic models generally do a poor job of capturing the many nuances that lead to technological investment and innovation (see Box 3.1 for more details on limits to economic models). Even with these shortcomings, under a scenario of aggressive climate action aimed at limiting warming to 2 degrees celsius, application of conventional models to the global economy results in a median loss of gross domestic product (GDP) of about 1.7 percent in 2030. The Global Commission concluded that this level of GDP impact is best viewed as "background noise" compared to the projected global economic growth of roughly 50 percent or more over the time period modeled.[18]

This section presents the economic impacts as modeled in NEMS for the energy sector, covering GDP, GDP growth, unemployment, and impacts on energy and electricity expenditures. More details appear in the Appendix.

GDP Effects

Reference Case GDP in the United States is expected to grow from $15 trillion in 2012 to $24 trillion in 2030 and to $30 trillion in 2040.(All GDP numbers here are in constant 2012 dollars.) Our results suggest that similar robust economic growth can be achieved while also cutting GHG emissions (Figures 3.6 and 3.7). In our low-carbon legislative pathways, GDP is projected to grow at a slightly lower rate in the near-term so that total GDP is marginally reduced from Reference Case levels through 2029 (1.3 percent below Reference Case levels on average). After 2025, GDP growth rates are slightly higher under our low-carbon pathways than those in the Reference Case, resulting in GDP levels that are only 0.4 percent below Reference Case GDP on average in the 2030–40 time frame.

However, these differences are fairly small in comparison to the size of the U.S. economy. In 2030, for example, GDP losses from climate action would be equivalent to about three days of economic output that year ($170 billion losses compared to a total economy of over $24 trillion). Compared to the normal variations in GDP growth that may occur in any given year due to a range of factors (e.g., major and minor recessions, oil price fluctuations, and others), the economy-wide GDP impacts projected here do resemble "background noise,"[19] as noted above.

Figure 3-6 | **Projected Annual GDP: Reference Case and Low Carbon Pathways**

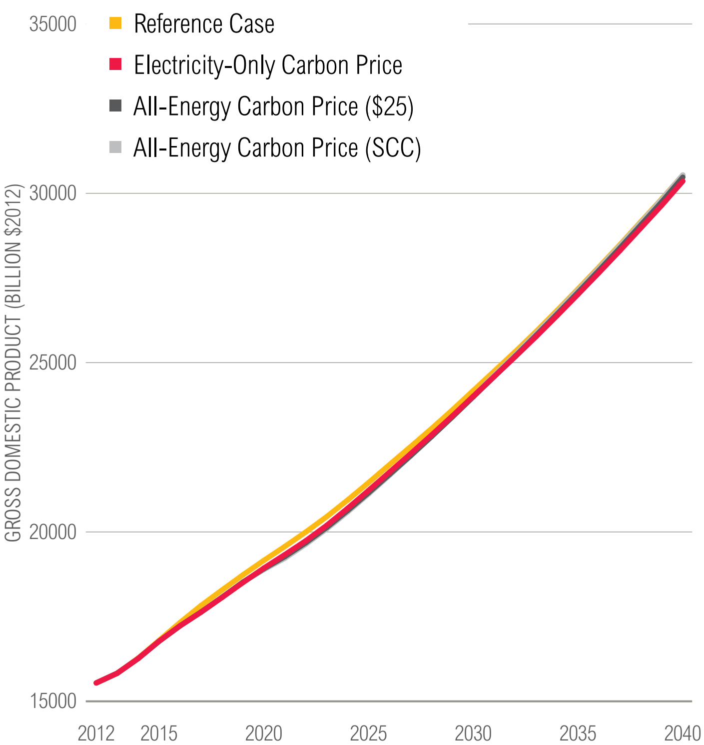
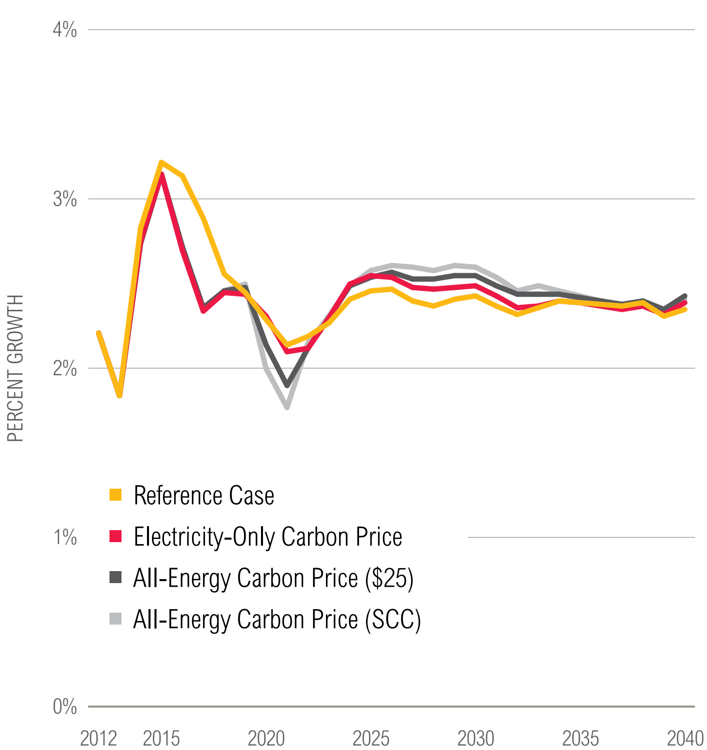


Figure 3-7 | **Projected Annual GDP Growth Rates: Reference Case and Policy Scenarios**



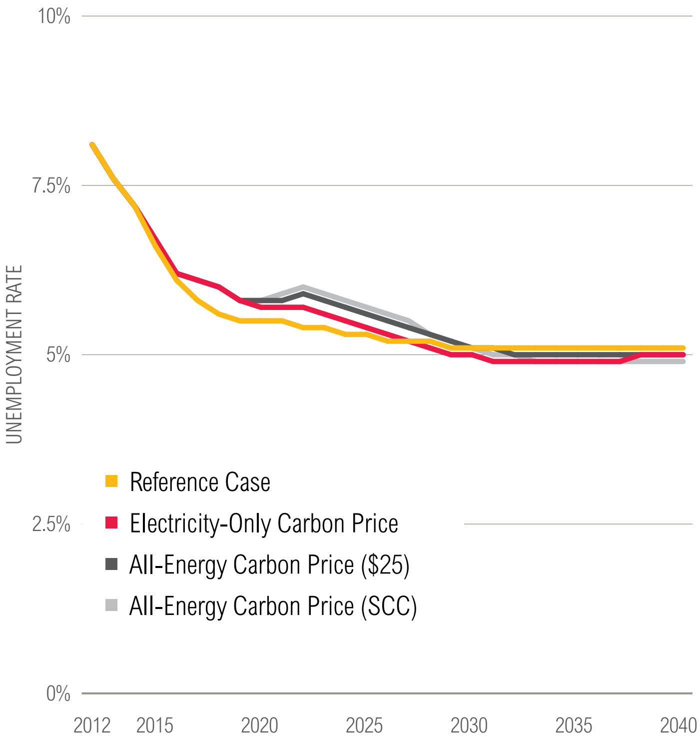
All economic models have strengths and weaknesses, and all modeling exercises have limitations. Some users of NEMS note that it doesn't fully or automatically capture new investment due to low-carbon policies and therefore tends to overestimate economic losses.[20] On the other hand, these results are reflective only of our policy assumptions affecting energy CO_2, as we were unable to model the macroeconomic impacts of policies affecting non-CO_2 gases.

Employment and Trade Effects

Under our Reference Case, U.S. unemployment rates drop from 8.1 percent in 2012 to roughly 5.5 percent in 2020, declining to 5.1 percent in 2030, and holding at that level through 2040 (Figure 3.8). Our legislative low-carbon pathways result in slightly higher unemployment rates in the short- to medium-term (through 2029), followed by slightly lower unemployment rates in the longer term (roughly 2030 to 2040). While we found relatively small impacts on overall employment, employment in some sectors would be expected to grow (e.g., renewable energy) while others would decline (e.g., coal production). The transition of future job seekers will need to be well managed to ensure that proper job training or other opportunities are provided so that all Americans looking for work are able to find it in a low-carbon economy. Transition assistance could also include support for maintenance of income, health, and pension benefits.

Explicit modeling of trade effects was beyond the scope of this study, but carbon pricing can raise concerns over potential impacts on the competitiveness of energy-intensive industries producing globally traded goods or services (e.g., chemicals, metals, or paper). If major trading partners do not have similar carbon pricing policies in place, such industries could lose market share and GHG emissions could simply shift to other countries. While carbon pricing is only one (often minor) factor influencing such decisions, in such circumstances, the United States might want to consider various policies that could help level the playing field, including potentially adjusting border taxes or offering direct compensation to affected industries.[21]

Figure 3-8 | **Projected Annual Unemployment Rates: Reference Case and Low Carbon Pathways**



Energy and Electricity Expenditures

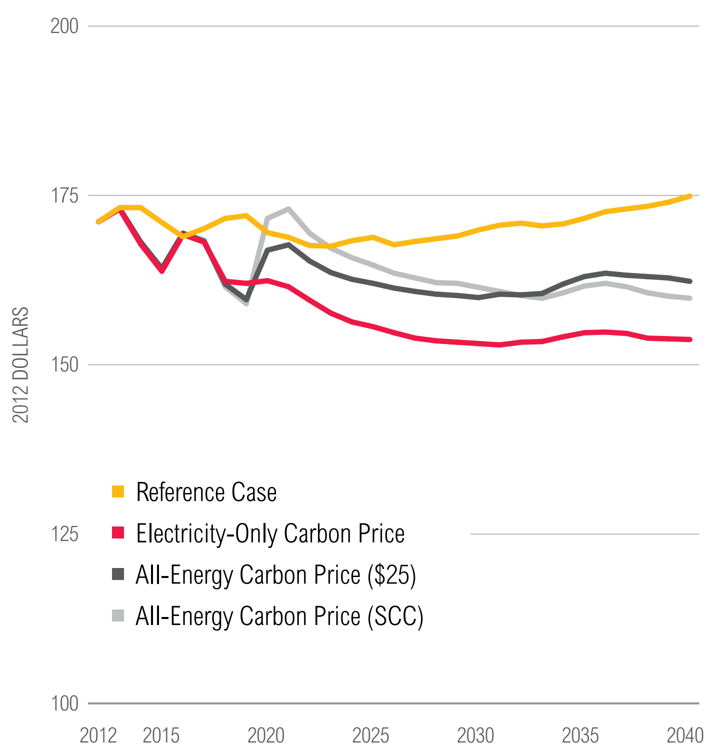
This section describes how our low-carbon pathways would affect expenditures, i.e., total spending,[c] on energy consumption in the residential, commercial, industrial, and transportation sectors. We also present total spending on electricity for residential, commercial, and industrial consumers.

Our results may be underestimating the total economic benefits from energy efficiency measures. While we were able to capture a lot of residential and commercial efficiency opportunities in our DUKE-NEMS modeling, we could not explicitly model state energy efficiency savings targets. Assessments by state public utility commissions and utilities demonstrate that state efficiency portfolios save money on a net basis, typically saving customers over $2 for every $1 invested, and in some cases up to $5.[22] As a result of these programs, EPA predicts that some states could approach zero or even negative electricity demand growth even as their economies continue to grow.[23]

Residential Sector

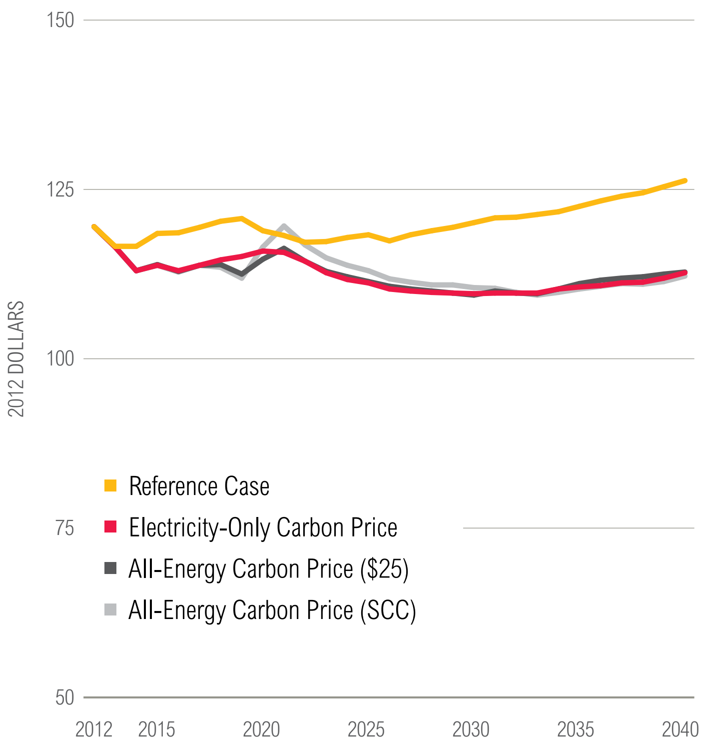
American households primarily use electricity (45 percent in 2012) and natural gas (41 percent), as well as oil and other fuels to heat and cool their homes and run their appliances. In 2012, the average household spent $171 (2012$) on energy each month. Looking forward, energy bills are projected to grow slightly between 2012 and 2040, to $175 per month (Figure 3.9). However, average household energy bills generally decrease over this same time period under our low-carbon pathways (by 0.2 to 0.4 percent per year), resulting in energy bills that are 5–10 percent lower on average than Reference Case projections in 2030 and 9–13 percent lower in 2040. Electricity is the largest source of household spending on energy, and we see similar trends in the average electricity bill under our low-carbon pathways, with monthly electricity bills reduced by 8–9 percent below our Reference Case in 2030 and 11 percent in 2040 (Figure 3.10). Both trends are due in part to the efficiency

Figure 3-9 | **Projected Average Monthly Household Energy Bill, Reference Case and Low Carbon Pathways**



[c] EIA defines "energy expenditures" as "the money directly spent by consumers to purchase energy. Expenditures equal the amount of energy used by the consumer multiplied by the price per unit paid by the consumer." See: U.S. Energy Information Administration. State Energy Data 2012: Prices and Expenditures, "Glossary." Accessible at: <http://www.eia.gov/state/seds/sep_prices/notes/pr_glossary.pdf>.

Figure 3-10 | **Projected Average Monthly Household Electricity Bill, Reference Case and Low Carbon Pathways**



programs under our low-carbon pathways that lead to improved efficiency of new and existing buildings, as well as more efficient appliances. Households also likely consumed less energy in response to higher prices. Electricity prices for households under our low-carbon pathways increased by roughly 18–21 percent compared to our Reference Case between 2030 and 2040. Under our Electricity-Only Carbon Price and All-Energy Carbon Price pathways, residential natural gas prices increased by 4–8 percent and 26–40 percent, respectively, between 2030 and 2040 compared to the Reference Case.

As a result of efficiency programs and higher energy prices, residential electricity consumption in our Electricity-Only Carbon Price pathway decreased by 23–24 percent below Reference Case levels between 2030 and 2040, and residential natural gas consumption decreased by 16–23 percent over the same time period, which more than compensated for the higher energy prices (i.e. lead to lower total electricity bills). The net effect is smaller under our All-Energy Carbon Price pathway because carbon prices impacted the price of all fossil fuels, rather than just electricity.

Commercial Sector

American businesses rely mostly on electricity (54 percent in 2012) and natural gas (32 percent), as well as oil and other fuels for heating, cooling, and running equipment. In the commercial sector, Reference Case energy expenditures are projected to increase at an average growth rate of 1 percent per year from 2012 to 2040 (Figure 3.11). Reduced energy consumption due to efficiency programs more than compensates for rising fuel and electricity prices under both pathways. However, energy bill savings are lower in the All-Energy Carbon Price pathway, where the carbon price affects heating fuel prices as well as electricity prices. In the Electricity-Only Carbon Price pathway, commercial energy spending fell to 7 percent below Reference Case levels in 2030 and 12 percent in 2040. In the All-Energy Carbon Price pathway, commercial energy spending fell 1–2 percent below Reference Case levels in 2030 and 5–7 percent in 2040.

Electricity expenditures in the Reference Case are also projected to grow at an average 1 percent per year from 2012 to 2040 (Figure 3.12). However, energy efficiency measures in

Figure 3-11 | **Projected Commercial Expenditures on Energy, Reference Case and Low Carbon Pathways**

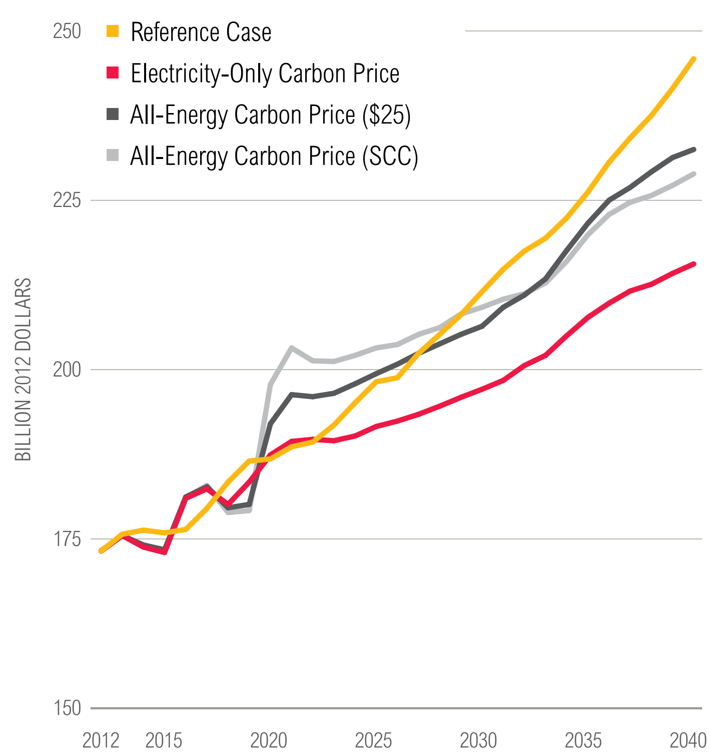


Figure 3-12 | **Projected Commercial Expenditures on Electricity, Reference Case and Low-Carbon Pathways**

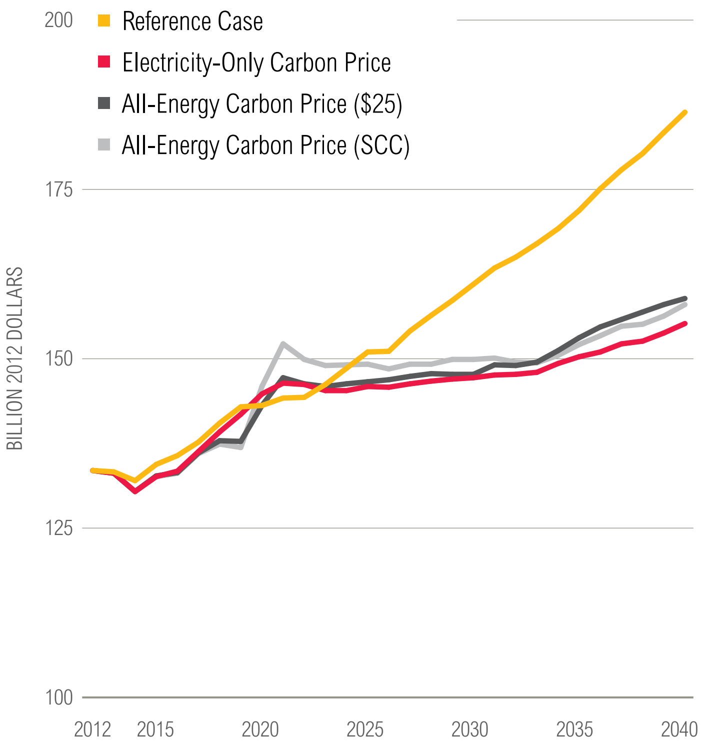
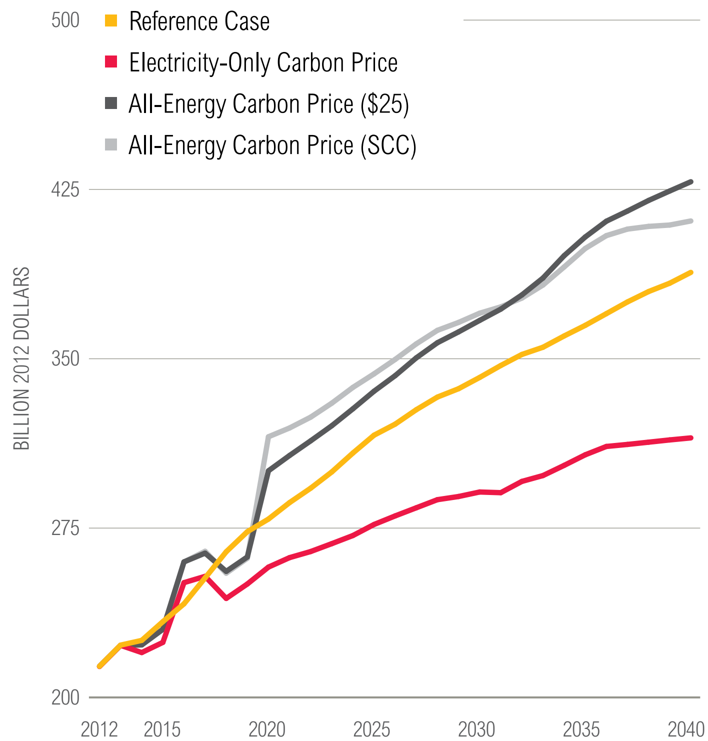


Figure 3-13 | **Projected Industrial Expenditures on Energy, Reference Case and Low Carbon Pathways**



our low-carbon pathways reduce the average annual growth rate to 0.3–0.6 over the same time period. In the Electricity-Only Carbon Price pathway, electricity expenditures fall to 9 percent below Reference Case levels in 2030 and 17 percent in 2040. In the All-Energy Carbon Price pathway, electricity expenditures fall to 7–8 percent below Reference Case levels in 2030 and 15 percent in 2040.

Industrial Sector

Expenditures on total energy use in industry were lower in our Electricity-Only Carbon Price pathway compared to Reference Case projections due to energy demand reductions and lower prices for liquid fuels and natural gas (Figure 3.13).[d] Total energy spending increased under the All-Energy Carbon Price pathway, where efficiency improvements were not enough to compensate for rising prices for electricity, liquid fuels, and natural gas.

In the industrial sector, growth rates of both electricity prices and electricity demand were higher than in the residential and commercial sectors (Figure 3.14). Efficiency in this case did not fully compensate for higher electricity prices, leading to higher overall expenditures on electricity in both pathways. However, electricity is a relatively small component of the energy mix of industry as a whole (about 14 percent, compared to about 50 percent on average in the commercial and residential sectors).

[d] DUKE-NEMS does not include non-energy and non-CO_2 gases. As a result, natural gas prices in the carbon price pathways in DUKE-NEMS do not reflect any potential impact from implementation of the standards on methane emissions from natural gas systems that we assume under all pathways.

Figure 3-14 | **Projected Industrial Expenditures on Electricity, Reference Case and Low Carbon Pathways**

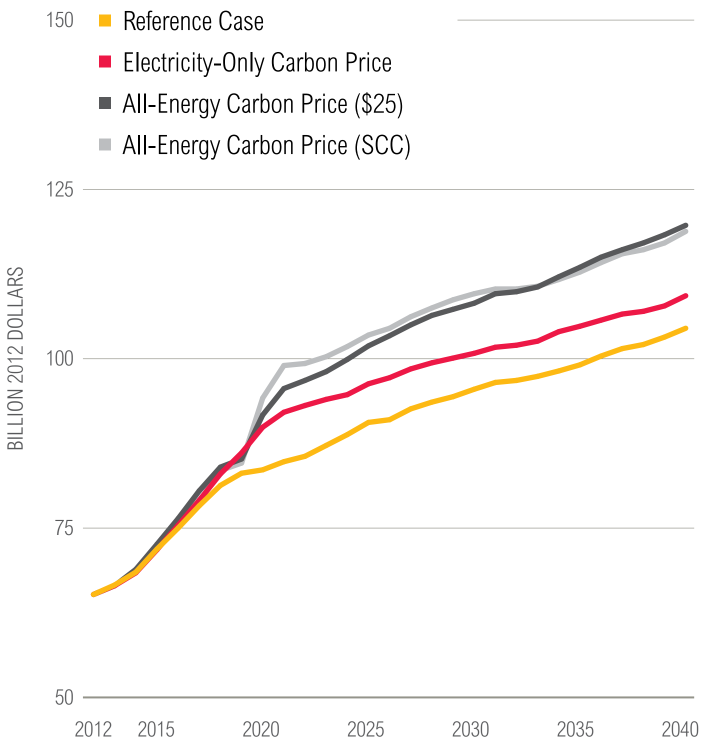
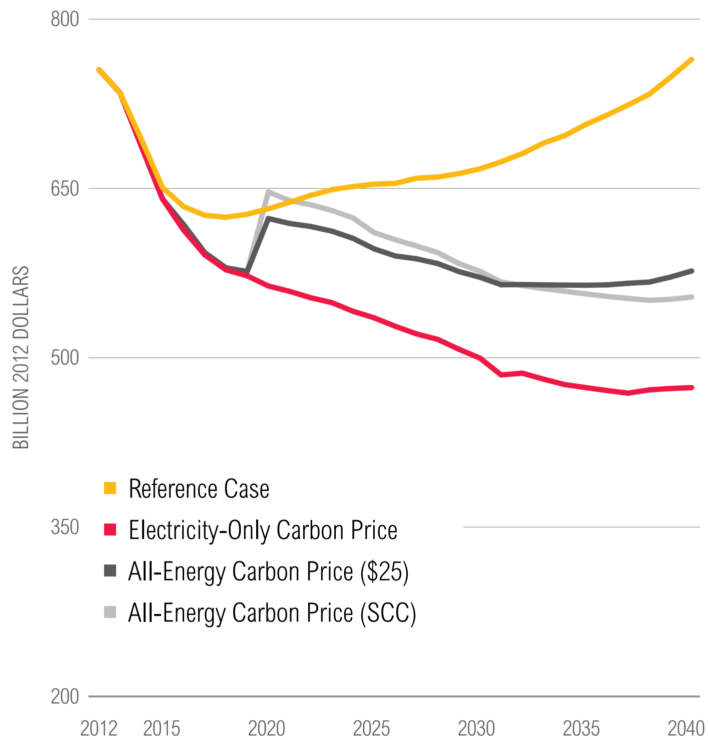


Figure 3-15 | **U.S. Transportation Expenditures on Energy: Reference Case and Low Carbon Pathways Using Carbon Price and Other Supportive Measures**



Transportation Sector

Our low-carbon pathways assume implementation of policies that increase the penetration of fuel-efficient passenger vehicles and heavy-duty trucks. As a result of more efficient vehicles and reduced travel demand for passenger vehicles, drivers and other consumers under our Electricity-Only Carbon Price pathway would spend 25 percent less on gasoline, diesel, and other fuels in 2030 compared to Reference Case projections (Figure 3.15). By 2040, total spending by drivers would decline by 38 percent below Reference Case projections. Drivers under our All-Energy Carbon Price pathway do not see quite as large decreases in spending due to higher fuel prices, with projected reductions of 14 percent below Reference Case spending in 2030 and 17–25 percent by 2040. Under all our pathways, Americans will spend slightly more on cars and light trucks compared to Reference Case projections (7–11 percent between 2030 and 2040), but will ultimately save billions of dollars on a net basis after taking into account decreased fuel consumption. We likely underestimate decreases in spending due to the limitations we encountered when attempting to model increases in vehicle efficiency and technology innovation in DUKE-NEMS. Additionally, these estimates do not consider fuel savings from more efficient aircraft and off-highway vehicles, two sectors which we modeled outside of DUKE-NEMS (see Chapter 2 and the Appendix for more information).

Potential Public Health Benefits

As previously mentioned, we were not able to include public health benefits due to the reduction of conventional air pollutants that would result from our low-carbon policy pathways or avoided climate damages in the longer term. However, other recent studies have examined these impacts for certain similar policies and they are substantial. EPA's Regulatory Impact Analysis of its proposed Clean Power Plan[24] monetized some of the co-benefits of reducing CO_2 emissions from the power sector (primarily reduced morbidity due to reduced exposure to fine particulate matter). EPA estimated that the Clean Power Plan as proposed would generate monetized health benefits of $15 billion to $40 billion (2011$, net present value basis), reflecting a range of implementation scenarios and discount rates (3 percent and 7 percent). Those health benefits far exceed the estimated compliance costs of roughly $4 billion to $8 billion. Research conducted for the Global Commission on the Economy and Climate found that the value of premature deaths from small particulate matter alone was nearly 4 percent of GDP in the United States in 2010.[25]

The Union of Concerned Scientists (UCS) also examined health benefits when it modeled deep emission reductions in the power sector (approximately 61 percent below 2005 levels in 2030) of similar magnitude to those in our Electricity-Only Carbon Price pathway (70 percent reduction in 2030).[26] UCS projected that on an annualized basis, benefits from reduced SO_2 and NO_x emissions alone would total $56 billion in 2025, growing to $69 billion in 2030 (equal to 5 and 10 times the annual compliance cost to the power sector).

Comparison With Other Studies

In general, our DUKE-NEMS modeling suggests that the macroeconomic impacts will be small in the context of the U.S. economy expanding by over 90 percent from 2012-40. This is consistent with other studies. The Energy Modeling Forum (EMF) published its most recent broad look at the impacts of deep cuts in U.S. emissions in 2009 in a paper titled *Overview of EMF 22 U.S. Transition Scenarios*.[27] In scenarios aiming for an 83 percent reduction in GHG emissions below 2005 levels by 2050, four models projected a range of declines in household consumption from 0.9-2.6 percent relative to business as usual in 2020, and a range of 3.5-4.7 percent in 2050. The EMF report did not contain projections of GDP, but household consumption is the largest component of GDP and changes in consumption are strongly correlated with changes in GDP. Some economists prefer consumption over GDP as a broad measure of economic welfare.

A more recent study, *American Energy Productivity*, by the Rhodium Group found similar economic impacts when it analyzed the energy, environmental, and economic implications of a scenario that doubles U.S. energy productivity by 2030.[28] Using NEMS, the Rhodium Group projected energy efficiency gains in buildings, industry, and transportation (but did not assume any changes in the fuel mix of any sectors). Similar to all of our pathways, their scenario included increases in CAFE standards, VMT decreases, cost-effective increases in building efficiency, and improvements in industrial energy efficiency. The authors found that total energy demand would decrease by 18 percent in 2030 relative to 2011 levels. This would lead to a 22 percent drop in CO_2 emissions below 2005 levels by 2020, and a 33 percent drop by 2030, as well as lead to economic benefits. By doubling energy productivity by 2030, the United States could gain up to $327 billion in net energy savings resulting from efficiency investments (2 percent of GDP in 2030), and an estimated net gain of 1.3 million jobs.

Our results, in combination with recent trends and other analyses, suggest that the United States has an opportunity to capture multiple economic benefits by pursuing a transition to a low-carbon economy. Well-designed policies can reduce GHG emissions, spur technological innovation, save American consumers money, and protect public health.

TRANSITIONING TO A LOW-CARBON ECONOMY

Climate change poses an enormous economic, social, and public health risk to the global community. But recent evidence indicates that averting climate change and moving toward a low-carbon future does not require sacrificing economic growth and can, in fact, present economic opportunities. To take full advantage of these opportunities and make a transition to a low-carbon future in the 2030–40 time frame, the United States will likely need to put new legislation into place, including a carbon tax, cap-and-trade system, or a national clean energy standard. It will also be important for the United States to develop a plan to maintain and even increase the nation's carbon sinks, especially since there is a lot of uncertainty surrounding these projections, and the latest data suggest that U.S. forests are likely to sequester carbon at a slower rate over the long term.[29] The country will also need to build on the steps it takes to meet its near-term climate goals by putting into place a suite of complementary measures that can stimulate investment in low-carbon technologies across the economy.

This includes promoting both public and private investment in research, development, and deployment of clean energy technology, especially in the power sector. Total federal spending on energy-related research and development fell 77 percent in inflation-adjusted dollars from 1980 to 2013 (from $8.3 billion to $1.9 billion), declining from 11 percent to 2 percent of total federal research and development spending.[30] In 2011, power companies spent only $280 million on research and development, or approximately 0.05 percent of power sector sales.[31] By comparison, company funds spent on research and development were 11 percent of sales for pharmaceuticals, 8 percent for computers and electronics, 5 percent for professional services, and 3 percent for general manufacturing.[32]

Looking beyond 2040, additional new legislation—including a price on carbon beyond what we consider here and adding other supportive measures—will likely be required to put the United States on a trajectory to reach a long-term, science-based goal of reducing emissions 80–95 percent below 2005 levels by 2050.

Three long-term recommendations can facilitate the transition to a low-carbon future:

1. **Congress should implement new legislation to drive a deep decarbonization across all sectors.**

   Long-term policy signals—in the form of a carbon tax, cap-and-trade system, or a national clean energy standard—will be needed to provide long-term certainty for investors in low-carbon technologies. This will minimize stranded assets and facilitate capture of economic opportunities in a low-carbon transition.

   New climate legislation should build on and support existing federal and state efforts to reduce GHG emissions, and should be designed to accelerate and promote market trends in clean power generation, efficiency, vehicles, and other clean energy technology. New laws could be designed to accomplish this directly (e.g., through flexible compliance with a clean energy standard) or through reinvestment of revenue from a carbon tax or cap-and-trade system. Additional measures may be needed to address emission sources, like HFCs, methane emissions from natural gas systems, landfills, and agriculture, as well as other GHG emission sources, not covered by new legislation.

2. **Federal, state, and local authorities should continue to implement supportive policies across key emission sources.**

   New climate legislation must be supported by a suite of other policies that can unlock investment in low-carbon opportunities and help develop and deploy new technologies. Below, we present policy options for sectors that offer significant emission reduction opportunities. This list is not meant to be exhaustive, but rather to indicate some promising opportunities we've identified through this analysis and our previous work, *Seeing is Believing*. In order to maximize emission reduction and minimize compliance costs, it will be important for these complementary policies to be designed and implemented in such a way that they do not conflict with carbon-pricing signals.

   Electric power

   - States and utilities should enhance access to long-term renewable energy contracts.
   - Congress should stabilize clean energy federal tax credits and eliminate inefficiency in their design.
   - Financial regulators and lenders should develop investment vehicles to reduce costs of clean energy finance.
   - States and utilities should update regulations and business models to promote a flexible power grid.

   Energy efficiency

   - Federal agencies like EPA, DOE, and others should continue to expand and enhance ongoing programs and partnerships to develop and deploy efficient technology (such as research and development, partnerships with businesses, benchmarking programs, and efficiency labeling).
   - States should adopt policies that remove natural disincentives for utilities to pursue efficiency as a resource (such as including energy efficiency in integrated resource planning, performance incentives for efficiency, and decoupling of utility profits from electricity sales).
   - Federal, state, and local governments should take steps to improve access to low-cost financing options (such as property-assessed clean energy programs, green banks, and private-public partnerships to stimulate private finance).

   Transport

   - EPA and the National Highway Traffic Safety Administration should consider strengthening fuel economy standards depending on the progress of new technologies over the coming years.

- Federal, state, and local governments should increase the number of alternative fuel stations (including electricity and hydrogen) to provide certainty for auto companies manufacturing alternative vehicles.
- Charging options should be improved by eliminating barriers to access and adopting communication standards for charging by grid operators.
- Federal and state governments should expand mandates and incentives to promote sales of alternative vehicles.
- Complementary measures should be put in place to encourage low-carbon generation of alternative fuels, like electricity and hydrogen.
- State and local policies should also aim to reinforce recent trends of slower growth in personal driving, for example, compact development patterns coupled with safe and reliable public transportation options.
- Federal agencies—including DOE, DOT, EPA, HUD and others—should encourage state and local travel demand strategies, for example through:
    - Increased funding for public transit infrastructure
    - Implementation of performance criteria for Highway Bill funding that reflects compact development and related strategies
    - Tax policies that promote infill development (such as EPA's Brownfield Tax Incentive)
    - Technical assistance

Industry

- Federal agencies should consider implementing targeted efficiency policies that could complement any new economy-wide legislation.
- Federal agencies should expand voluntary benchmarking and labeling programs, as well as minimum performance standards for industrial equipment.

HFCs

- The U.S. should continue to work toward an amendment to the Montreal Protocol, which would be much more effective than a few individual countries taking action alone.

3. **The federal government should increase investment in research, development, and deployment of clean energy technology.**

The positive technology trends we are seeing today, from taller wind turbines and cheaper solar panels to electric vehicle batteries, have benefited at some point from government support. The United States should increase its support of research, development, and deployment of technologies that will help transition the nation to a low-carbon economy in order to spur both private and public investment. This will help bring next-generation technologies to market, drive costs down through learning-by-doing, help overcome market barriers, and help the United States to remain a world leader of innovation.

ENDNOTES | CHAPTER 3

1. U.S. Energy Information Administration. Annual Energy Outlook 2014.
2. While new natural gas generation is almost always cheaper to build than new coal generation, the cost of building new wind or solar generation is now becoming cheaper than coal in many areas of the country. For example, see U.S. Energy Information Administration. 2014. “Annual Energy Outlook 2014 Early Release Overview.” Accessible at: http://www.eia.gov/forecasts/aeo/electricity_generation.cfm. Bloomberg New Energy Finance. 2014. Sustainable Energy in America Factbook. Accessible at: http://www.bcse.org/factbook/pdfs/2014%20Sustainable%20Energy%20in%20America%20Factbook.pdf>. T. Randall. 2014. “U.S. Wind Power Blows New Records. Again. And Again.” Bloomberg Sustainability (April 2014). Accessible at: http://www.bloomberg.com/news/2014-04-07/u-s-wind-power-blows-new-records-again-and-again-.html. Michigan Environmental Council. “MEC Priorities.” Accessible at: http://www.environmentalcouncil.org/priorities/article.php?x=326. N. Ankrum. “AE’s Solar Deal: ‘Game Changer.’” Austin Chronicle (July 4, 2014). Accessible at: <http://www.austinchronicle.com/news/2014-07-04/aes-solar-deal-game-changer/>.
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4. N. Bianco, K. Meek, R. Gasper, M. Obeiter, S. Forbes, and N. Aden. 2014. “Seeing is Believing: Creating a New Climate Economy in the United States.” Working Paper. Washington, DC: World Resources Institute. Accessible at: <http://www.wri.org/publication/new-climate-economy>.
5. The first price trajectory assumed that the price was consistent with a scenario from the U.S. Energy Information Administration’s Annual Energy Outlook 2014, which set a $25 per ton fee on CO_2 beginning in 2015 that escalates annually at 5 percent above inflation. (U.S. Energy Information Administration (EIA). 2014. “Annual Energy Outlook 2014 – with Projections to 2040.” Washington, DC: EIA Office of Integrated and International Energy Analysis. Accessible at: <http://www.eia.gov/forecasts/aeo/>.) The second price trajectory assumed the CO_2 price was equal to the Administration’s central estimate of the social cost of carbon. The social cost of carbon is meant to provide an estimate of the monetized damages associated with the incremental emissions of greenhouse gases. (Interagency Working Group on Social Cost of Carbon. 2010. Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866.)
6. Industry is a broad category that includes a wider range of economic activities than residential, commercial, and transport sectors. The energy and emission intensiveness of industrial activity varies among manufacturing, construction, agriculture, energy transformation, mining, and forestry subsectors.
7. U.S. Energy Information Administration, Annual Energy Outlook 2014.
8. For more information, see M. M. Hand, S. Baldwin, E. DeMeo, J. M. Reilly, T. Mai, D. Arent, G. Porro, M. Meshek, and D. Sandor (eds.). Renewable Electricity Futures Study. 4 vols. NREL/TP-6A20-52409. Golden, CO: National Renewable Energy Laboratory. Accessible at: <http://www.nrel.gov/analysis/re_futures/>.
9. D. Nelson. 2014. “Roadmap to a Low Carbon Electricity System in the U.S. and Europe.” Climate Policy Initiative. Accessible at: <http://climatepolicyinitiative.org/wp-content/uploads/2014/06/Roadmap-to-a-Low-Carbon-Electricity-System-Parts-1-and-2.pdf>.
10. Our Reference Case projects that renewable generation will account for around 18 percent of total generation in 2030. However, while the variability of renewable generation creates some challenges for grid balancing authorities, several studies have shown that grids across the country can handle up to 35 percent generation from variable renewable resources with minimal cost. For example, PJM, National Renewable Energy Laboratory (NREL) for the Western United States, and the state of Michigan have all found that 30–35 percent of electricity could be generated using variable renewable resources with minimal cost. See GE Energy Consulting. 2014. “PJM Renewable Integration Study Executive Summary Report.” Revision 05. Accessible at: http://pjm.com/~/media/committees-groups/task-forces/irtf/postings/pris-executive-summary.ashx. GE Energy. 2014. “Western Wind and Solar Integration Study.” Prepared for National Renewable Energy Laboratory. Accessible at: http://www.nrel.gov/docs/fy10osti/47434.pdf. J.D. Quackenbush and S. Bakkal. 2013. “Readying Michigan to Make Good Energy Decisions: Renewable Energy.” Michigan Public Service Commission, Licensing and Regulatory Affairs. Michigan Economic Development Corporation. Accessible at: <http://www.michigan.gov/documents/energy/renewable_final_438952_7.pdf>. For more information, see M. M. Hand, S. Baldwin, E. DeMeo, J. M. Reilly, T. Mai, D. Arent, G. Porro, M. Meshek, and D. Sandor (eds.). Renewable Electricity Futures Study. 4 vols. NREL/TP-6A20-52409. Golden, CO: National Renewable Energy Laboratory. Accessible at: <http://www.nrel.gov/analysis/re_futures/>. R. Wiser and M. Bolinger. 2013. “2013 Wind Technologies Market Report.” Lawrence Berkeley National Laboratory. Accessible at: <http://emp.lbl.gov/sites/all/files/2013_Wind_Technologies_Market_Report_Final3.pdf>.
11. For more information and examples from the pulp and paper sector, see N. Aden, J. Bradbury, and F. Tompkins. 2013. Energy Efficiency in U.S. Manufacturing: The Case of Midwest Pulp and Paper Mills. Wasington, DC: World Resources Institute. Accessible at: <http://www.wri.org/publication/energy-efficiency-us-manufacturing>.
12. U.S. Department of Energy. 2014. “Photovoltaic System Pricing Trends: Historical, Recent, and Near-Term Projections.” SunShot. Accessible at: <http://www.nrel.gov/docs/fy14osti/62558.pdf>. R. Wiser and M. Bolinger. 2013. “2013 Wind Technologies Market Report.” Lawrence Berkeley National Laboratory. Accessible at: <http://emp.lbl.gov/sites/all/files/2013_Wind_Technologies_Market_Report_Final3.pdf>.
13. U.S. Department of Energy. 2014. “Saving Energy and Money with Appliance and Equipment Standards in the United States.” Accessible at: <http://energy.gov/sites/prod/files/2014/05/f16/Saving%20Energy%20and%20Money2.pdf>. For state-specific examples of consumer savings due to efficiency programs, see N. Bianco, K. Meek, R. Gasper, M. Obeiter, S. Forbes, and N. Aden. 2014. “Seeing is Believing: Creating a New Climate Economy in the United States.” Working Paper. Washington, DC: World Resources Institute. Accessible at: <http://www.wri.org/publication/new-climate-economy>.
14. Since 2000 the United States has primarily built lower-carbon resources, constructing 249 gigawatts (GW) of gas, along with 57 GW of wind, and only 18 GW of coal. This includes new capacity built for the electric utility sector and independent power producers between 2000 and 2012. See U.S. Energy Information Administration, Form EIA-860 2012. Accessible at: <http://www.eia.gov/electricity/data/eia860/>. U.S. Energy Information Administration. 2014. Monthly Energy Review. (June). Accessible at: <http://www.eia.gov/totalenergy/data/monthly/pdf/sec12_9.pdf>.

15. N. Bianco, K. Meek, R. Gasper, M. Obeiter, S. Forbes, and N. Aden. 2014. "Seeing is Believing: Creating a New Climate Economy in the United States." Working Paper. Washington, DC: World Resources Institute. Accessible at: <http://www.wri.org/publication/new-climate-economy>.
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The Open Climate Network (OCN) brings together independent research institutes and stakeholder groups to monitor countries' progress on climate change. We seek to accelerate the transition to a low-emission, climate-resilient future by providing consistent, credible information that enhances accountability both between and within countries.

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