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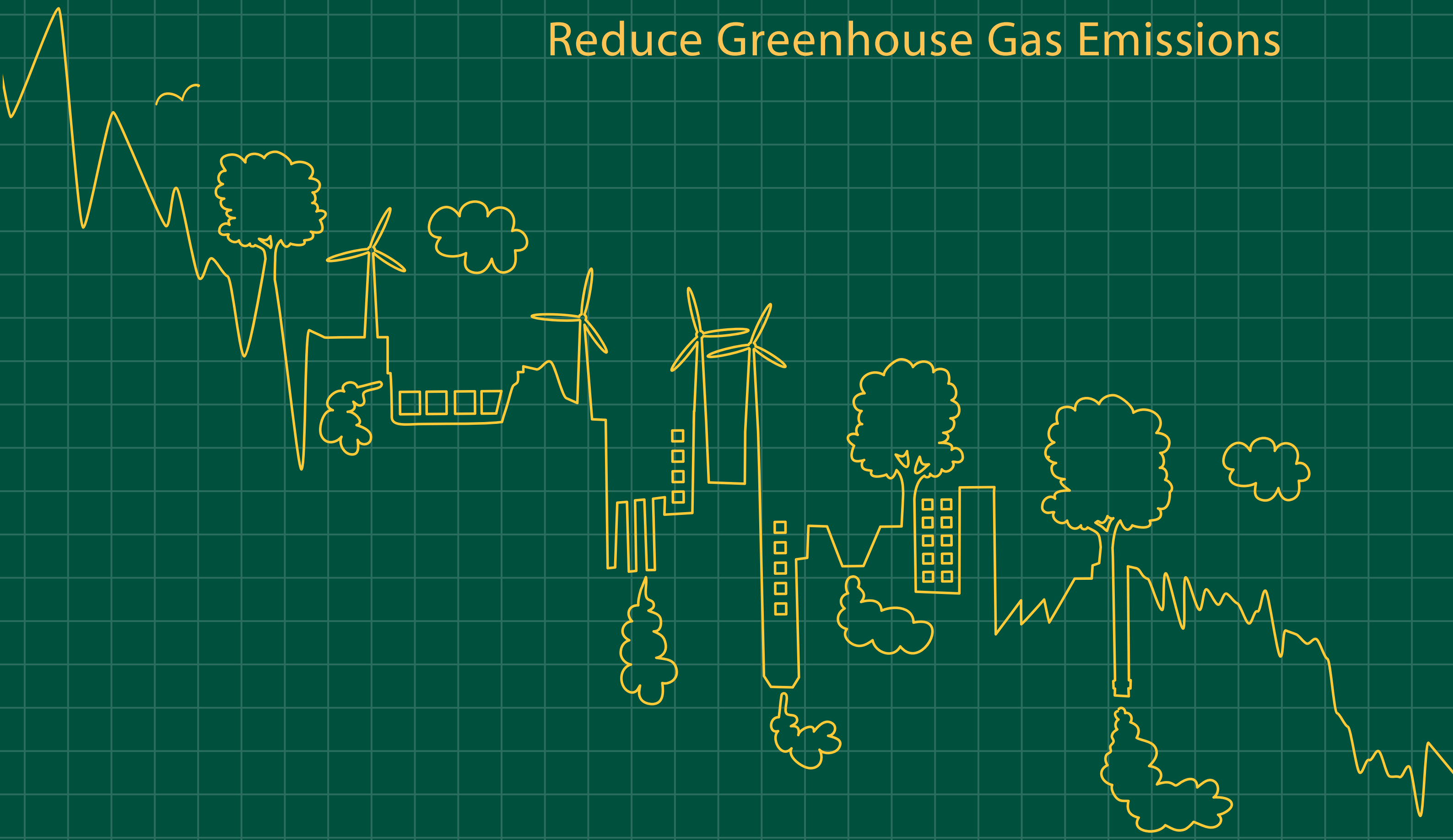
WRI REPORT

Can The U.S. Get There From Here?

Using Existing Federal Laws and State Action to Reduce Greenhouse Gas Emissions



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I. Introduction

CLIMATE CHANGE IMPACTS IN THE UNITED States are increasingly evident and come with steep economic and social costs. The frequency and intensity of extreme weather events has increased in recent years, bringing record-breaking heat, heavy precipitation, coastal flooding, severe droughts, and damaging wildfires.[1] According to the National Oceanic and Atmospheric Administration (NOAA), weather-related damages in the United States were $60 billion in 2011, and are expected to be significantly greater in 2012.[2]

The mounting costs convey an unmistakable urgency to address climate change by reducing greenhouse gas emissions (GHGs). This report examines pathways for GHG reductions in the United States through actions taken at the federal and state levels without the need for new legislation from the U.S. Congress.

This report answers a number of key questions:

- What are current U.S. GHG emissions? Without further action to reduce emissions, what are they projected to be in 2020 and 2035?
- What legal and policy tools exist under current federal law to achieve emissions reductions? What additional actions can states pursue to contribute to emissions reductions?
- Which legal and policy tools at the state and federal levels offer the greatest potential for achieving emissions reductions in the near- and mid-term?
- Can the U.S. meet its international commitment to reduce emissions 17 percent below 2005 levels by 2020 without new federal legislation?
- Can the U.S. put itself on a trajectory to meet or exceed its long-term commitment of reducing emissions by more than 80 percent below 2005 levels by 2050, without new legislation from Congress?

The answers to these questions are set out in detail in the body of this report. Two significant findings stand out. First, it is clear the U.S. is not currently on track to meet its 2020 reduction pledge, however, this target is achievable through implementation of strong new federal measures to reduce emissions using existing legal authorities. Second, the mid-century goal of reducing emissions by 80 percent or more appears unattainable using existing authorities. New legislation will eventually be needed.

BOX 1 Key Conclusions and Recommendations

1. Without new action by the U.S. Administration, greenhouse gas (GHG) emissions will increase over time. The U.S. will fail to make the deep emissions reductions needed in coming decades, and will not meet its international commitment to reduce GHG emissions by 17 percent below 2005 levels by 2020.
2. The U.S. EPA should immediately pursue “go-getter” emissions reductions from power plants and natural gas systems using its authority under the Clean Air Act. These two sectors represent two of the top opportunities for substantial GHG reductions between now and 2035.
3. The U.S. Administration should pursue hydrofluorocarbon (HFC) reductions through both the Montreal Protocol process and under its independent Clean Air Act authority. Eliminating HFCs represents the biggest opportunity for GHG emissions reductions behind power plants.
4. U.S. states should complement federal actions to reduce emissions through state energy efficiency, renewables, transportation, and other actions. States can augment federal reductions.
5. New federal legislation will eventually be needed, because even go-getter action by federal and state governments will probably fail to achieve the more than 80 percent GHG emissions reductions necessary to fend off the most deleterious impacts of climate change.

Potential reductions in the United Stated were assessed in a 2010 WRI Report entitled *Reducing Greenhouse Gas Emissions in the United States Using Existing Federal Authorities and State Action.*[3] This updated report revisits these questions, taking into account the latest GHG emissions information and recent actions taken at the federal and state levels. Since the publication of the last report, notable factors influencing U.S. GHG emissions include:

- Reduced global economic growth, including slower growth of economic output in the United States;
- Increased fuel switching from coal to natural gas in the generation of electricity; and
- Reduced demand for transportation fuel, partly as a result of higher petroleum prices, lower miles traveled, and more efficient vehicles.

These factors and others, including the issuance of new motor vehicle emissions and fuel efficiency standards for cars and trucks, will reduce greenhouse gas emissions. However, even with these factors, we project that total U.S. emissions will experience relatively modest growth over the coming decades.

BOX 2 Ambition Matters

Within the bounds of what is legally and technically possible, the single most important factor influencing emissions reductions is political and policy ambition. This analysis considers three levels of ambition:

- **Lackluster.** This is low ambition and represents the results of actions of lowest cost or least optimistic technical achievement.
- **Middle-of-the-Road.** This is mid-level ambition and represents the results of actions of moderate cost and moderately optimistic technical achievement.
- **Go-Getter.** This is the highest ambition achievable without new congressional action. It represents the results of actions of higher cost or most optimistic technical achievement.

The term “go-getter” is not meant to suggest the actions are adequate to achieve U.S. reduction targets or reductions the science suggests are necessary to ward off the worst effects of climate change.

At the 2009 Conference of the Parties of the United Nations Framework Convention on Climate Change in Copenhagen, Denmark, President Obama made a commitment to reduce U.S. greenhouse gas emissions in the range of 17 percent below 2005 levels by 2020. Despite the inability of Congress to pass comprehensive climate change legislation, the Administration has re-committed to the Copenhagen pledge and taken some steps to reduce emissions using authority under existing laws.[4] While the Administration has reaffirmed its commitment to this target, it has not yet matched that commitment with adequate action. Though significant progress has been made in some areas since our 2010 analysis, most notably with the vehicle rules, key opportunities, such as reductions from power plants, remain untapped. The fact that the U.S. remains far from the "go-getter" emissions trajectory laid out in our 2010 report reinforces the urgency for taking strong action now.

Although the U.S. emissions reduction commitment for 2020 represents an important step toward reducing GHG emissions, much greater reductions are necessary. According to the Intergovernmental Panel on Climate Change, industrialized countries need to collectively reduce emissions between 25 and 40 percent below 1990 levels by 2020 and 80 to 95 percent below 1990 levels by 2050 in order to keep global average temperatures from increasing more than 2 degrees Celsius above preindustrial levels. This report evaluates the potential for meeting the 17 percent commitment and the deeper longer-term reduction pathway necessary to avoid the worst impacts of climate change.

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1. *America's Climate Choices: Panel on Advancing the Science of Climate Change.* National Research Council, 2010.ISBN 978-0-309-14588-6. Accessible at: <http://www.nap.edu/catalog.php?record_id=12782>.
2. *Preliminary Info on 2012 U.S. Billion-Dollar Extreme Weather/ Climate Events.* National Oceanic and Atmospheric Administration. Accessible at: <http://www.ncdc.noaa.gov/news/preliminary-info-2012-us-billion-dollar-extreme-weatherclimate-events>. (Last accessed January 15, 2013)
3. Accessible at: <http://www.wri.org/publication/reducing-ghg-emissions-using-existing-federal-authorities-and-state-action>.
4. Most recently, the U.S. delegation to the Conference of the Parties of the UN Framework Convention on Climate Change in Doha, Qatar, made it clear that the 17 percent pledge is not contingent on new legislation from Congress.

Attaining even the 17 percent reduction goal will require new and ambitious action from the U.S. Administration—ambitious action that must survive court challenges. Real progress depends on numerous actions not yet taken by the U.S. Administration—especially for stationary emissions sources like power plants, natural gas systems, and industry. U.S. states may also need to take action to fill any emissions gaps left by the federal government. Achieving the necessary mid-century reductions will almost certainly require the U.S. Congress to act to achieve the needed reductions.

Section II summarizes the report's key findings, including the range of reductions that are possible and a brief description of the analytical approach. An examination of current emissions in the United States and projected emissions without new actions follows in Section III. Section IV summarizes the sector-by-sector actions the federal government might take under existing laws. Section V summarizes potential state actions. Section VI sets out summary conclusions. Two detailed appendixes set out the assumptions and methodologies for the federal and state analyses. The picture revealed is one of significant potential greenhouse gas emissions reductions, provided there is sufficient political will to take strong action.

II. Charting a Path Forward in the U.S.: Summary of Key Findings

This report identifies significant potential for GHG emissions reductions by the U.S. Administration under current laws and through state-level actions, as well as the limitations of current tools. The reductions actually achieved will depend on the level of ambition brought to the effort by the U.S. Administration, including executive agencies such as the U.S. Environmental Protection Agency. At the state level, outcomes will depend on the number of states that choose to support renewable energy, energy efficiency, and transportation measures, and to pursue policies that the federal government opts not to pursue or that go beyond the minimum stringency set by the federal government. Key findings are set out below for federal and state actions.[5]

A. FEDERAL GHG REDUCTIONS POSSIBLE WITHOUT NEW LEGISLATION

- Only with "go-getter" ambition by the U.S. Administration can the United States achieve emissions reductions using current law that meet or exceed the Copenhagen commitment to reduce global warming pollution by at least 17 percent below 2005 levels by 2020.[6] With middle-of-the-road ambition, the United States will fall well short of its 17 percent commitment, unless supplemented by go-getter actions by the states.

- Even with go-getter ambition, long-term emissions reductions fall short of the level of reductions necessary to put the United States on pace to reach its long-term reduction goal of reducing emissions 83 percent below 2005 levels by 2050. New congressional legislation is therefore necessary to achieve reductions in line with what the international scientific community agrees is necessary by mid-century in order to stabilize global average temperatures and avert the worst impacts of climate change.

- After taking action to significantly improve motor vehicle fuel efficiency, the U.S. Administration should now apply similar ambition to reducing emissions from a wider range of sources, such as existing power plants, if it is to achieve the needed reductions.

- The greatest projected emissions reduction opportunities by 2020 and beyond come from four federal policy measures. The Administration will need to pursue these opportunities if the United States is to achieve the 17 percent reduction target. Those policies are:

    - standards to reduce carbon pollution from existing power plants (48 percent of total emissions gap between business-as-usual (BAU) and 2020 target);

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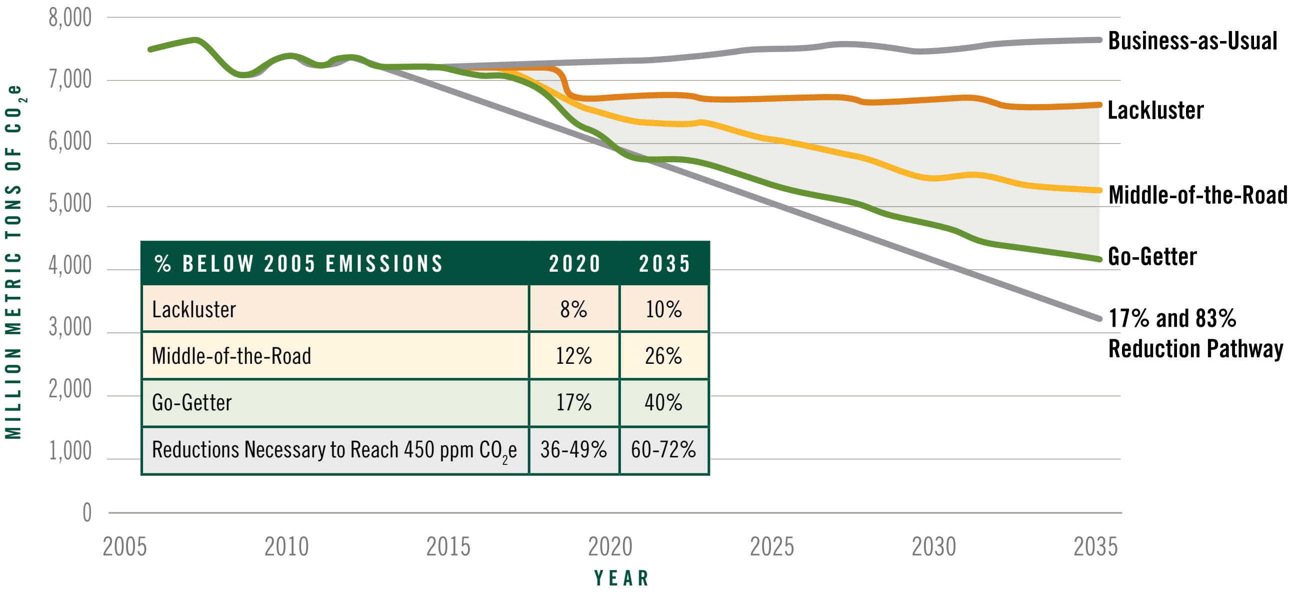
[5] For data sources and an explanation of how expected emissions trends were compiled, please consult the appendixes. For the sake of clarity and brevity, sources are not provided in this summary.

[6] The U.S. commitment in Copenhagen calls for reductions in 2020 "in the range of 17 percent [below 2005 levels], in conformity with anticipated U.S. energy and climate legislation." The U.S. submission notes that the ultimate goal of legislation pending at the time was to reduce emissions by 83 percent below 2005 levels in 2050.

FIGURE 1 Projected U.S. Emissions under Different Federal Regulatory Scenarios



% BELOW 2005 EMISSIONS	2020	2035
Lackluster	8%	10%
Middle-of-the-Road	12%	26%
Go-Getter	17%	40%
Reductions Necessary to Reach 450 ppm CO_2e	36-49%	60-72%

Note: The Intergovernmental Panel on Climate Change's (IPCC's) *Fourth Assessment Report* (2007) indicates that industrialized countries need to collectively reduce emissions between 25 and 40 percent below 1990 levels by 2020 and 80 to 95 percent below 1990 levels by 2050 to keep atmospheric concentrations of greenhouse gases from exceeding 450 parts per million of CO_2e and to keep global average temperatures from increasing more than 2 degrees Celsius above pre-industrial levels. This target does not necessarily represent any particular country's share. Due to modeling limitations, this figure depicts HFC consumption, which is generally thought to be equivalent to life-cycle emissions. For this and all other figures, we use the global warming potentials provided in IPCC's *Fourth Assessment Report*. There are some limited exceptions. See Appendix I for more details.

- requirements to phase out the use of certain hydrofluorocarbons (HFCs) (23 percent of total emissions gap between BAU and 2020 target);
- standards to reduce methane emissions from natural gas systems (11 percent of total emissions gap between BAU and 2020 target);[7] and
- actions to improve energy efficiency in the residential, commercial, and industrial sectors (8 percent of total emissions gap between BAU and 2020 target).

B. STATE ACTION COULD HELP THE U.S. MEET NEAR-TERM PLEDGE

- States can be important contributors to efforts to reduce GHG emissions. If the U.S. Administration were to pursue policies with middle-of-the-road ambition, for example, states could pick up the slack and help the United States reach its goal of reducing emissions 17 percent below 2005 levels by 2020.
- If the federal government pursues a lackluster effort, even a go-getter effort by states is unlikely to achieve the U.S. Administration's 2020 reduction goal.
- Beyond 2020, go-getter state action combined with middle-of-the-road federal action falls short of putting the United States on track to make the mid-century reduction target. This suggests that strong new federal legislative action will be needed.

C. THE STUDY IN BRIEF

This updated report represents the authors' projections of the range of greenhouse gas emissions reductions possible if federal agencies and certain states implement measures to reduce GHG emissions. The report projects the range of reductions possible under current federal law based on a review of published analyses of technical feasibility. The report characterizes three emissions scenarios based on different levels of effort by federal and state actors: "lackluster," "middle-of-the-road," and "go-getter."

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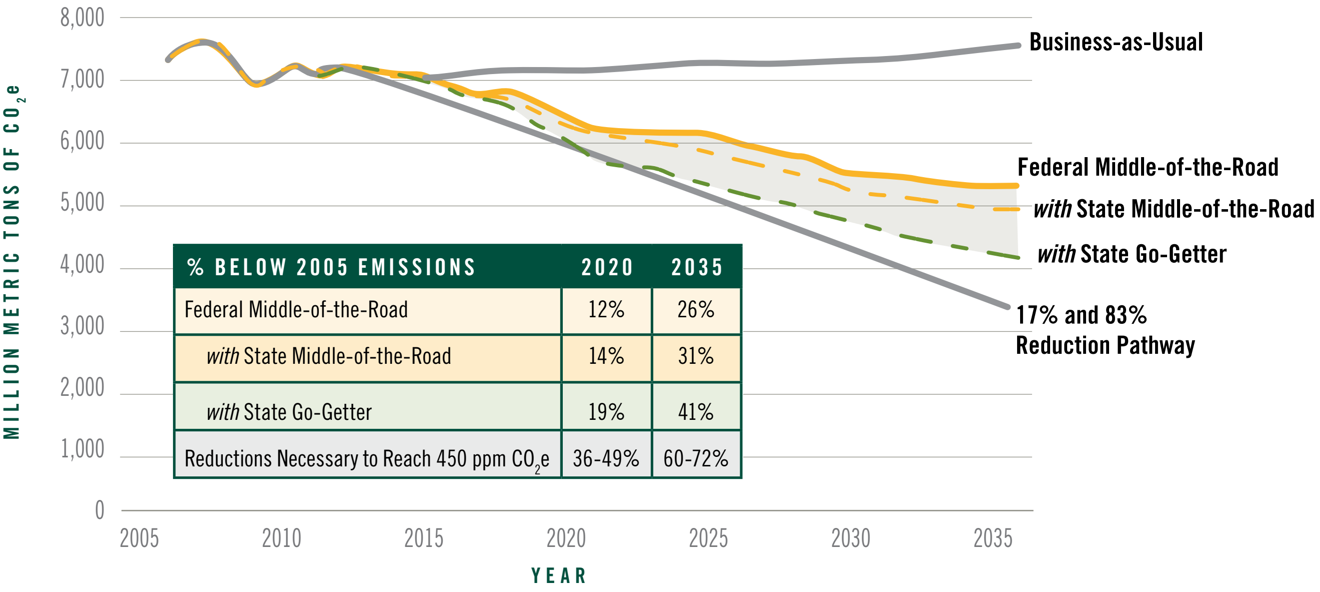
7. There is considerable uncertainty with regard to emissions for natural gas systems. The absolute magnitude of abatement opportunities is thus also uncertain. Nevertheless, our analysis suggests that there are important opportunities to reduce emissions from this sector. Those reductions are some of the lowest cost opportunities identified in this analysis.

FIGURE 2 Projected U.S Emissions with State Action Coupled with Middle-of-the-Road Federal Action



% BELOW 2005 EMISSIONS	2020	2035
Federal Middle-of-the-Road	12%	26%
with State Middle-of-the-Road	14%	31%
with State Go-Getter	19%	41%
Reductions Necessary to Reach 450 ppm CO_2e	36-49%	60-72%

Note: Due to modeling limitations, this figure depicts HFC consumption, which is generally thought to be equivalent to life-cycle emissions.

1. Analysis of Federal Actions

The analysis of federal actions is based on a legal assessment of the measures the U.S. Administration, including key federal agencies like EPA, may take under existing federal laws. The federal analysis assumes no new legislation is adopted. Technical studies were used to identify the range of reductions possible within a given sector or subsector. The legally and technically feasible range of reductions was then evaluated based on the level of ambition necessary to achieve a particular point in the range. Where available, we relied more heavily on studies that provided a consideration of the costs needed to achieve a particular outcome to provide a sense of the federal regulatory resolve necessary to achieve those reductions.

Where only a low level of ambition is necessary to achieve a particular technically and legally feasible outcome within a specific sector or subsector, the outcome was judged to be "lackluster." If a high level of ambition is necessary to achieve a particular reduction outcome deemed technically and legally possible, the effort necessary was deemed "go-getter" in our scenarios. "Middle-of-the-road" outcomes were those judged possible with moderate ambition and usually at the middle of the range deemed technically and legally possible.

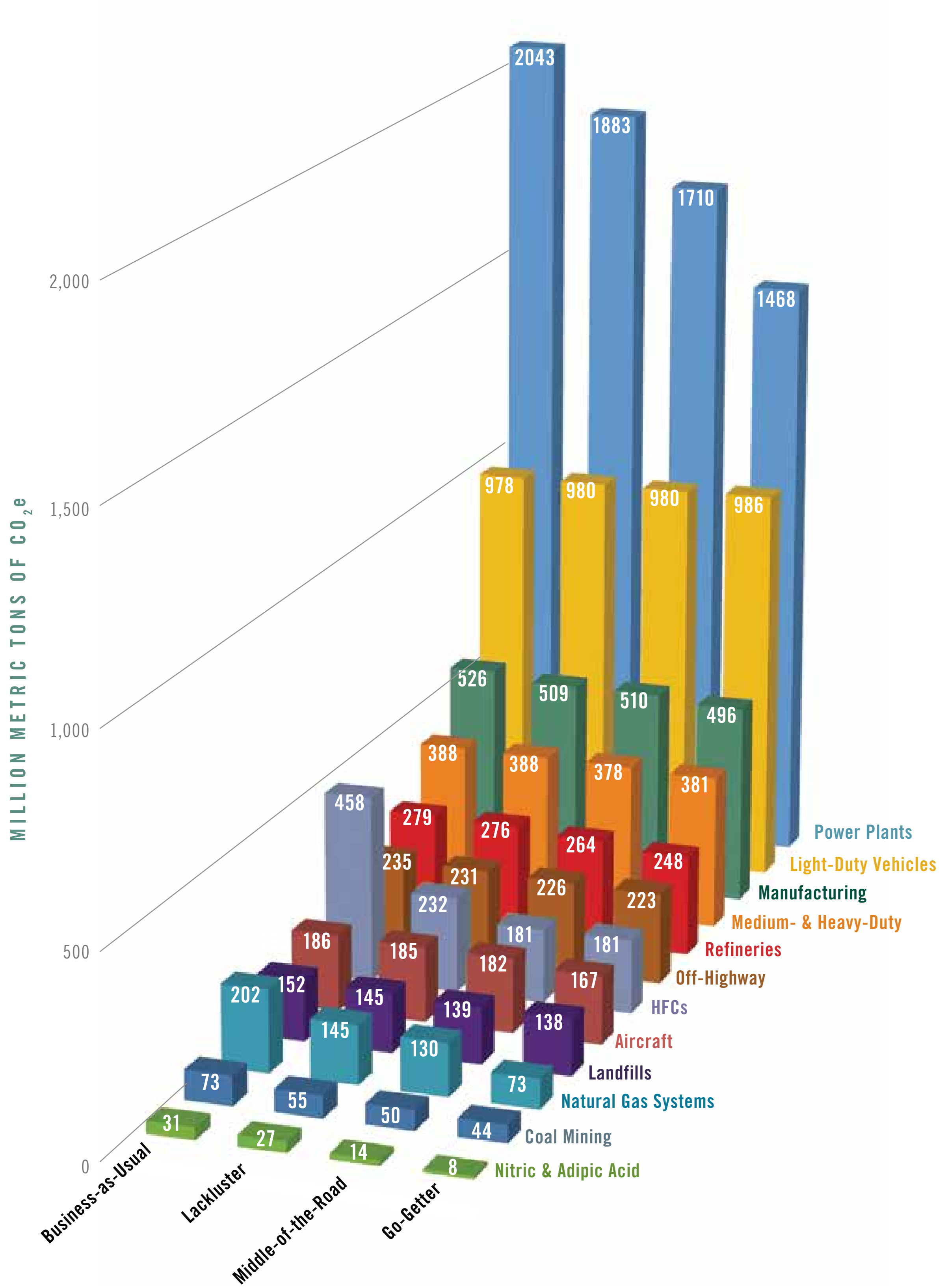
Lackluster emissions reductions from all sectors and subsectors analyzed were aggregated to determine the lackluster emissions pathway through 2035. The same approach was taken for middle-of-the-road and go-getter reductions.

2. Analysis of State Actions

The state analysis has two components: the first considers the impact of states taking action in the absence of federal action; the second considers the impact of states taking action in the presence of varying levels of federal action. In both components we examine the implication of states implementing the same types of policies modeled for the federal government, as well as complementary state-level actions in the transportation, energy efficiency, and renewables areas.

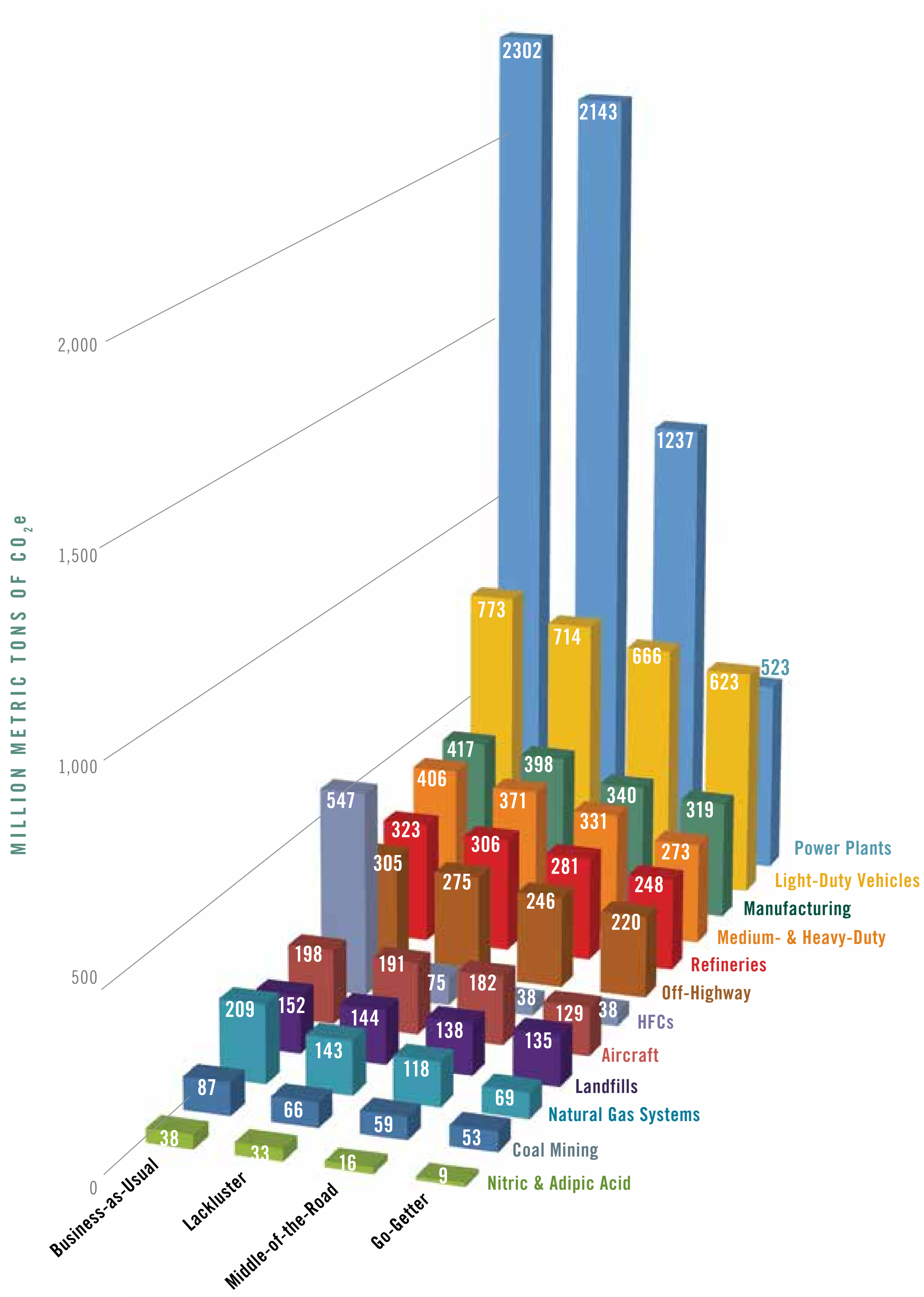
For transportation, the state scenarios consider measures to encourage low carbon fuels and reduce vehicle miles traveled. In the energy efficiency area, measures examined include increased electric end-use energy efficiency, improved building performance, and increased deployment of combined heat and power. For renewables, the analysis adds new and additional renewable energy policies across a certain number of states.

FIGURE 3 Projected U.S. Emissions in 2020 by Sector under Different Federal Regulatory Scenarios



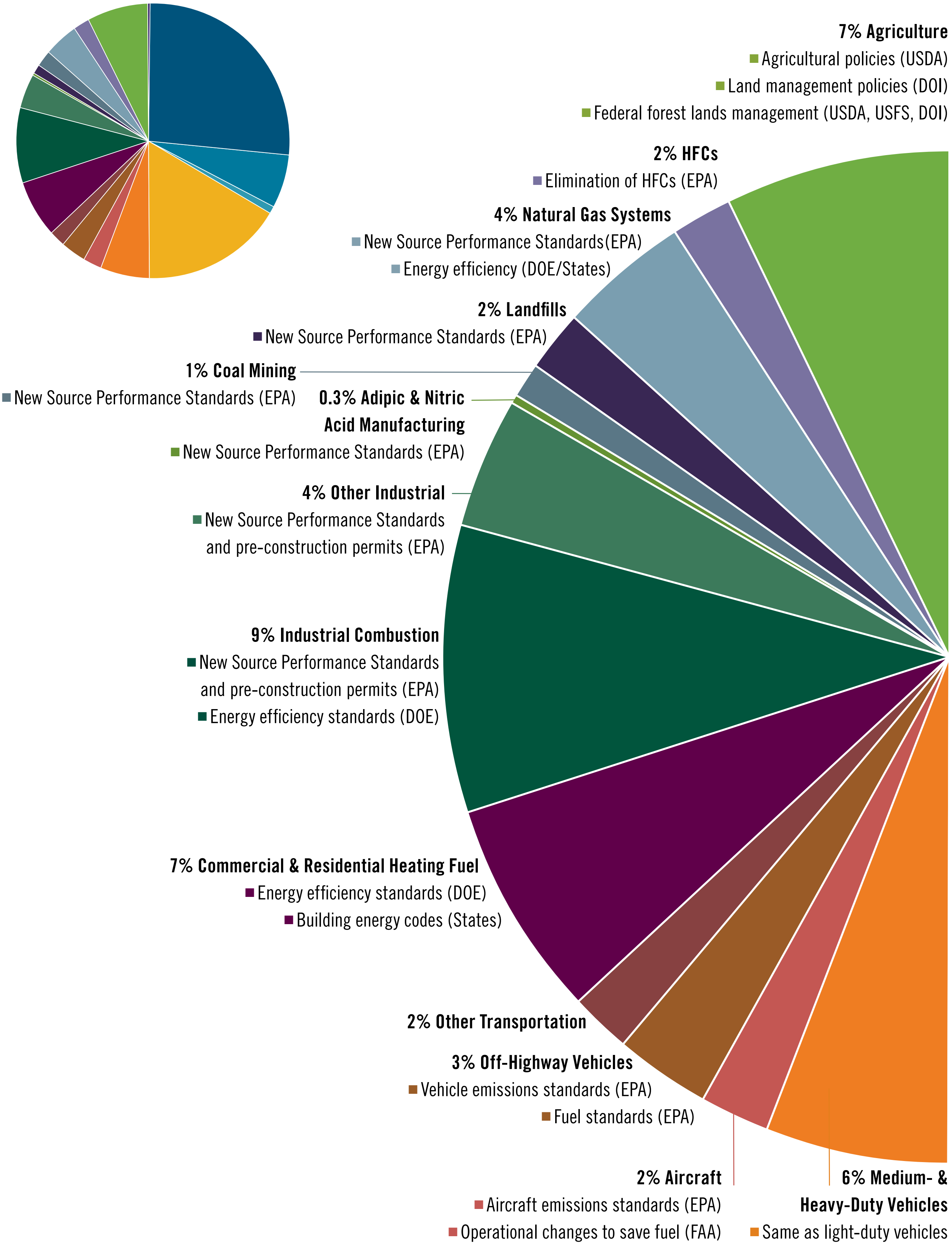
Note: Figure 3 depicts the emissions under the three federal regulatory scenarios by sector or category of sources in 2020. The bars on the left represent business-as-usual emissions. Emissions under the lackluster, middle-of-the-road, and go-getter scenarios are then shown moving from left to right of the business-as-usual emissions. Light-duty vehicle emissions initially increase in our scenarios due to assumptions about vehicle electrification and crediting rates. As shown in Figure 4, these trends reverse in later years. See Appendix I for more information. Due to modeling limitations, this figure depicts HFC consumption, which is generally thought to be equivalent to life-cycle emissions.

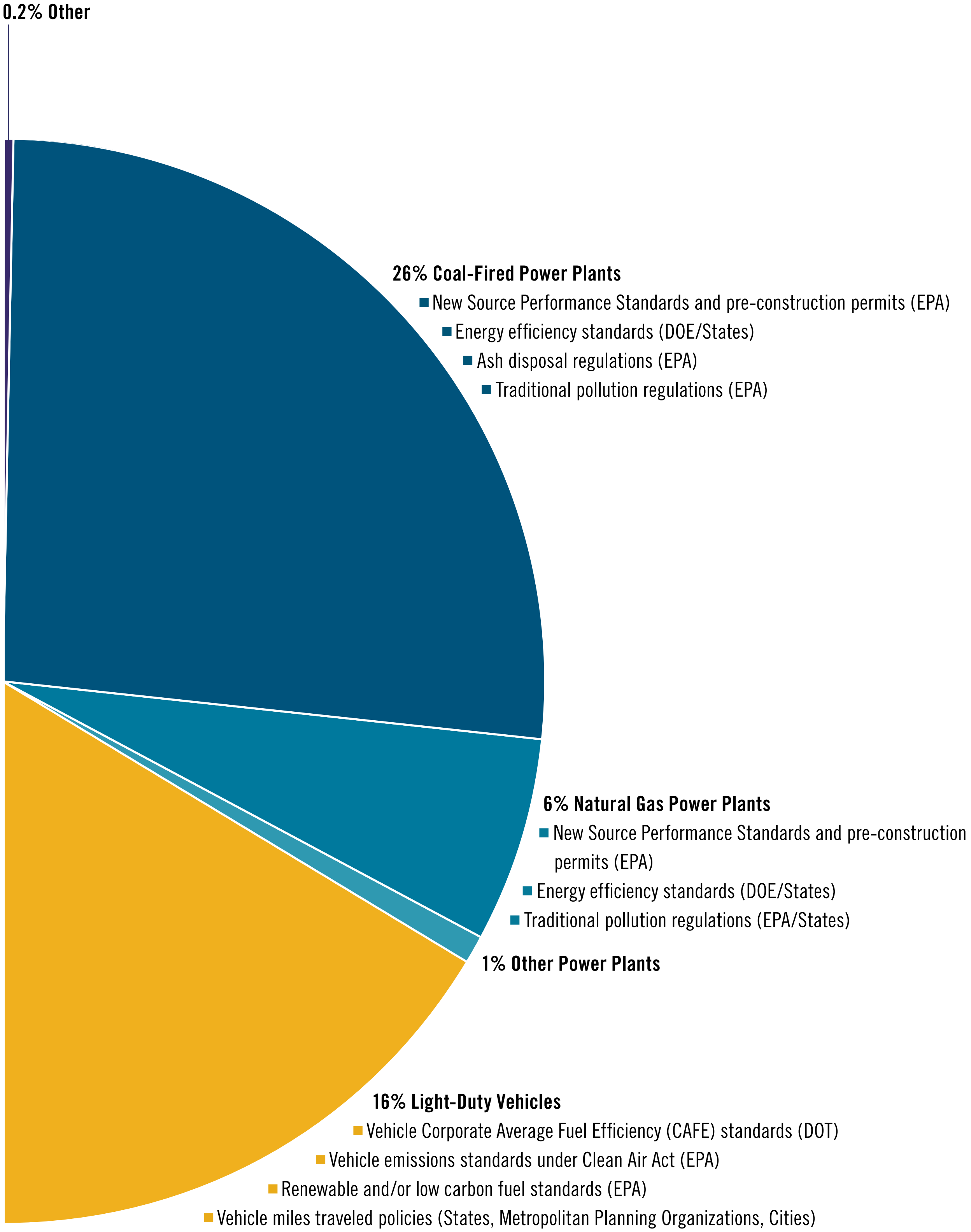
FIGURE 4 **Projected U.S. Emissions in 2035 by Sector under Different Federal Regulatory Scenarios**



Note: Figure 4 depicts the emissions under the three federal regulatory scenarios by sector or category of sources in 2035. The bars on the left represent the business-as-usual emissions. Emissions under the lackluster, middle-of-the-road, and go-getter scenarios are then shown moving from left to right of the business-as-usual emissions. Due to modeling limitations, this figure depicts HFC consumption, which is generally thought to be equivalent to life-cycle emissions.

FIGURE 5 **U.S. Greenhouse Gas Emissions by Sector and Corresponding Federal Authorities, 2010**





Source: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010.* U.S. Environmental Protection Agency, April 2012. Accessible at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>; *Clearing the Air on Shale Gas Emissions: Assessing and Reducing the Carbon Footprint of Natural Gas.* James Bradbury, Michael Obeiter, Laura Draucker, Wen Wang, and Amanda Stevens. World Resources Institute, Working Paper, forthcoming.

Unlike the federal analysis, many of the state measures modeled would require new legislation at the state level. Also unlike the federal scenario, whether state action is "lackluster", "middle-of-the-road" or "go-getter" is a function of how many states adopt the measures modeled, and in some cases the ambition of the policies pursued.

3. Analysis of Federal and State Actions Together

Given that it is unlikely that federal action will occur without state action or that state action will occur without federal action, we analyzed emissions scenarios with both federal and state action. States can be expected to continue to be active in areas of traditional state purview such as energy resource planning and energy efficiency, while also compensating for weak federal action. To capture this dynamic, we modeled varying levels of action for federal and state action.

III. The Road the U.S. is on Now: Business as Usual

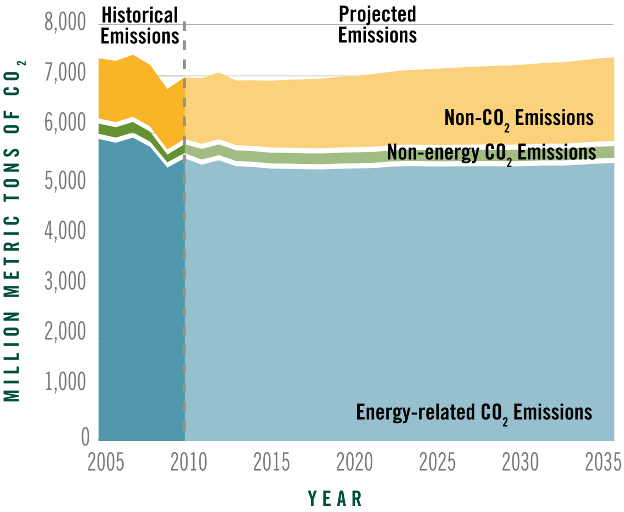
The reduction pathways presented in this report are best considered in light of current U.S. emissions, along with recent and future emissions trends. A snapshot of U.S. emissions using the most recent data available is presented below, together with a summary of U.S. emissions by key sectors and recent actions to reduce them by federal agencies.

A. CURRENT U.S. EMISSIONS

In 2010 the United States emitted almost 7 billion metric tons of carbon dioxide equivalents (CO_2e), which represents a decrease of about 6 percent below 2005 levels and a 10 percent increase over 1990 levels. Fossil-fuel combustion was responsible for nearly 80 percent of U.S. emissions, with power plants accounting for about 40 percent of combustion emissions, or one-third of the total U.S. GHG inventory, according to EPA. The second largest contributor to total GHG emissions is the transportation sector, with approximately 30 percent of U.S. emissions. Non-CO_2 emissions and CO_2 emissions that result from industrial processes (as opposed to combustion) represented approximately 22 percent of U.S. total GHG emissions.

Figure 5 shows the 2010 U.S. emissions inventory by sector and subsector, together with the corresponding federal regulatory tools available to achieve reductions in the sector.

FIGURE 6 Projected U.S. Greenhouse Gas Emissions if no New State or Federal Action is Taken



Source: See sources listed under Figures 7 and 8 below.

B. WHAT HAPPENS WITH NO NEW POLICIES? UNDERSTANDING CURRENT U.S. EMISSIONS TRENDS

Before discussing the reduction pathways projected for this report, it is important to describe the major emissions trends that are part of the business-as-usual projections. Business-as-usual emissions trends have shifted downward since the 2010 version of this report. While energy-related CO_2 emissions are projected to rise slowly but remain below 2010 levels through 2035, non-CO_2 emissions are projected to steadily increase over the same time period. The primary trends are noted here:

- **Current Energy-related Carbon Dioxide Emissions Down from 2005 Levels.** In 2011 carbon dioxide emissions from energy sources, which account for nearly 80 percent of U.S. GHG emissions, were 8.7 percent below 2005 levels. Nearly half of those reductions (48 percent) came from the power sector. The rest of the reductions came from transportation (28 percent), industry (18 percent), and buildings (6 percent).[8]

- **Future Energy-CO_2 Emissions Expected to be Relatively Flat.** Our projections suggest that if no future policy actions are taken, then energy-CO_2 emissions will remain approximately 10 percent

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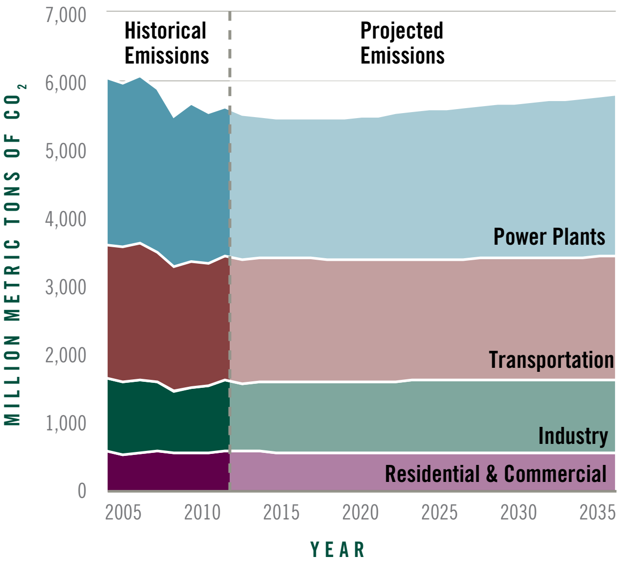
[8] *Closer than You Think: Latest U.S. CO_2 Pollution Data and Forecasts Show Target Within Reach.* NRDC Issue Brief. Dan Lashof. July 2012.

below 2005 levels in 2020, and will increase slightly through 2035 to levels that are about 8 percent below 2005 levels (Figure 7).

- Those trends are driven by a number of factors, including:
    - **Falling Energy Demand.** The economic slowdown experienced by the United States and other parts of the world over the period from 2008 to 2012 has led to decreased demand for goods and services and reduced energy consumption.[9] Over time, this trend is expected to reverse as economic growth picks up. In addition, the industrial sector was affected significantly by the recent economic turndown and saw a decrease in both production and emissions. This decline is projected to be temporary. Manufacturing output is expected to accelerate from 2010 through 2020, and emissions are projected to increase by 4 percent over this time.[10]
    - **Rise of Natural Gas and Renewables.** The power sector is shifting from coal-fired generation toward natural gas-fired and renewable generation. This trend is driven in part by increases in natural gas extraction, low natural gas prices, increasing coal prices, and new (non-GHG) regulations for the power sector. Increases in renewable generation are driven by state renewable standards, voluntary purchases of "green" energy, and decreasing renewable energy costs. However, gas prices are expected to slowly rise from current levels and demand for electricity is expected to rise 18 percent by 2035 from 2010 levels.[11]
    - **New Vehicle Rules.** The transportation sector is expected to become less carbon-intensive, due in large part to high petroleum prices and new federal GHG emissions and fuel efficiency standards covering light-, medium- and heavy-duty vehicles. These gains will be partially offset by continued increases in vehicle miles traveled.[12] Transportation emissions are projected to increase 1 percent below 2011 levels by 2035.

FIGURE 7 **Projected U.S. Energy-Related Carbon Dioxide Emissions if no New State or Federal Action is Taken**



Source: U.S. Energy Information Administration, Annual Energy Review (Years 2005-2011); U.S. Energy Information Administration, Annual Energy Outlook (Years 2012-2035)

- **Non-Energy Emissions on the Rise.** Trends for non-energy and non-CO$_2$ emissions, such as natural gas systems, refrigerants, and landfills, show a likely rise. In 2010, non-energy and non-CO$_2$ sources accounted for about 22 percent of total U.S. emissions. We project that these emissions will increase roughly 18 percent above 2005 levels by 2020 and 36 percent above 2005 levels by 2035, even after accounting for 2012 regulations that affect portions of natural gas systems and HFCs from vehicles. Those trends are driven by several factors, including:
    - **CFCs Phased Out, HFCs Phased In.** HFC emissions are increasing due to the phaseout of chlorofluorocarbons (CFCs) and other ozone-depleting substances under the Montreal Protocol, which is intended to

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9. *Annual Energy Review 2012.* Figure 1.1, Primary Energy Overview (Consumption). EIA, September 2012. Accessible at: <http://www.eia.gov/totalenergy/data/annual/pdf/aer.pdf>.
10. *Annual Energy Outlook 2012 with Projections to 2035. EIA, June 2012.* Accessible at: <http://www.eia.gov/forecasts/aeo/pdf/0383(2012).pdf>.
11. *Annual Energy Outlook 2012 with Projections to 2035.* EIA, June 2012. Accessible at: <http://www.eia.gov/forecasts/aeo/pdf/0383(2012).pdf>.
12. *Annual Energy Outlook 2012 with Projections to 2035.* EIA, June 2012.

BOX 3 Recent Federal Action 2010–12

Since the 2010 report, federal agencies have taken a number of actions that are reducing GHG emissions. The most significant actions from a GHG reduction perspective are summarized below. These are all incorporated into our new business-as-usual projections.

- **Passenger cars and light-duty trucks.** In August 2012 EPA and the National Highway Traffic Safety Administration (NHTSA) finalized new fuel economy and GHG standards for passenger cars and light-duty trucks for model years 2017–2025. These standards equate to a fleet-wide average of 54.5 mpg (101 g CO_2e/km) if they are met solely through fuel economy improvements (as opposed to reductions in HFC emissions from air conditioners). This is approximately double the fuel economy of vehicles sold in 2010. EPA estimates that the rule will save nearly 2 billion tons of CO_2e over the life of the program. This is in addition to the estimated 960 million tons of CO_2e over the life of the prior regulations for model years 2012–2016.

- **Heavy-duty vehicles.** In August 2011 EPA and NHTSA finalized the first-ever fuel efficiency and GHG emission standards for model year 2014 through 2018 medium- and heavy-duty vehicles. EPA estimates that this rule will reduce CO_2 emissions by approximately 270 million metric tons over the life of vehicles sold during the 2014–2018 model years.

- **Natural gas systems.** In April 2012 EPA finalized four regulations that will reduce emissions of volatile organic compounds, sulfur dioxide (SO_2), and air toxics from oil and natural gas systems. EPA estimates that the new standards will have the co-benefit of reducing annual methane emissions by an estimated 19–33 million metric tons of CO_2e.

- **Energy efficiency standards for new appliances.** Between 2009 and 2011, the Department of Energy established 17 new standards. According to analysis by the Appliance Standards Awareness Project and the American Council for an Energy-Efficiency Economy, these standards are expected to save 126.2 TWh in 2025 and 146.8 TWh in 2035.

- **Non-GHG regulations for power plants.** EPA has also finalized several other non-GHG-related environmental regulations for power plants, most notably those for mercury and other air toxics. Some modeling has suggested that these rules could lead to the retirement of old, inefficient, coal-fired power plants.

protect and restore the ozone layer in the upper atmosphere, and the Clean Air Act. This trend is expected to continue as the interim substitutes, HCFCs, are also phased out as they are currently being replaced with gases that have a high global warming potential.

- **With the Natural Gas Boon, More Methane Leaks.** Extraction of natural gas in the United States has increased by over 25 percent over the period of 2005 to 2011 due to rapid development of shale gas resources.[13] Increases in natural gas extraction lead to larger fugitive methane emissions from natural gas systems. Fugitive methane emissions are expected to fall significantly, however, due to 2012 EPA regulations that reduce emissions of volatile organic

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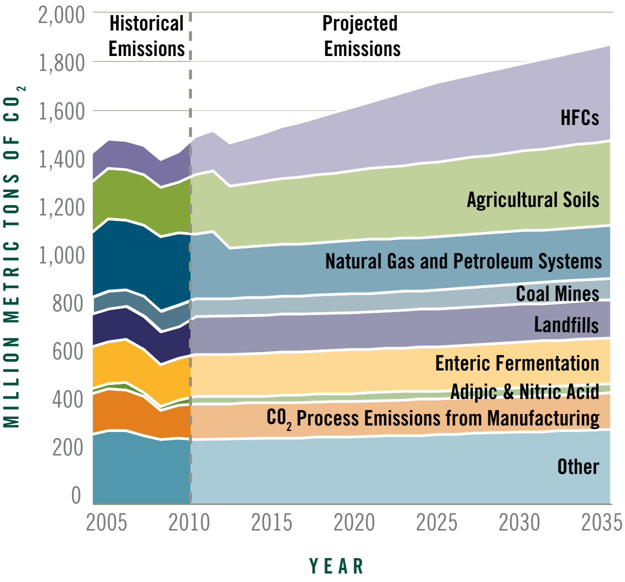
[13] *Monthly Energy Review.* Table 1.2, Primary Energy Production by Source. EIA, December 2012. Accessible at: <http://www.eia.gov/totalenergy/data/monthly/pdf/sec1_5.pdf>.

FIGURE 8 Projected U.S. Non-CO_2 and Non-Energy Emissions if no New State or Federal Action is Taken



Source: U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010 (Years 2005-2010)*; U.S. Environmental Protection Agency, *Draft Global Non-CO_2 Emissions Projections Report 1990-2030 (Non-CO_2 Years 2011-2035)*; RTI, *Applied Dynamic Analysis of the Global Economy Model (Non-energy CO_2 Years 2011-2035)*; *Clearing the Air on Shale Gas Emissions: Assessing and Reducing the Carbon Footprint of Natural Gas.* World Resources Institute. Working Paper. James Bradbury, Michael Obeiter, Laura Draucker, Wen Wang, and Amanda Stevens.

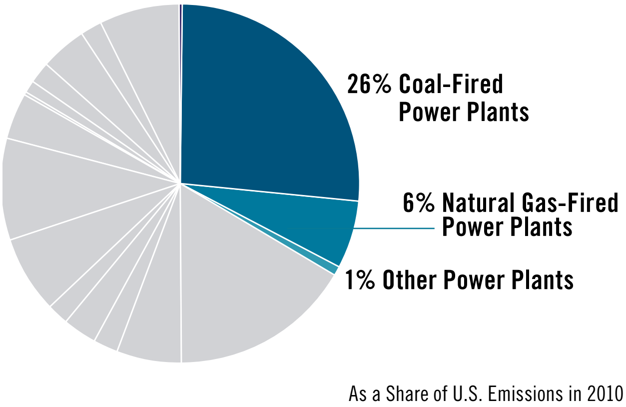
compounds, sulfur dioxide, and air toxics from natural gas systems. Actions to reduce those emissions will also reduce methane emissions (see Box 3 for more details).

IV. Understanding the Federal Reduction Pathways

A. ABOUT THE SECTOR-BY-SECTOR APPROACH

This analysis is a bottom-up assessment of the policies and regulatory tools available to the U.S. Administration, through the federal executive agencies tasked with implementing such regulations—to reduce GHG emissions. The analysis began with an examination of the makeup of U.S. emissions in 2010, followed by research and analysis into existing laws on authority to reduce emissions. We reviewed available literature to determine the range of emissions reductions technically feasible for each sector or subsector. Lastly, we considered legal authority, technical feasibility, cost and political will in constructing lackluster, middle-of-the-road, and go-getter scenarios for each sector or subsector. We briefly describe the scenarios for each sector or subsector below, beginning with the sectors that our analysis indicates offer the greatest potential for reductions. A more detailed discussion of our federal methods is provided in Appendix I.

FIGURE 9 Power Plant Emissions



B. ELECTRIC POWER

The electric sector is the largest single source of GHG emissions in the United States. In 2010 it made up 33 percent of total U.S. GHG emissions, and about 40 percent of all carbon pollution from the combustion of fossil fuels. This sector also represents the single biggest opportunity for emissions reductions using existing legal and regulatory tools.

1. Power plants

Carbon pollution from power plants can be reduced through the following federal regulatory authorities:

TABLE 1 Projecting New Source Performance Standards for Power Plants

	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Existing plants	Emissions reductions consistent with a 5 percent improvement in efficiency starting in 2018.	Aggregate emissions reductions across all electric generators equal to an 18 percent reduction in emissions in 2021 compared to 2012 emission levels, and a 33 percent reduction in 2035.	Aggregate emissions reduction across all electric generators equal to a 38 percent reduction in emissions in 2021 compared to 2012 emission levels, and a 74 percent reduction in 2035.
New plants	Standards initially consistent with EPA's proposal (1,000 pounds of CO_2 per megawatt-hour of output). Beginning in 2020, new unit performance improves to 570 pounds of CO_2 per megawatt-hour by 2030.	Standards initially consistent with the lackluster scenario. Beginning in 2028, new units achieve emissions rates equivalent to carbon capture and storage (CCS) with a 90 percent capture rate.	Standards initially consistent with the lackluster scenario. Beginning in 2020, new units achieve emissions rates equivalent to CCS with a 90 percent capture rate.

TABLE 2 Appliance and Equipment Efficiency Standards (Electric)

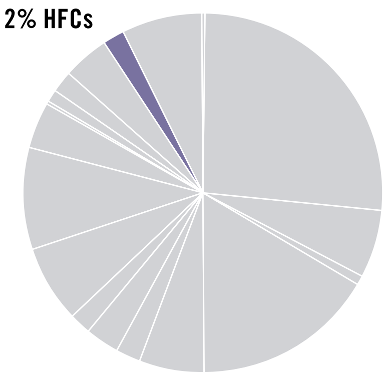
LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
192 TWh savings in 2025 from the residential and commercial sectors, plus additional savings from the industrial sector. Annual savings remain constant through 2035.	212 TWh savings in 2025 and 306 TWh savings in 2035 from the residential and commercial sectors, plus additional savings from the industrial sector.	364 TWh savings in 2025 and 525 TWh savings in 2035 from the residential and commercial sectors, plus additional savings from the industrial sector.

a. **Performance standards for new and existing sources under section 111 of the federal Clean Air Act**
Under section 111 of the Clean Air Act, EPA may prescribe emissions 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.[14] To determine the "best system of emission reduction," EPA considers technological feasibility, cost, lead time, and energy and non-air environmental impacts.[15] In the spring of 2012 EPA proposed new source performance standards (NSPS) for new power plants.

In addition, for any source category EPA regulates on the federal level, EPA must also promulgate guidelines to states to use in developing requirements for existing sources under section 111(d). In regulating existing sources, states must determine the "best system of emission reduction" for existing sources while taking into account the same factors EPA uses to set limitations for new sources, and also the remaining useful life of existing sources.[16] The form of regulations imposed on existing sources is not tightly prescribed in the statute, and EPA has previously taken the position that states could implement flexible, market-based approaches in setting standards from existing sources. Table I specifies our three scenarios for new and existing power plants under section 111.

b. **Appliance and equipment efficiency standards under Department of Energy authority**
The Department of Energy (DOE) may promulgate efficiency standards for consumer appliances and non-consumer equipment under authority already granted DOE in current law. Based on available studies, the three scenarios analyzed assume progressively greater reductions through appliance and equipment standards, ranging up to 364 TWh of annual savings from residential and commercial consumers in 2025 and 525 TWh annual savings in 2035, with additional savings from industrial consumers.

FIGURE 10 HFC Emissions



As a Share of U.S. Emissions in 2010

C. HYDROFLUOROCARBONS

Hydrofluorocarbons (HFCs), used primarily for refrigeration and air conditioning, represented only 2 percent of all U.S. global warming pollution in 2010. Despite their relatively small share of the U.S. emissions picture today, our analysis finds HFCs can provide some of the greatest reductions by 2020 and through 2035. EPA has existing authority to regulate HFC consumption under Title VI of the Clean Air Act. EPA can phase down the use of HFCs under

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14. 42 U.S.C. §§ 7411(a)(1) & 7411(b)(1)(A).). U.S. Environmental Protection Agency. "Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act." Accessible at: <http://www.gpo.gov/fdsys/pkg/FR-2009-12-15/pdf/E9-29537.pdf>.
15. 42 U.S.C. §§ 7411(a)(1).
16. 42 U.S.C. §§ 7411(d)(1)(B).

TABLE 3 Emissions Reduction Schedule for Hydrofluorocarbons

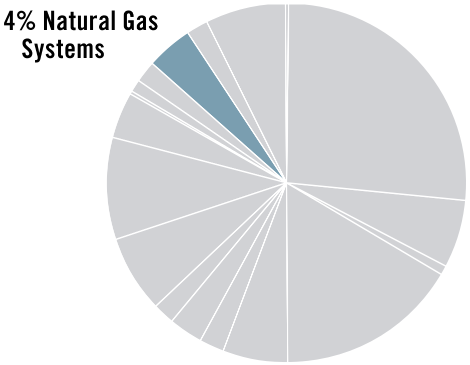
LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Consumption ramp-down occurs three years later than the schedule detailed in the joint North American Proposal.	Consumption is ramped-down in a manner consistent with the joint North American Proposal, which calls for an 85 percent reduction below 2005–2008 levels by 2033.	Consumption is ramped-down more rapidly than in the joint North American Proposal, achieving the 85 percent reduction target in 2028, five years earlier than detailed in the joint North American Proposal.

its Significant New Alternatives Program (SNAP), implementing section 612 of the Clean Air Act. The U.S. Administration has proposed an international ramp-down schedule to achieve reductions worldwide under the Montreal Protocol. Our middle-of-the-road scenarios for HFCs assume this proposed ramp-down schedule is met in the United States. The lackluster scenario assumes that the same ramp-down schedule is implemented, but on a delayed timeline, commencing in 2019 instead of 2016. Meanwhile, the go-getter scenario assumes a more ambitious reduction schedule.[17]

D. NATURAL GAS SYSTEMS

Global warming pollution from natural gas systems accounts for approximately 4 percent of U.S. emissions. Yet like HFCs, our analysis suggests that natural gas systems may be among the top emissions reduction opportunities in the near term. Similar to power plants, EPA can regulate natural gas systems by implementing emissions performance standards for methane under section 111 of the Clean Air Act for new and existing natural gas systems. They may also be able to achieve additional GHG emissions reductions

FIGURE 11 Emissions from Natural Gas Systems



As a Share of U.S. Emissions in 2010

TABLE 4 Performance Standards to Reduce Emissions from Natural Gas Systems

LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Emissions reductions of 26 percent from business-as-usual starting in 2019. Assumes implementation of plunger lift systems to reduce emissions from liquids unloading at new and existing wells, and leak monitoring and repair to reduce fugitive emissions from production, processing, and compressor stations.	Emissions reductions of 37 percent from business-as-usual starting in 2019. Assumes implementation of measures in lackluster scenario and conversion of existing high-bleed pneumatic controllers to low-bleed or no-bleed controllers to reduce emissions from production, processing, and transmission.	Emissions reductions of 67 percent from business-as-usual starting in 2019. Assumes implementation of measures in middle-of-the-road scenario, as well as 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.

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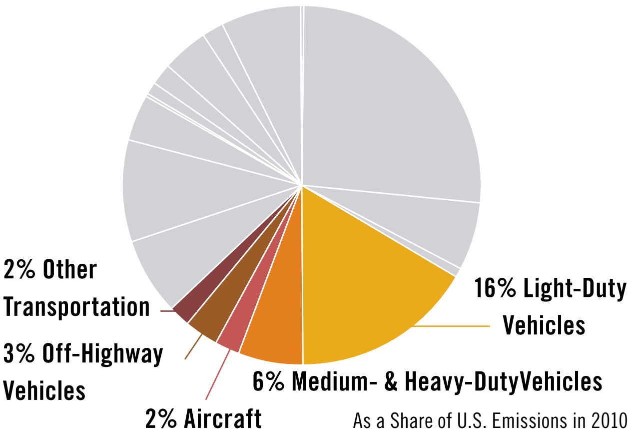
[17] Due to modeling limitations, our analysis examines changes in HFC consumption. In the United States, HFC consumption is roughly equivalent to life-cycle emissions due to low rates of capture and destruction. See Appendix I for a more detailed discussion.

by tightening standards for other air pollutants, such as volatile organic compounds and air toxics, as they recently did with respect to new equipment in the U.S. oil and gas sector. Through one or more of these regulatory paths, EPA could require equipment changes, upgrades, changes to operational practices, and inspection and leak prevention. Table 4 details the three scenarios analyzed. However, there is a great deal of uncertainty with regard to emissions for natural gas systems. This means that the absolute magnitude of abatement opportunities is uncertain. Nevertheless, our analysis identifies important opportunities to reduce emissions from this sector. Those reductions are some of the lowest cost opportunities identified in this analysis. See the appendix for a more detailed discussion of uncertainties and opportunities.

FIGURE 12 **Transportation Emissions**



E. TRANSPORT VEHICLES

Transportation is one of the largest sources of global warming pollution in the United States, accounting for 30 percent of the 2010 inventory. Improving the efficiency of motor vehicles has been a priority for the Obama Administration, which promulgated new standards to reduce emissions and raise the fuel efficiency of light-, medium- and heavy-duty vehicles. Our analysis finds that it is possible to achieve additional reductions from light-, medium-, and heavy-duty vehicles. In addition, there are opportunities to reduce emissions of global warming pollution from aircraft and off-highway vehicles.

1. Passenger vehicles

Under Title II of the Clean Air Act, EPA has the authority to regulate greenhouse gas emissions from new light-duty cars and trucks, and has done so already in two consecutive rulemakings covering vehicles sold through model year 2025. In conjunction with EPA's rulemaking, the Department of Transportation's National Highway Traffic Safety Administration (NHTSA) may promulgate corporate average fuel economy (CAFE) standards regulating the average fuel efficiency of new vehicles. Because standards have already been issued covering light-duty vehicles through model year 2025, our analysis focuses on the time period after 2025. Table 5 outlines the three scenarios, with the lackluster scenario projecting improvements at half the rate of the previous standards, middle-of-the-road projecting continuation of the same rate of improvement, and go-getter increasing the rate of improvement significantly.

2. Medium- and heavy-duty vehicles

For medium- and heavy-duty vehicles, EPA has established emissions standards and NHTSA has established fuel economy standards for model years 2014 through 2018. These standards are included in our business-as-usual emissions trajectory. Our emissions reduction scenarios pick up in model year 2020 using the same legal authority, but making different assumptions about the stringency of the next set of standards. As shown in Table 5, our lackluster scenario assumes a rate of improvement that is just half that of the current standards through 2035, middle-of-the-road projects a continuation of the current standards through 2035, and the go-getter scenario considerably increases new standards to meet the maximum level of efficiency currently thought to be technically achievable in that time frame.

3. Off-Highway engines

EPA may also regulate off-highway sources of global warming pollution under Title II of the Clean Air Act. For the lackluster, middle-of-the-road, and go-getter scenarios, respectively, the analysis assumes new standards can achieve 0.9 percent, 1.8 percent, and 2.4 percent annual improvement in the emissions rate for new equipment and engines from 2018 to 2035.

4. Aviation and aircraft

The Federal Aviation Administration (FAA) may make operational improvements in the air traffic control system that could achieve significant carbon pollution reductions over time. We draw our assumptions about operational improvements from an EPA analysis of the reductions possible and the FAA's comments on that analysis. Our scenarios, shown in Table 5, bound the range of reductions estimated by EPA and FAA.

TABLE 5 **Vehicle Emissions Standards, Efficiency Standards, and Operational Improvements**

	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Light-duty vehicles	Vehicle standards continue to improve from 2026–2035 at roughly half the rate of the 2017–2025 standards (2 percent per year). This results in a 131 grams per mile emissions standard and a 61 mpg CAFE standard in 2035.	Vehicle standards continue to improve from 2026–2035 at roughly the same rate as the 2017–2025 standards (4 percent per year). This results in a 104 gram per mile emissions standard and a 75 mpg CAFE standard in 2035.	Vehicle standards continue to improve from 2026–2035 at 6 percent annually. This results in a 81 grams per mile and a 92 mpg CAFE standard in 2035.
Medium- & heavy-duty vehicles	Standards continue to improve through 2035 at half the rate of the 2013–2018 standards by vehicle category—about a 1.3 percent annual improvement.	Standards continue to improve through 2035 at the same rate as the 2013–2018 standards by vehicle category—about a 2.6 percent annual improvement.	By 2020–2022, the medium- and heavy-duty fleet reduces its emissions rate by an average 26 percent and by 42 percent in 2023–2025 compared to 2010. Standards continue to improve annually by 1 percent through 2035.
Off-highway	From 2018 to 2035, a 0.9 percent annual improvement in the emissions rate for new equipment and engines.	From 2018 to 2035, a 1.8 percent annual improvement in the emissions rate for new equipment and engines.	From 2018 to 2035, a 2.4 percent annual improvement in the emissions rate for new equipment and engines.
Aviation	Through 2035, a 0.17 percent annual emissions reduction from operational improvements via FAA's NextGen Program.	Through 2035, a 0.4 percent annual emissions reduction from operational improvements via FAA's NextGen Program.	Through 2035, a 1.4 percent annual emissions reduction from operational improvements via FAA's NextGen Program, plus a 2.3 percent annual improvement in the performance of new aircraft and engines.

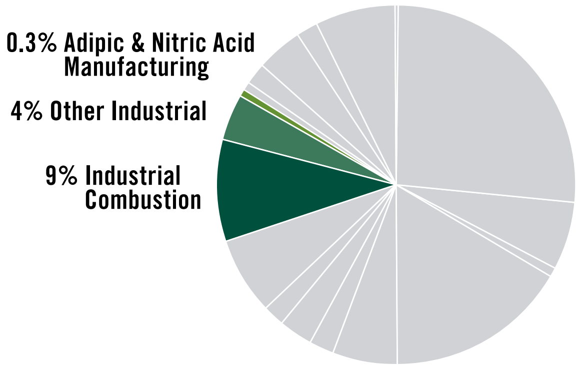
EPA has statutory authority under Title II of the Clean Air Act to promulgate standards to reduce emissions from new and existing aircraft engines. To date, EPA has never exercised that authority to require aircraft engine manufacturers to meet standards that the industry association has not previously adopted voluntarily. Nevertheless, our go-getter scenario, shown in Table 5, projects the emissions reductions that could be achieved if EPA were to pursue this regulatory course of action.

F. INDUSTRY

Emissions from industrial facilities comprised 13 percent of U.S. global warming pollution in 2010. Fossil fuel combustion at industrial facilities accounts for 9 percent of U.S. emissions, while non-combustion industrial processes account for 4 percent of emissions. When accounting for upstream, indirect CO_2 emissions from power plants, the industrial sector is responsible for 23 percent of total U.S. GHG emissions.

EPA may regulate industrial stationary sources of emissions through performance standards under section 111 of the Clean Air Act. As with power

FIGURE 13 **Industrial Emissions**



As a Share of U.S. Emissions in 2010

TABLE 6 Performance Standards to Reduce Industry Emissions

	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Fossil-fuel combustion in manufacturing and cement kilns	Emissions reductions consistent with a 10 percent improvement in combustion efficiency by boilers.	Emissions reductions consistent with harnessing all cost-effective energy efficiency across all processes and energy uses at manufacturing facilities. Emissions standards also drive reductions in process emissions from cement kilns.	Emissions reductions consistent with harnessing all cost-effective energy efficiency across the entire manufacturing facility. All new units must meet emissions rate equivalent to natural gas combustion. Emissions standards also drive reductions in process emissions from cement kilns.
Refineries	Emissions reductions consistent with a 1 percent improvement in efficiency beyond business-as-usual projections.	Emissions reductions consistent with a 5 percent improvement in efficiency beyond business-as-usual projections.	Emissions reductions consistent with a 10 percent improvement in efficiency beyond business-as-usual projections.
Nitric and adipic acid manufacturing	A 13 percent reduction in emissions.	A 56 percent reduction in emissions.	A 75 percent reduction in emissions.

plants, this is accomplished through EPA's setting of standards for new sources and issuing regulations that provide states with guidelines for covering existing sources. New source requirements typically take the form of a simple emissions rate, while regulation of existing sources can be more flexible.

1. Fossil fuel combustion in manufacturing and cement kilns

As with fossil-fuel burning power plants, reducing the GHG emissions profile of the industrial sector can be accomplished through improvements to the efficiency of boilers, fuel switching, and use of renewable energy such as biomass or geothermal, among other methods. Additional reductions are possible if regulations require a manufacturing facility to capture all cost-effective process efficiencies across an entire operation, beyond the boiler. Table 6 details the three scenarios analyzed for projecting possible reductions from the industrial sector. In addition, for the middle-of-the-road and go-getter scenarios for cement kilns, we assume emissions standards are used to drive reductions in process emissions through greater use of blended cements, and potentially carbon capture and storage, achieving reductions in process emissions of 2 percent in 2020 and 13 percent in 2035.

2. Petroleum refineries

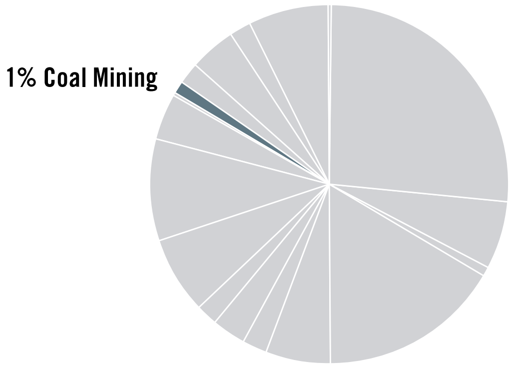
EPA's advanced notice of proposed rulemaking, *Regulating Greenhouse Gas Emissions Under the Clean Air Act,* indicated that efficiency improvements in refineries are possible in the range of 10 to 20 percent. Some efficiency improvements are included in our business-as-usual projections, however. Therefore, in order to generate conservative estimates of emissions reductions, starting in 2018 we model lackluster, middle-of-the-road, and go-getter scenarios with reductions in annual GHG emissions of 1, 5, and 10 percent reductions beyond business-as-usual projections, respectively.

3. Nitric and adipic acid manufacturing

Nitric acid is primarily used as a feedstock for synthetic fertilizer, and also used to produce adipic acid and explosives. Adipic acid is used in the production of nylon and is a flavor enhancer in foods. The production of both compounds leads to emissions of nitrous oxide, a potent greenhouse gas. Though nitric and adipic acid manufacturing makes up less than 0.5 percent of total U.S. global warming pollution, there are opportunities to achieve dramatic reductions at low cost, making it a good target for policy.

To reduce emissions from acid manufacturing, EPA can use its authority under section 111 of the Clean Air Act to set standards for new manufacturing plants and issue guidelines to states to cover existing sources. Our lackluster, middle-of-the-road and go-getter scenarios project reductions of annual GHG emissions of 13 percent, 56 percent, and 75 percent, respectively, compared to the business-as-usual projections.

FIGURE 14 Coal Mine Emissions

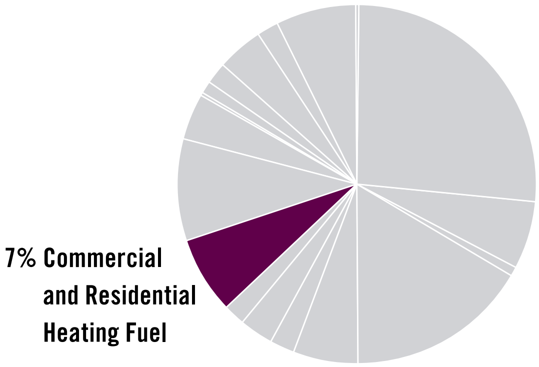


As a Share of U.S. Emissions in 2010

G. COAL MINES

Methane emissions from coal mines represented 1 percent of total U.S. global warming pollution in 2010. EPA may regulate coal mines as a source category under section 111 of the Clean Air Act. As discussed above for power plants and industry, this would entail EPA issuing performance standards for new coal mines and regulations to guide states in their regulation of existing coal mines. The statute does not prescribe the specific form of regulations applied to existing sources. For the lackluster, middle-of-the-road, and go-getter scenarios, we projected reductions from coal mines of 24 percent, 32 percent, and 39 percent, respectively, compared to business-as-usual projections.

FIGURE 15 Commercial & Residential Heating Emissions

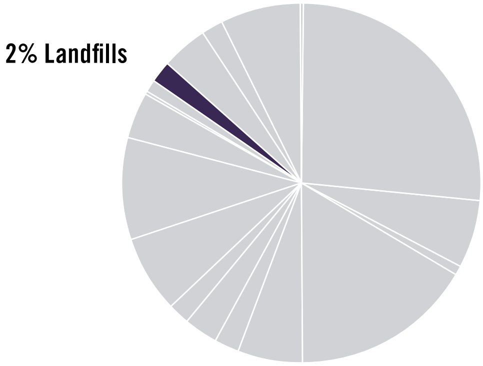


As a Share of U.S. Emissions in 2010

H. COMMERCIAL AND RESIDENTIAL HEATING

Carbon pollution from commercial and residential heating, mostly through natural gas combustion, accounted for 7 percent of U.S. emissions in 2010. This includes things such as home heating, cooking, and water heating. The most effective way to decrease emissions in this sector is to improve the building envelope—a path traditionally the province of state and local governments in the United States. However, the federal government can promulgate efficiency standards for appliances and equipment used to heat buildings. Based on our survey of the available literature, we conclude that efficiency standards implemented in 2015 could reduce natural gas demand by 126 Trillion British thermal units (TBtu) in 2025 and 235 TBtu in 2035, reducing GHG emissions by 6.7 million tons of CO_2 in 2025 and 12.5 million tons CO_2 in 2035 compared to business-as-usual projections. Due to limitations in the available literature, we project the same reductions level for all three scenarios.

FIGURE 16 Landfill Emissions



As a Share of U.S. Emissions in 2010

I. LANDFILLS

Methane emissions from landfills represented 2 percent of total U.S. global warming pollution in 2010. EPA already regulates emissions of volatile organic compounds from landfills under section 111 of the Clean Air Act. These standards provide the co-benefit of reducing methane emissions. EPA could either strengthen those standards or establish new standards for GHG emissions. The statute does not prescribe the form of regulations applied to existing sources. For the lackluster, middle-of-the-road, and go-getter scenarios, we projected reductions of 5 percent, 9 percent, and 9 percent, respectively, compared to our business-as-usual projections. The reductions we project for landfills in this report are substantially smaller than the reductions projected in the 2010 report. These differences are attributable to changes in the EPA data used in the analysis.

V. Understanding the State Reduction Pathways

Policy action to address environmental challenges frequently begins at the state level, and greenhouse gases are no exception. States were the first to push ambitious emissions standards for vehicles, adopt greenhouse gas regulations for the power sector, and establish economy-wide reduction targets. Many states already have programs that reduce emissions from transportation, improve energy efficiency, and promote renewable generation. In the state scenarios, we examine what would happen if states continue to adopt policies that reduce their GHG footprint.

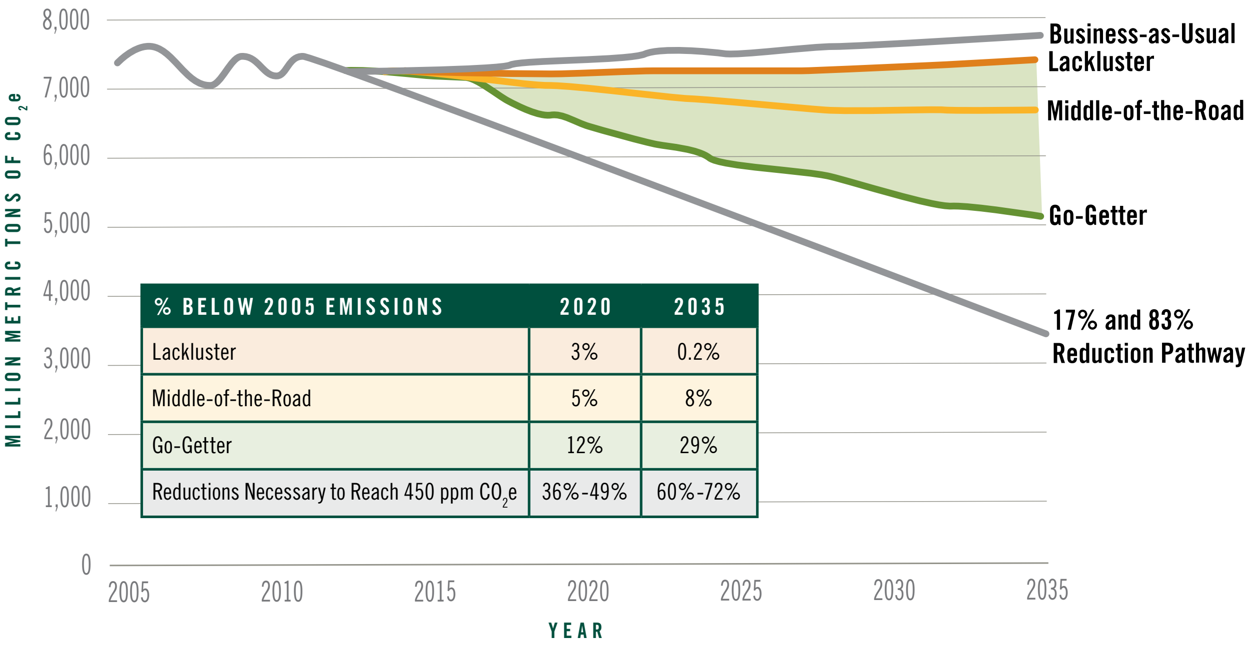
A. ABOUT THE STATES APPROACH

The state analysis takes a two-pronged approach. First, we project the potential greenhouse gas emissions reductions from transportation, end-use energy efficiency, and renewable electricity policies typically undertaken by states. Second, we consider the potential for state action in areas we also consider for the federal government, such as emissions standards for power plants and industry. This is based on the observation that the Constitution grants states broad authority to regulate their energy sources and emissions. States thus have the ability to implement many of the same policies as federal agencies.

In this analysis, the difference between lackluster and go-getter action at the state level is a function of the number and size of the states that adopt the measures modeled, and in some cases the ambition of the policies pursued. Unlike the federal analysis, in some cases state action would require new state legislation. However, we did not attempt to determine which states would require new legislation to implement the state measures and which states could implement without new legislation. A detailed discussion of our state methods is provided in Appendix II.

In addition to the direct emission reduction opportunities modeled here, state-level action can help trigger more ambitious action at the federal level. In the words of Justice Brandeis, states can serve as "laboratories of democracy," testing out approaches that provide possible models for federal action. Action at the state level can also lead to broader support for federal action, with the most ambitious states helping establish a floor for federal ambition.

FIGURE 17 **Projected U.S Emissions when States Pursue the Full Range of Policies within their Authority (No Federal Action)**



% BELOW 2005 EMISSIONS	2020	2035
Lackluster	3%	0.2%
Middle-of-the-Road	5%	8%
Go-Getter	12%	29%
Reductions Necessary to Reach 450 ppm CO_2e	36%-49%	60%-72%

Note: Due to modeling limitations, this figure depicts HFC consumption, which is generally thought to be equivalent to life-cycle emissions.

B. TRANSPORTATION

As noted above, the transport sector is responsible for about 30 percent of GHG emissions in the United States, making it the second largest emitting sector behind power plants. State and local policies have traditionally played a significant role in transportation, and as a result we project reductions that states might be able to achieve in this area, including through policies to encourage the use of lower carbon fuels and reduce vehicle miles traveled.

1. Lower Carbon Fuels

States may establish requirements for the fuels delivered in their jurisdictions to reduce the carbon profile of those fuels. To project potential reductions through state policies that reduce the life-cycle emissions of transportation fuels, we do not select specific policies in specific states. Rather, we model percent improvements in the carbon profile of fuels generally. These general improvements in the carbon profile of fuels are a proxy for what is likely to be a diverse set of measures across numerous states.

For modeling purposes, we assume that those policies further reduce the average life-cycle carbon intensity of transportation fuels by 1 percent per year between 2015 and 2035. In the lackluster scenario, we assume this annual reduction is achieved by states accounting for 15 percent of total energy consumption from U.S. transportation fuels. In the middle-of-the-road and go-getter scenarios, we assume that these policies are pursued by states accounting for 25 percent and 35 percent of total U.S. transportation fuel consumption, respectively.[18]

2. Reducing Vehicle Miles Traveled

States play a big role in designing and implementing policies that directly impact the number of vehicle miles traveled. These include smart growth strategies, such as targeting new development near public transportation, favoring infill, limiting sprawl, mixed-use development, and provision of smartly located affordable housing options. These strategies can be complemented by a variety of strategies, including improving and expanding public transportation options, bike and pedestrian pathways, car sharing, and HOV lanes, as well as through speed limit restrictions, intercity tolls, and strategies to limit driving within urban centers (e.g., parking restrictions).

In our lackluster and middle-of-the-road scenarios, we assume that states that implement policies and programs achieve VMT reductions of 0.5 percent per year beginning in 2016, leading to a 10 percent reduction below business-as-usual projections in 2035.

TABLE 7 State Transportation Measures

ACTION	POLICIES AND PROGRAMS DRIVING ACTION	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Reduce carbon content of fuels by 1 percent per year from 2015 to 2035	■ Low-carbon fuel standard ■ Clean fuel standard ■ Advanced biofuels standard ■ Infrastructure incentives	States accounting for 15 percent of transportation fuel consumption implement measures to achieve a reduction.	States accounting for 25 percent of transportation fuel consumption implement measures to achieve a reduction.	States accounting for 35 percent of transportation fuel consumption implement measures to achieve a reduction.
Vehicle miles traveled reductions of 0.5 or 1 percent per year from 2016 to 2035	■ Smart growth ■ Improved public transit ■ Pedestrian and biking infrastructure ■ Improved traffic systems operations	States accounting for 15 percent of GHG emissions from light-duty vehicles implement measures to achieve a reduction of 0.5 percent per year.	States accounting for 25 percent of GHG emissions from light-duty vehicles implement measures to achieve a reduction of 0.5 percent per year.	States accounting for 35 percent of GHG emissions from light-duty vehicles implement measures to achieve a reduction of 1 percent per year.

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[18] See Appendix II for context about what it would take to achieve the state uptake in this and the other state scenarios.

This is on the conservative end of the range found in the state programs under way. Therefore, in our go-getter scenario we assume that states reduce VMT 1 percent per year. We assume that these policies and programs are implemented by states accounting for 15, 25, and 35 percent of GHG emissions from light-duty vehicles in our lackluster, middle-of-the-road, and go-getter scenarios, respectively.

C. ENERGY EFFICIENCY

Energy efficiency measures avoid the need to use fossil fuels and save consumers money, creating significant economic benefits.[19] States are on the front lines in designing and implementing programs to enhance energy efficiency, both for end-use electricity and heating fuels. Our analysis projects the emissions reductions states may achieve implementing energy efficiency programs, building codes, and the increased penetration of combined heat and power. Each type of measure is outlined below.

1. Electricity Savings

States have been the primary drivers of end-use energy efficiency within their borders. Many states have implemented energy efficiency portfolio standards and/or other ratepayer-funded programs to fund energy efficiency investments. Other states have sought to integrate energy efficiency into the process for procuring new generation resources (e.g., in the context of long-term resource planning), so that energy efficiency can compete as a viable alternative to more traditional generating resources.

To project potential emissions reductions from increased state-level energy efficiency policies, we made different assumptions about states with and without such policies. We assume that some states with and without existing energy efficiency targets adopt policies and programs that lead to electricity savings beginning in 2015. Both the rate of savings and the number of states covered varies across the scenarios, as shown in Table 8.

2. Natural Gas Savings

A number of states have also begun to implement energy efficiency programs targeted at natural gas consumption. These programs can resemble those for electricity savings, taking the form of energy efficiency portfolio standards or system benefit charges. As with the electricity savings scenarios, we assume that some states with targets increase those targets, and that some states without targets implement those targets. The scenarios are shown in Table 8.

3. Improving Building Performance

States and municipalities are generally responsible for adopting and updating state and local building energy codes, which apply to new construction and major renovations. Responsibility for enforcing these codes is part of the states' police powers. In our lackluster scenario, we assume that states accounting for 10 percent of the energy consumed by the building sector implement more ambitious building codes. In our middle-of-the-road and go-getter scenarios, we assume that states accounting for 30 and 50 percent of the energy consumed by the building sector implement more ambitious building codes, respectively.

4. Increased Penetration of Combined Heat and Power

The U.S. electricity system is designed to accommodate large central station power plants located away from the electricity customers. Fossil-fuel generating plants operate at 30 to 60 percent efficiency, wasting significant energy in unused heat from the combustion process. Combined heat and power (CHP), or cogeneration, is a form of distributed generation located at or very near end-use customers that captures and puts waste heat to beneficial use.

States have been at the forefront in driving the spread of CHP. They have done so through a variety of policies, including standard interconnection rules, reduced standby rates, net metering policies, friendly air quality regulations (such as output-based emissions regulations), technical assistance programs, and various financial incentives.[20] In our lackluster, middle-of-the-road, and go-getter scenarios, we assume that state action results in deployment of an additional 10, 20, and 40 GW of new CHP by 2025, respectively, beyond business-as-usual projections.[21]

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19. *The Long-Term Energy Efficiency Potential: What the Evidence Suggests.* American Council for an Energy Efficient Economy, Research Report E121, January 2012. Accessible at: < http://www.aceee.org/research-report/e121>.
20. *Challenges Facing Combined Heat and Power Today: A State-by-State Assessment.* ACEEE Report Number IE111, September 2011.
21. In the go-getter scenario, we assume that state action results in deployment of 27 GW of CHP in 2020, in addition to the 13 GW built into our business-as-usual projections. Combined, they result in CHP deployment consistent with the executive order target of 40 GW of new CHP by 2020.

TABLE 8 State Energy Efficiency Measures

ACTION	POLICIES AND PROGRAMS DRIVING ACTION	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Electricity savings from states with EE targets	■ Energy efficiency resource standards ■ System benefit charge funds or other funds ■ Least-cost procurement requirements	States responsible for 75 percent of electricity consumption that have annual energy efficiency targets below 1.5 percent increase their annual target to 1.5 percent from 2015 to 2035.	States responsible for 75 percent of electricity consumption that have annual energy efficiency targets below 2 percent increase their annual targets to 2 percent from 2015 to 2035.	States responsible for 75 percent of electricity consumption that have annual energy efficiency targets below 2.5 percent increase their annual targets to 2.5 percent from 2015 to 2035.
Electricity savings from states without EE targets		States responsible for 25 percent of electricity consumption achieve electricity savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 25 percent of electricity consumption achieve electricity savings of 1.5 percent of total demand per year from 2015 to 2035.	States responsible for 50 percent of electricity consumption achieve electricity savings of 1.5 percent of total demand per year from 2015 to 2035.
Natural gas savings from states with EE targets	■ Energy efficiency resource standards ■ System benefit charge funds or other funds	States responsible for 25 percent of natural gas consumption that have energy efficiency targets below 1 percent achieve savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 50 percent of natural gas consumption that have energy efficiency targets below 1 percent achieve savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 75 percent of natural gas consumption that have energy efficiency targets below 1.5 percent achieve savings of 1.5 percent of total demand per year from 2015 to 2035.
Natural gas savings from states without EE targets		States responsible for 10 percent of natural gas consumption achieve natural gas savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 25 percent of natural gas consumption achieve natural gas savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 50 percent of natural gas consumption achieve natural gas savings of 1.5 percent of total demand per year from 2015 to 2035.
Reduced energy consumption in buildings	■ Commercial and residential building codes ■ Financial incentives	States accounting for 10 percent of the energy consumed by the building sector implement more ambitious building codes.	States accounting for 30 percent of the energy consumed by the building sector implement more ambitious building codes.	States accounting for 50 percent of the energy consumed by the building sector implement more ambitious building codes.
Increased penetration of combined heat and power	■ Standard interconnection rules ■ Reduced standby rates ■ Net metering policies ■ Output-based emissions regulations	State action results in deployment of an additional 10 GW of new CHP beyond business-as-usual projections by 2025.	State action results in deployment of an additional 20 GW of new CHP beyond business-as-usual projections by 2025.	State action results in deployment of an additional 40 GW of new CHP beyond business-as-usual projections by 2025.

TABLE 9 **State Renewable Energy Policies**

	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Increased renewables from states with renewables targets	States responsible for 25 percent of electricity consumption increase their renewable generation by 1 percent annually after the last year for which a standard is set.	States responsible for 50 percent of electricity consumption increase their renewable generation by 1 percent annually after the last year for which a standard is set.	States responsible for 75 percent of electricity consumption increase their renewable generation by 1 percent annually after the last year for which a standard is set.
Increased renewables from states without renewables targets	States responsible for 10 percent of electricity consumption increase their renewable generation 0.5 percent annually beginning in 2015.	States responsible for 25 percent of electricity consumption increase their renewable generation 0.5 percent annually beginning in 2015.	States responsible for 50 percent of electricity consumption increase their renewable generation 0.5 percent annually beginning in 2015.

D. RENEWABLE ELECTRICITY GENERATION

Similar to energy efficiency, state policies have been major drivers of renewable electricity generation in the United States. Twenty-nine states and the District of Columbia have renewable energy portfolio standards or advanced energy standards. Numerous states also support distributed or customer-sited renewables as part of their RPS or through other ratepayer-funded programs. In order to capture the reductions possible from states taking new or additional action to increase renewable generation serving their residents, we assumed that a certain number of states without renewable energy targets add 0.5 percent renewables per year beginning in 2015. For those states that already have renewables targets, we assumed they continued to add 1 percent a year to those targets after the target is achieved. Table 9 provides details on differences across the scenarios.

E. WHEN STATES TAKE A MORE EXPANSIVE TACK

States have broad authority to regulate energy sources and emissions within their boundaries. They may therefore implement many of the same policies that we ascribe to the federal government in the federal analysis. In determining what reductions states might make in the future, the analysis considers not only traditional state energy policies, but also scenarios in which states decide to approach carbon pollution more expansively. For example, the states participating in the Northeast and Mid-Atlantic Regional Greenhouse Gas Initiative (RGGI) have chosen to design and implement a multistate cap-and-trade program to reduce carbon pollution from power plants in their states. Other states could join them, or take alternative approaches to reducing carbon pollution from power plants. The most significant example of this is California, which has taken an expansive approach to reducing GHGs in its Global Warming Solutions Act of 2006 and the regulations adopted under that law.

Because it is hard to predict which other states, if any, will pursue ambitious standards for greenhouse gases, we modeled more broad-based action by assuming a portion of total national emissions within each sector would be covered by the reduction measures analyzed for the federal government in section IV above. In the lackluster, middle-of-the-road, and go-getter scenarios, we assume these measures are adopted by states accounting for 10, 25, and 50 percent of GHG emissions from a given sector, respectively.

These approaches include state action for all sectors discussed in the federal action section, except for those policies that are ill-suited for state implementation. We deemed policies that eliminate HFCs, regulate off-highway vehicles, adopt appliance and equipment efficiency standards where federal standards already exist, or regulate aviation to be ill-suited to state implementation because they are preempted by federal law.

It is important to note that we vary both the number of states taking action and the level of ambition they each pursue. In all sectors, the level of ambition pursued is the same as the ambition defined in the federal scenario described in Section IV. Therefore, in our lackluster scenario for power plants, we assume states accounting for 10 percent of GHG emissions from the power sector implement policies equivalent to the lackluster scenario for federal action. In our go-getter scenario, we assume states accounting for 50 percent of GHG emissions from the power sector implement policies equivalent to the go-getter scenario for federal action.

VI. Conclusion: Finding Our Way to a Low-Carbon Future

The enormous economic and social costs of climate disruption are increasingly evident in the United States. Yet the urgency conveyed by the mounting evidence is not yet reflected in U.S. federal and state actions or climate policies. The United States is not currently on path to meet its international pledge to reduce GHG emissions to 17 percent below 2005 levels by 2020, though it could meet this goal with go-getter action by the U.S. Administration under current laws. In order to achieve adequate mid-century reductions, it appears almost certain that the U.S. Congress will eventually have to enact new legislation aimed at getting deep reductions. Ultimately, a cooperative approach bringing together Congress, states, and the executive branch will be necessary for the United States to do its part.

States can contribute to U.S. emissions reductions, both through state-level transportation, energy efficiency, and renewables programs, as well as through new legislative efforts to initiate a wide array of other policies aimed at reducing GHGs. It appears unlikely that state actions alone will put the United States on the necessary course. However, they can help complement federal action, and can enable the United States to meet its 17 percent target if federal agencies fail to pursue go-getter-level action.

KEY RECOMMENDATIONS

- In the short term, federal agencies and the states should aggressively move forward with a "go-getter" emissions reduction scenario. This will necessitate taking action in the following key areas that present the greatest opportunities for GHG emissions reductions through 2020:
    - EPA and the states should focus on achieving significant reductions in carbon pollution from power plants and natural gas systems.
        - For power plants, EPA should finalize its proposed greenhouse gas emissions standards for new power plants and should move ahead with flexible and ambitious standards for existing power plants. States should move ahead with measures to reduce emissions from the power sector, such as increasing the use of renewable power and cogeneration and reducing electricity demand.
        - For natural gas systems, EPA and the states should propose rules that address methane as a greenhouse gas pollutant, which can result in significant reduction of methane leakage throughout the natural gas life cycle. Such rules would complement the volatile organic compound and air toxics rules established in 2012 for natural gas systems that have the co-benefit of reducing methane leakage.
    - The State Department should continue to seek reductions in hydrofluorocarbons through amendments to the Montreal Protocol. But, in the meantime, EPA should begin reducing consumption in the United States using its authority under the Clean Air Act.
    - EPA and the states should also work to improve energy efficiency in the residential, commercial, and industrial sectors.
- Over time, we will need to see reductions from all sectors, and the Administration should use its existing authorities to achieve go-getter-level reductions across the economy.
- Even with go-getter-level action, however, reductions will fall short of the long-term targets necessary to avoid the worst impacts of climate disruption. As a result, congressional action will be necessary.

BOX 4 Risks and Uncertainties

Uncertainties associated with the methods and results of this analysis include:

- **Uncertainties inherent in the models.** As with any modeling analysis of this sort, there is significant uncertainty in projecting the future. The analysis relies heavily on the Energy Information Administration's *Annual Energy Outlook 2012*, which attempts to project energy and emissions trends into the future based on a number of assumptions, including likely fuel costs, economic activity, and source turnover rates. There are also considerable uncertainties in the estimates of fugitive emissions from natural gas systems. All projections are only as good as the assumptions that go into them and the quality of the data modeled.

- **Regulatory impetus.** As the different scenarios suggest, a major uncertainty in the analysis is whether the federal administration will carry out the regulatory actions in a manner sufficient to achieve the reductions that available studies suggest are technically feasible. The lackluster, middle-of-the-road, and go-getter scenarios stand for different levels of regulatory ambition. The go-getter scenario, it should be emphasized, will require steadfast resolve on the part of the Administration and the states.

- **Congressional action.** Federal agencies depend on the U.S. Congress for their budgets. In order to carry out a series of new regulatory actions, federal agencies will require sufficient resources through the annual budget process. In addition, it should be noted that existing authorities can be curtailed through new legislation.

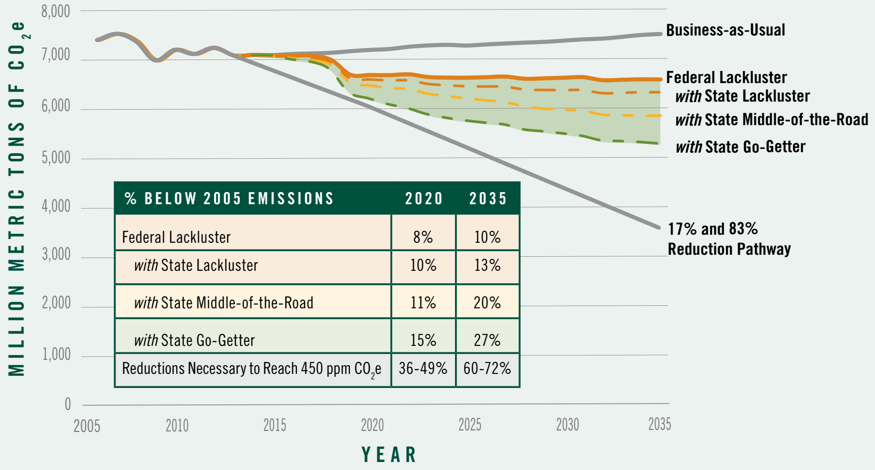
- **Legal risk.** The assumptions made in this analysis were informed by sound legal analysis and vetted with legal experts in the field. Nevertheless, when federal agencies take new actions under existing statutes, the new actions are often challenged in federal court on the grounds that the agency has exceeded the authority originally granted to it in the statute. It is impossible to predict with any precision whether the challenges will be successful.

- **Technological development.** The results modeled depend in part on the development and deployment of new technologies over time. Indeed, many of the regulatory policies are technology-based and must be revised by federal agencies as technology progresses. If technologies emerge rapidly, emissions reductions are more likely. Conversely, if technologies are slow to appear, emissions reductions will slow. This uncertainty is especially important further out into the future.

Supplemental Figures

BOX S-1 Greenhouse Gas Emissions Reductions from State Action Coupled with Lackluster Federal Action

FIGURE S-1 Projected U.S Emissions with State Action Coupled with Lackluster Federal Action



% BELOW 2005 EMISSIONS	2020	2035
Federal Lackluster	8%	10%
with State Lackluster	10%	13%
with State Middle-of-the-Road	11%	20%
with State Go-Getter	15%	27%
Reductions Necessary to Reach 450 ppm CO_2e	36-49%	60-72%

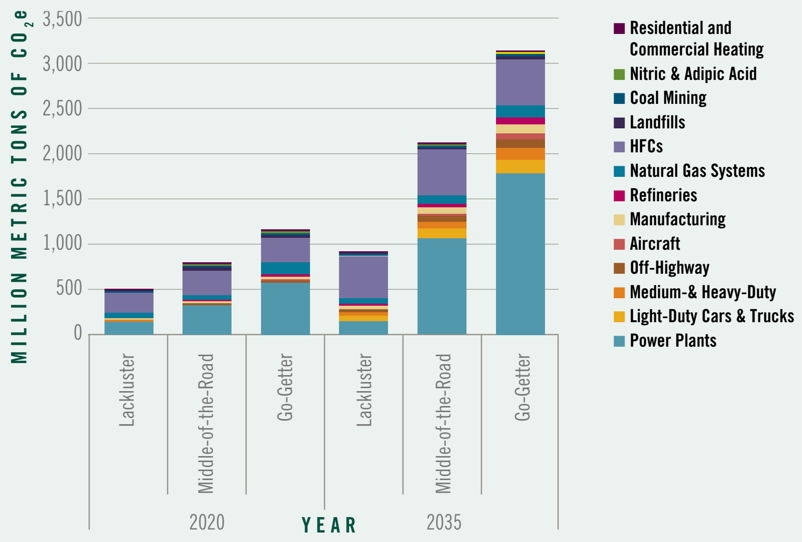
Note: Figure depicts changes in consumption of HFCs.

If the U.S. Administration pursues a lackluster effort, go-getter state action will not be sufficient to make up the emissions gap and reduce GHG emissions 17 percent below 2005 levels by 2020. However, as shown in Figure 2, the 17 percent GHG reduction goal can be achieved with a state go-getter effort along with middle-of-the-road federal action. State action with go-getter federal action is not shown, as it does not provide significant reductions above and beyond other combinations of state and federal action that were considered as a result of the way the scenarios are defined.

BOX S-2 Greenhouse Gas Emissions Reductions from Federal Action

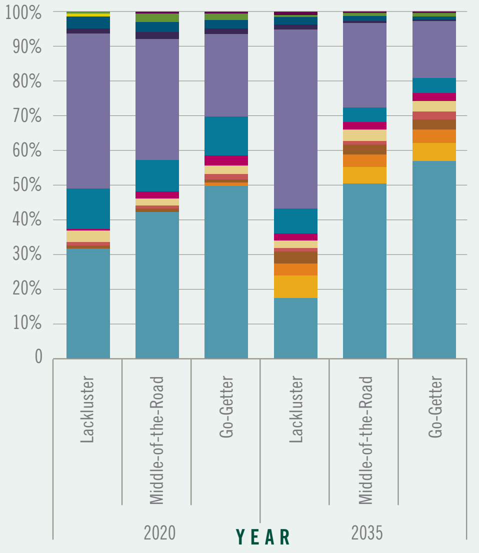
The majority of potential GHG benefits come from actions taken in the power sector, energy efficiency improvements, reducing HFC consumption, and reducing methane emissions from natural gas systems. These actions represent between 80 and 93 percent of potential GHG reductions across all scenarios in 2020 and 2035, and are necessary to achieve a 17 percent reduction below 2005 GHG emissions levels.

FIGURE S-2 Greenhouse Gas Emissions Reductions from Federal Action, in million metric tons



Note: Figure depicts changes in consumption of HFCs.

FIGURE S-3 Greenhouse Gas Emissions Reductions from Federal Action, as a percent of total reductions



Note: Figure depicts changes in consumption of HFCs.

BOX S-3 Greenhouse Gas Emissions Reductions from State Action Only

Improvements in the power sector largely drive reductions in all of the scenarios that examine the impact of state actions without any new federal actions. This is accomplished through a combination of GHG performance standards, renewable and energy efficiency standards, building codes, and policies to promote combined heat and power. In our scenarios those actions can alleviate the demand for up to 1,280 terra watt-hours of conventional sources of electricity in 2035. This is offset to a limited extent through increased vehicle electrification, which increases demand by up to 66 terra watt-hours of electricity in 2035.

States can implement many of the same types of policies as federal agencies. They can also take additional actions that increase electric efficiency, renewable electricity generation, building performance, and combined heat and power penetration.

However, states are less well-equipped to reduce HFC consumption, adopt appliance and equipment efficiency standards where federal standards already exist, and to drive reductions in GHG emissions from off-highway vehicles and aviation. As a result, under our scenarios, state action alone is insufficient to achieve the near-term and long-term GHG reduction targets.

FIGURE S-4 State Actions that Affect Electricity Supply and Demand

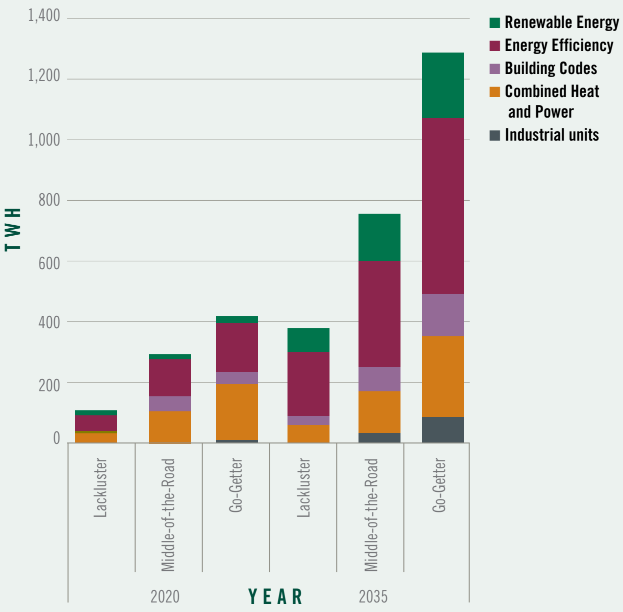


FIGURE S-5 Greenhouse Gas Emissions Reductions from State Action, in million metric tons

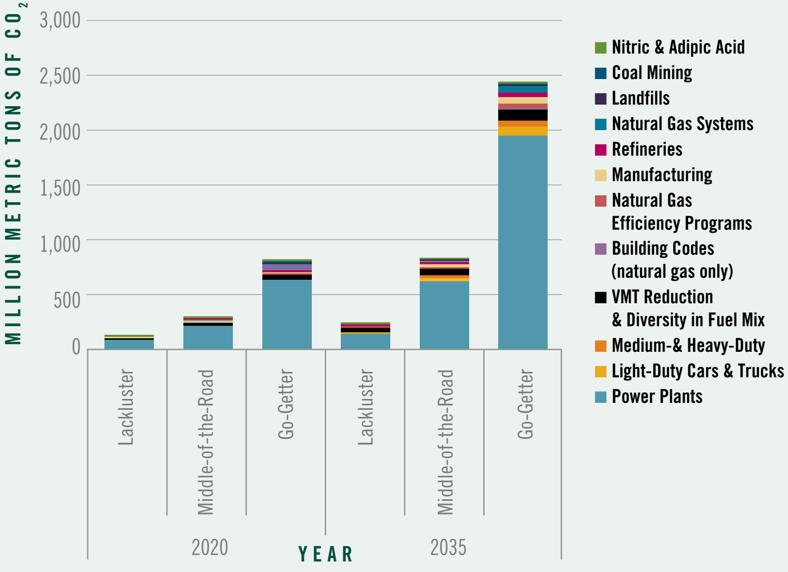
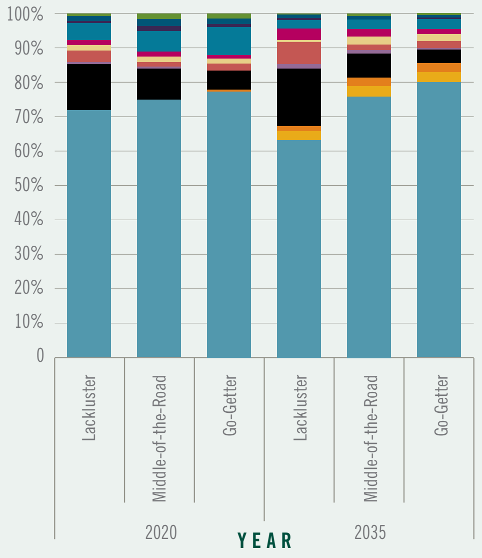


FIGURE S-6 Greenhouse Gas Emissions Reductions from State Action, as a percent of total reductions from state actions



Appendix I: Federal Methods

I. Overview

This analysis projects the range of greenhouse gas (GHG) emissions reductions achievable through regulations and policies implemented by federal agencies under existing federal law and by states under existing or new state laws. This assessment builds on our 2010 report, which began by examining the 2008 national emissions inventory to determine the major sources of emissions. The 2010 report examined both the boundaries of existing federal law and evaluated the published literature to determine the level of emissions reductions achievable from sources in key sectors and subsectors. Due to the difficulty in predicting how federal agencies will act within the bounds of their legal authority, we continue the approach from our 2010 report, which defines three scenarios meant to capture a range of potential reductions in each sector or subsector. Reflecting the available literature, we have defined the scenarios to span a range of different costs, technological assumptions, and types of policies.

Our literature survey examined government and independent reports. We focused on those analyses whose scale was translatable to our model inputs. For example, we focused on studies of entire industrial categories (such as pulp and paper) and not process components (such as steam cracking). We also relied more heavily on studies that provided some assessment of cost in order to provide a sense of the federal regulatory resolve necessary to achieve those reductions. Where a federal agency has provided preliminary estimates of the reductions achievable through regulatory activity, we have attempted to incorporate those estimates into one of the scenarios.

This analysis contains bottom-up analyses of both federal and state action, assessing the total emissions reductions achievable through regulatory actions and policies sector by sector. This appendix provides a summary of the federal analysis. Appendix II provides details on the state analysis.

We calculated the emissions reductions associated with each scenario using an Excel-based model that utilizes publicly available detailed emissions reports, as well as outputs from a publicly available off-the-shelf transportation model (Argonne National Laboratory's VISION model). 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. We account for changes in electric demand through an electric demand module that selectively turned units on and off in a predetermined manner (see Section III.C for more information). 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.

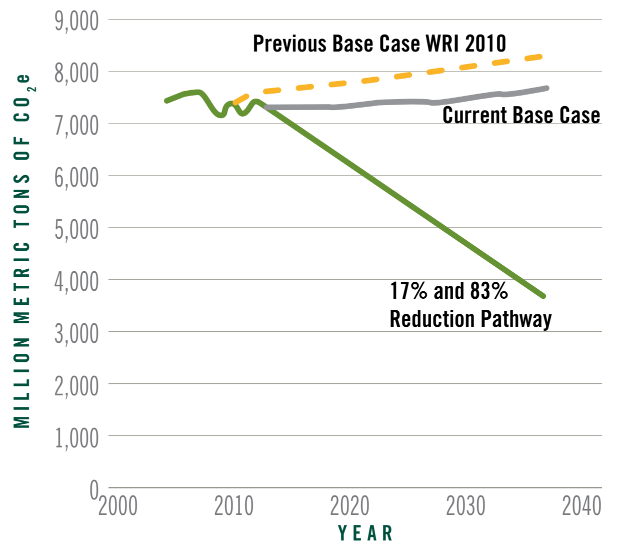
In the pages that follow we describe the base case, modeling assumptions, and scenarios.

II. Base Case

The base case, or "business-as-usual" case, was developed using several different projections. Carbon dioxide (CO_2) emissions from fossil fuel combustion come from the U.S. Energy Information's (EIA's) *Annual Energy Outlook 2012* (AEO2012). Non-CO_2 emissions projections were obtained from EPA's *Draft Global Non-*CO_2 Emissions Projections Report: 1990–2030.[1] Non-energy CO_2 emissions projections were obtained from EPA's ADAGE model reference scenario, as developed for their analysis of HR 2454, the American Climate and Energy Security Act of 2009.[2] The base case emissions projections for natural gas systems come from analysis conducted for *Clearing the Air on Shale Gas Emissions: Assessing and Reducing the Carbon Footprint of Natural Gas*, a forthcoming WRI working paper that examines emissions and abatement opportunities for natural gas systems.[3]

Base case emissions in this report are lower than the base case projections in our 2010 report *Reducing Greenhouse Gas Emissions in the United States Using Existing Federal Authorities and State Action* (see Figure A-1.1). This is largely due to reductions in CO_2 emissions from fossil fuel combustion, driven by a variety of factors, including lower natural gas prices, less optimistic economic projections, and new standards for power plants and light-, medium-, and heavy-duty vehicles. In addition, new standards for natural gas systems have reduced projections of methane emissions.

FIGURE A-1.1 Comparison of Base Case Emissions Projections (2010 v. 2013 Analysis)



A. EIA AEO2012

The AEO is updated annually and is one of the leading sources of economy-wide energy emissions projections through 2035. Data outputs are disaggregated, and more detailed data tables are publicly available upon request, making this an attractive starting point. The 2035 timeline provides enough time to see noticeable impacts from unit turnover. Longer time frames would allow for greater unit turnover, but were not desirable due to the considerable uncertainty in predicting technological availability in future time frames. AEO2012 incorporates updated economic projections, which include a slightly lower growth in GDP through 2035 compared to previous projections. Increases in the natural gas supply, along with lower natural gas prices, are also incorporated into this AEO. It also incorporates several new rules and regulations not included in AEO2009, which was used in our previous report. These include (in a side case) standards for light-, medium-, and heavy-duty vehicles, as well as several regulations affecting the power sector. AEO2012 is described in greater detail in the sections that follow.

B. EPA'S DRAFT GLOBAL NON-CO_2 EMISSIONS PROJECTIONS REPORT: 1990–2030

The AEO does not generally include non-energy and non-CO_2 emissions. Non-CO_2 emission projections for all sources, except for natural gas and petroleum systems and HFC consumption, came from EPA's *Draft Global Non-CO_2 Emissions Projections Report: 1990–2030.*[4] In this report, EPA developed country-specific emissions projections using assumptions about economic activity, technology development, emissions reduction programs and agreements, and other factors. Results were provided in five-year intervals. We estimated emissions between the five-year intervals by applying a linear rate of change. Emissions for 2030 through 2035 were estimated by applying the same rate of change observed from 2025 to 2030.

C. ADAGE

Non-energy CO_2 emissions projections come from the Applied Dynamic Analysis of the Global Economy (ADAGE) reference scenario of EPA's modeling of the American Clean Energy and Security Act of 2009 (ACES).[5] ADAGE is a dynamic computable general equilibrium model run by RTI International.[6] ADAGE projects emissions in five-year intervals from 2010 to 2050. To estimate emissions between those intervals, we applied a linear rate of change between intervals. EPA does not run the ADAGE model annually, but does so in response to congressional requests. For purposes of this report, we are using the most recent publically available results.

D. ADDITIONAL DATA SOURCES

Base case emissions projections for natural gas systems come from analysis conducted for *Clearing the Air on Shale Gas Emissions*, a forthcoming WRI working paper that examines emissions and abatement opportunities for natural gas systems.[7] Their base case projections were developed using EPA's *Inventory of Greenhouse Gas Emissions and Sinks 2012*[8], shale gas production projections from AEO2012, and emissions factors from *Life Cycle Carbon Footprint of Shale Gas: Review of Evidence and Implications.*[9] This report only considers abatement opportunities from natural gas systems. However, because EPA's *Draft Global Non-CO_2 Emissions Projections Report: 1990-2030* lumped natural gas systems with petroleum systems, we also developed projections for petroleum systems using historical emissions[10] and historical production data,[11] as well as projected production data.[12]

Base case projections for HFC consumption come from EPA's *Benefits of Addressing HFCs under the Montreal Protocol.*[13] Additional discussion of this approach is provided in Section V.C. on hydrofluorocarbons. Aspects of the transportation analysis require assumptions about the vehicle fleet, including stock turnover. For this part of the analysis, we used Argonne National Laboratory's VISION model,[14] adjusting their base case to incorporate the latest EPA and NHTSA standards for light-duty vehicles.

E. NOTE ABOUT GLOBAL WARMING POTENTIALS

Where possible, we have attempted to provide emissions and consumption estimates using the latest state of the science, as reported in the Intergovernmental Panel on Climate Change's (IPCC) *Fourth Assessment Report.* Several data sources—including EPA's *Draft Global Non-CO_2 Emissions Projections Report: 1990-2030*—utilize the global warming potential estimates reported in IPCC's Second Assessment Report. This is done in order to be consistent with international reporting standards under UNFCCC. We do not follow this convention, however, and instead seek to use a more accurate accounting of the actual global warming impact of the different gases. This allows for a more accurate accounting of the actual GHG impacts of new policies as well as inaction.

Unfortunately, we could not update all gases to the global warming potentials reported in the *Fourth Assessment Report*. Detailed speciation is not available for projections of F-gases, and therefore it was not possible to accurately update their projections. Therefore, we did not update historical emissions for F-gases in order to remain consistent with our approach for projected emissions.

III. Power Plants

A. GREENHOUSE GAS PERFORMANCE STANDARDS

1. Base Case

Modeling of the electric sector was based on the AEO2012 reference case and utilized detailed AEO2012 outputs provided by the U.S. Energy Information Administration (EIA) that indicate annual capacity, generation, consumption, and emissions changes by technology type.[15] AEO2012 projects that end-use efficiency will increase over time, and the emissions intensity of generation will decrease. However, it also predicts that electric demand will grow from 3.8 trillion kWh in 2010 to 4.7 trillion kWh in 2035, resulting in an increase in CO_2 emissions to 2.3 billion metric tons in 2035, which is 3 percent above 2010 levels.[16]

The AEO2012 reference case includes mandatory state renewable portfolio standards, the Northeastern and Mid-Atlantic Regional Greenhouse Gas Initiative (RGGI), and California Assembly Bill 32 (AB32).[17] It also includes the Mercury and Air Toxics Standard (MATS) issued by the U.S. Environmental Protection Agency (EPA) in December 2011, as well as the Cross-State Air Pollution Rule (CSAPR) finalized by EPA in July 2011, which reduces sulfur dioxide (SO_2) and nitrous oxide (NO_x) emissions from power plants. CSAPR was vacated by the Federal Circuit Court for the D.C. Circuit in August 2012, marking an inconsistency between the model assumptions and real-world regulatory requirements for power plants. EPA has petitioned for a rehearing of the CSAPR appeal en banc and is expected to appeal the DC

BOX A-1 Modeling New Source Performance Standards under Section 111 of the Clean Air Act

Few performance standards for existing units have been issued to date, and thus far there are no such standards that cover greenhouse gases. In modeling the impact of any future standards, we made certain assumptions about the timing of the implementation of those standards. That timeline is described below. EPA announced their intention to establish emissions standards for existing power plants and refineries in December 2010. Therefore, for modeling purposes we assume that some of the background analysis has been done and that it would be possible for those standards to take effect within five years; that is, beginning in 2018.

TIMELINE
1.5–2 years to adopt federal standards & guidelines to states
1–2 years for states to develop standards for existing sources
3 years for existing units to comply
Total: 6-year lag

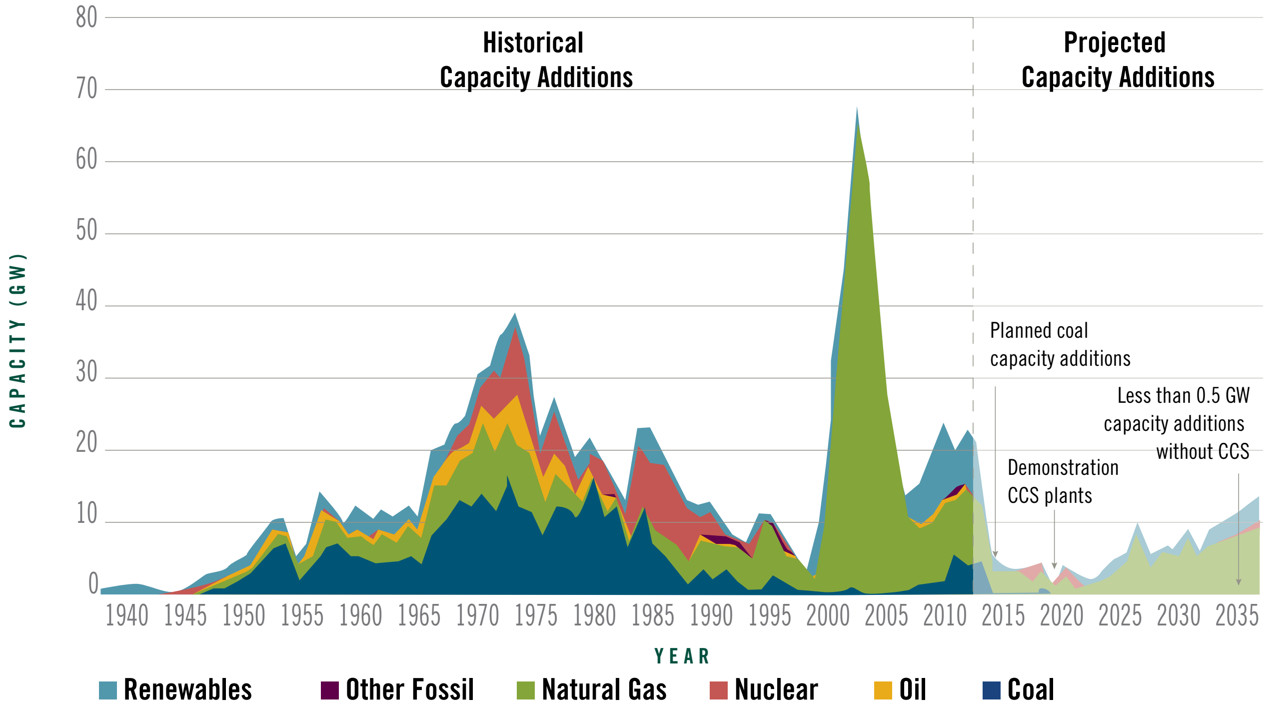
Circuit's decision if it stands. In the meantime, SO_2 and NO_x emissions will be regulated under the Clean Air Interstate Rule (CAIR), which remains in effect.

AEO2012 does not predict any new unplanned coal generation that does not include carbon capture and storage until 2030. This is consistent with trends in new power plant construction since the late 1990s (see Figure A-1.2).

2. Lackluster Scenario for Power Plants

In December 2010 EPA announced they would establish GHG performance standards for new and existing power plants using their authority under section 111 of the Clean Air Act, and that they would finalize those standards by May 2012.[18] In April 2012 EPA proposed performance standards for new power plants. These standards have not yet been finalized, and thus they do not meet the necessary criteria for

FIGURE A-1.2 New Electric Generating Capacity Additions by Fuel Type



Sources: This figure was developed using projections from U.S. EIA's AEO2012 and historical data from EIA Form EIA-860.

Notes: Planned units are defined in the AEO as those units that have commenced construction, but not yet begun operation.

TABLE A-1.1 New Source Performance Standards for Power Plants

	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Existing plants	NSPS are established for existing coal units that achieve fleet-wide average efficiency improvement of 5 percent starting in 2018.	Standards achieve an 18 percent reduction in emissions in 2021 compared to 2012 emission levels, and a 33 percent reduction in 2035.	Standards achieve a 38 percent reduction in emissions in 2021 compared to 2012 emission levels, and a 74 percent reduction in 2035.
New plants	EPA finalizes NSPS as proposed, which set a standard of 1,000 pounds of CO_2 per megawatt-hour of output. After eight years (2020), EPA updates these standards so that new unit performance gradually improves to 570 pounds of CO_2 per megawatt-hour in 2030.	EPA finalizes standards consistent with our lackluster scenario until 2028, at which time they establish new standards equivalent to CCS with a 90 percent capture rate.	EPA finalizes NSPS of 1,000 pounds of CO_2 per megawatt-hour of output. In 2020, they establish new standards equivalent to CCS with a 90 percent capture rate.

inclusion in the base case. EPA has not yet proposed performance standards for existing power plants. For the lackluster scenario (and all subsequent scenarios), we assume that EPA establishes performance standards for new and existing fossil-fuel-fired plants.

a. New Power Plants

In general, EPA's proposed New Source Performance Standards (NSPS) would require new power plants with a base load rating more than 73 MW to meet an annual emissions rate of 454 kgCO_2/MWh (1,000 lbs per MWh).[19] To achieve this emissions rate, new plants will need to employ natural gas, carbon capture and storage, waste heat recovery, or possibly biomass.[20] In all three scenarios, we assume that EPA finalizes an emissions standard that is equivalent to their proposed standards. The Clean Air Act stipulates that once the new standards are finalized they will apply to any covered source that commences construction after the date the **draft** rule was proposed. Therefore, the actual date of finalization is not relevant to this analysis. Consistent with EPA's proposed standards for new units, we assume that coal plants that have already broken ground will not be subject to the proposed standards for new power plants. We therefore do not apply the new standards to the 9.3 GW of "planned" coal units in EIA's reference case.

The Clean Air Act requires EPA to evaluate standards for new units every eight years. Thus, in the lackluster scenario we assume that EPA updates these standards after eight years, and that the new standard requires new units to gradually improve their emissions rate so that they reach 570 lbs/MWh by 2030. This target is consistent with increasing the efficiency of a natural gas unit to 70 percent, a target set by the Electric Power Research Institute (EPRI) in their 2009 Prism/MERGE analysis. This study identifies itself as a "technically and economically feasible roadmap for the electricity sector as it seeks to reduce its greenhouse gas emissions over the next few decades."[21] We assume EPA holds this 570 lbs per MWh emissions standard constant from 2030 through 2035.

As noted previously, AEO2012 does not predict any new unplanned coal generation that does not include CCS until 2030. We also note that GE has reported achieving 61 percent efficiency in their new combined cycle units, which is not required under the lackluster scenario until 2021.[22]

b. Existing Power Plants

In the lackluster scenario, we assume that performance standards achieve a modest 5 percent reduction in the emissions rate at existing coal plants through efficiency improvements. The average 5 percent improvement rate comes from EPA's *Advanced Notice of Proposed Rulemaking: Regulating Greenhouse Gas Emissions under the Clean Air Act* (ANPR) issued on July 11, 2008. In the ANPR, EPA noted that heat rate reductions of up to 10 percent are feasible at many coal-fired power plants, and that the potential average heat rate reduction for the entire coal fleet would likely be about 5 percent.[23] A 5 percent improvement in heat rate would reduce greenhouse gas emissions by 5 percent at existing coal plants. Alternatively, plants could achieve (or exceed) a 5 percent reduction in emissions by switching in whole or in part to lower carbon fuels such as natural gas and sustainably harvested biomass, or through greater use of waste heat.

The 5 percent improvement rate is assumed to be a fleet-wide average as some units may be able to achieve greater or fewer reductions. This average improvement rate could be realized through the establishment of unique standards for various subcategories of power plants.[24,25]

We assume that the new standards take effect in 2018. This is one year earlier than performance standards for most other source categories. We believe that this more expedited time frame is relevant, however, because EPA's December 2010 announcement about their development of performance standards for existing units (and for refineries) suggests that some of the regulatory analysis should already be completed.

After consulting with a variety of technical experts and conducting a literature review, we were unable to find a reliable public source that would support an assumption about immediately available opportunities for improving the efficiency of the existing natural gas fleet. As a result, we do not include reductions from existing gas plants in the reductions for the lackluster scenario.

c. Modeling Notes

To model reductions achieved through these standards, we made use of intermediary coal modeling results for the AEO2012 reference case, which were furnished upon request from EIA.[26] Those results show projected capacity, generation, consumption, and emissions by technology type for new, planned, and existing units through 2035.

We relied on the AEO2012 reference case for predictions of new unit construction and generation. We assume that all new units meet the new source standard applicable at the time of construction, with the exception of simple cycle units, which are excluded from EPA's new unit standards.

For modeling purposes, the 5 percent average improvement was applied evenly across all existing coal-fired units. We assumed that improving the efficiency of coal plants would decrease the marginal cost of generation, which would increase their competitiveness and lead to increased operation at those plants (and decreased generation by gas plants). This phenomenon has been examined by two recent studies by Resources for the Future, *Retail Electricity Price Savings from Compliance Flexibility in GHG Standards for Stationary Sources*,[27] and *Regulating Greenhouse Gases from Coal Power Plants under the Clean Air Act*.[28] The studies did not examine this precise scenario. However, based on conversation with the authors (Burtraw and Woerman), we decided that the greatest parallels were with the unit-specific subcategorization approach they presented at the annual meeting of the Association of Environmental and Resource Economists. Therefore, we modeled a 0.83 percent increase in coal generation as a result of the efficiency gains driven by the performance standards.[29]

3. Middle-of-the-Road Scenario for Power Plants

a. New Power Plants

The middle-of-the-road scenario builds off the assumptions in the lackluster scenario, establishing an initial standard of 1,000 lb/MWh, and the subsequent improvement period, which would achieve 570 lbs per MWh by 2030. Before reaching that 2030 goal, however, we assume that EPA updates their standards again (eight years after the previous update), so that in 2028 new units are held to a standard that is consistent with the utilization of carbon capture and storage at a 90 percent capture rate. We assume that this emissions rate would apply to all units regardless of fuel type. This treatment is consistent with EPA's proposed emissions standards for new power plants.

b. Existing Power Plants

For the middle-of-the-road and go-getter scenarios, we assume that EPA takes a more flexible approach when establishing performance standards for existing power plants. Thus, instead of requiring source-by-source compliance with a fixed emissions rate (as we did in the lackluster scenario), we assume that sources can comply through a range of other measures that reduce emissions from regulated emissions sources in the power sector. Such options could include fuel switching, low-carbon dispatch of existing power plants (e.g., operating a gas plant more and a coal plant less), increased generation by renewable sources, and energy efficiency, among other actions. These reductions could be recognized through a range of different programs such as fleet-wide averaging, rate-based trading programs, a portfolio of measures, or cap and trade.

In the middle-of-the-road scenario, we assume that standards take effect in 2018 and gradually improve, resulting in an 18 percent reduction in emissions in 2021 compared to 2012 emission levels. We assume that EPA would subsequently update these standards in 2026, which would lead to an additional 18 percent reduction in emissions in 2029 compared to 2021 emissions levels. These standards result in 33 percent fewer CO_2 emissions from power plants in 2035 compared to 2012.

Several recent proposals—introduced in conferences and meetings by academics and environmental organizations—have discussed potential approaches to regulating greenhouse gas emissions under the Clean Air Act. The level of reductions included here is comparable to a recently published proposal by the Natural Resources Defense Council (NRDC), though we did not model their specific proposal.[30] NRDC's proposal would allow for power plants to comply through onsite efficiency improvements, by shifting power generation to lower or non-emitting plants, and through demand-side efficiency improvements. However, we also note that analysis of EIA's AEO2012 projections of natural gas-fired plant capacity shows that there is sufficient slack capacity in existing natural gas units to achieve the initial 18 percent reduction entirely from re-dispatch of the existing fleet (i.e., increasing generation from natural gas plants and decreasing generation from coal plants).[31] Further reductions of the magnitude we model through 2035, however, would likely require new sources of carbon-free electricity (e.g., renewable or nuclear), increased deployment of carbon capture and storage, or a significant expansion of energy efficiency programs.

c. Modeling Notes

Note that due to the low projections of unit turnover in AEO2012, for modeling purposes we did not explicitly include additional NSPS for new units in the middle-of-the-road scenario; instead, we assumed that more stringent standards for new sources will make it easier to achieve the reductions required under the existing unit standards, as new units covered by the standard will emit fewer GHG emissions than the units that they are replacing.[32]

4. Go-Getter Scenario for Power Plants

a. New Power Plants

Similar to the lackluster and middle-of-the-road scenarios for new plants, the go-getter scenario assumes that EPA finalizes emissions standards for new units that mirror their proposed standards. The go-getter scenario assumes that EPA updates these standards again in 2020 to a standard that is consistent with the utilization of carbon capture and storage at a 90 percent capture rate, eight years earlier than assumed in the middle-of-the-road scenario.

b. Existing Power Plants

The go-getter scenario assumes EPA sets emissions standards for existing units that lead to a 38 percent and 74 percent reduction in energy CO_2 in 2020 and 2035 (respectively) compared to 2012. This level of reductions would likely require implementation of a flexible compliance program, such as the one described in the middle-of-the-road scenario. Because no NSPS for existing units have been proposed to date that cover greenhouse gases, we made the assumption that implementation of those standards would not start until 2018, and that EPA would provide a three-year glide path before achieving the emissions reduction target.

To establish the emission targets for this scenario, we used carbon price modeling results from EIA. Specifically, we utilized a side case from EIA's AEO2012 that examined the impact of an initial $25 price on carbon starting in 2013 that increases by 5 percent each year above inflation and reaches $35 per metric ton in 2020 and $73 per metric ton in 2035. It is clear that EPA does not have the authority to establish a carbon tax. These results are valuable, however, as they help elucidate the cost of abatement, and thus offer insight into the level of reductions that could be achieved through flexible standards under section 111(d).

c. Modeling Notes

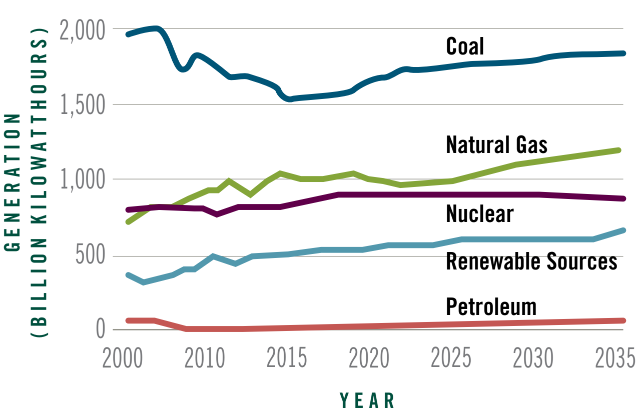
To model the existing standards for power plants, we assumed that generation and emissions would remain consistent with the base case (AEO2012 reference case) through 2017, and steadily change so that in 2021, generation and emissions would be the same as those projected in EIA's carbon price side cases.

The go-getter scenario assumes more than 2.5 times more new generation capacity will be built by 2035 compared to the base case scenario. The vast majority of this new capacity consists of renewable, nuclear and natural gas sources. The only coal units built under this scenario have carbon capture and storage technology installed. Because of the trend for installing low- or no-carbon emitting power units inherent under this scenario, for modeling purposes we did not explicitly include additional NSPS for new units; instead, we assumed that these standards help achieve the more flexible and ambitious existing unit standards.

5. Additional Notes for Power Plants

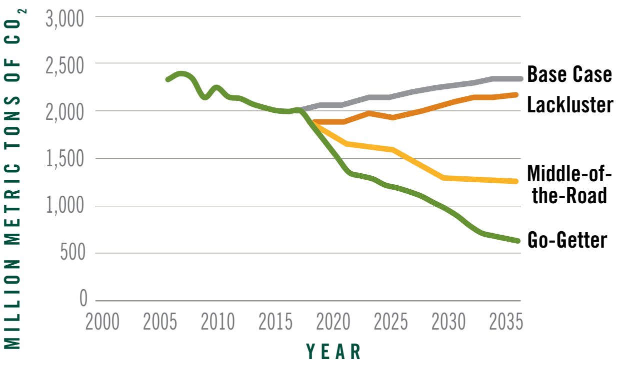
In addition to performance standards for new and existing power plants, emissions from electric generation are also affected by changes in the demand for electricity. We account for demand changes resulting from a wide-range of actions in an electric demand module, as described in section III.C.

FIGURE A-1.3 **Base Case Electricity Generation by Fuel Type**



Source: AEO2012, EIA

FIGURE A-1.4 Power Sector Emissions After Accounting for Changes in Demand



B. APPLIANCE AND EQUIPMENT EFFICIENCY STANDARDS (ELECTRIC)

1. Base Case for Appliance and Equipment Efficiency Standards (Electric)

The base case uses the AEO2012 reference case. The AEO2012 reference case assumes total electricity consumption in the residential sector increases over time, but the delivered energy per household declines at an average rate of 0.9 percent. About one-half of the decline in energy delivered per household can be attributed to more efficient space heating. Additional demand decreases for space heating is predicted to result from population shifts to warmer and drier climates. The reference case also assumes that despite growth in commercial floor space, improved commercial equipment efficiency slows the increase in purchased electricity through 2035.[33] Between 2009 and 2011, the Department of Energy established 17 new equipment standards that are expected to save 126 TWh in 2025 and 147 TWh in 2035.[34]

The Department of Energy may promulgate efficiency standards for consumer appliances and non-consumer equipment under existing federal law.[35] The law lists appliances and equipment that may be the subject of efficiency standards, prescribes minimum standards for certain appliances and equipment, and also prescribes a process through which the Secretary of Energy may add additional appliances and equipment to those regulated.[36]

2. Lackluster Scenario for Appliance and Equipment Efficiency Standards (Electric)

We identified three studies that quantify energy savings achievable through enhanced energy efficiency standards beyond the base case. Those three studies are summarized below. For the lackluster scenario, we chose the lowest range of energy efficiency improvements over the study period from all of the studies, which was estimated to result in 192 TWh of savings from the residential and commercial consumers in 2025, plus an additional 36 TWh of savings from the industrial sector.

In *The Efficiency Boom: Cashing In on the Savings from Appliance Standards*, the American Council for an Energy-Efficient Economy (ACEEE) and the Appliance Standards Awareness Project (ASAP)[37] quantified the benefits from potential new or updated standards for 34 product categories that could be adopted within the next several years. They estimate that those standards could result in 212 TWh savings from residential and commercial consumers in 2025, and 306 TWh savings in 2035. Energy savings were calculated as reductions compared to current units, assuming fixed demand for the appliances. The authors note that many important standards are due between 2013 and 2015. The standards included were found to save consumers money over the life of the product, with an average simple payback period of 3.3 years. Individual product payback periods range from less than a year to 10.1 years.

TABLE A-1.2 Appliance and Equipment Efficiency Standards (Electric)

LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
192 TWh savings in 2025 from the residential and commercial sectors, plus additional savings from the industrial sector. Annual savings remain constant through 2035.	212 TWh savings in 2025 and 306 TWh savings in 2035 from the residential and commercial sectors, plus additional savings from the industrial sector.	364 TWh savings in 2025 and 525 TWh savings in 2035 from the residential and commercial sectors, plus additional savings from the industrial sector.

The Institute for Electric Efficiency's (IEE)[38] study—*Assessment of Electricity Savings in the U.S. Achievable through New Appliance/Equipment Efficiency Standards and Building Efficiency Codes (2010-2025)*[39]— examined what IEE deemed "moderate" and "aggressive" efficiency improvement scenarios. IEE's moderate scenario assumes existing efficiency standards are increased to levels consistent with currently available products, and efficiency standards are created for some appliances and equipment that do not currently have standards. The IEE moderate scenario was found to result in electricity savings of 228 TWh in 2025 from the AEO2011 reference case for the residential, commercial, and industrial sectors. Of those savings, 192 TWh were projected to come from the residential and commercial consumers, and 36 TWh were projected to come from the industrial sector. The IEE aggressive scenario contains "more aggressive efficiency assumptions onto those embedded in the moderate case." The IEE study concluded that 364 TWh could be saved in 2025 compared to the AEO2011 reference case under the IEE aggressive scenario for the residential and commercial sectors. Another 63 TWh of savings were projected to come from the industrial sector.

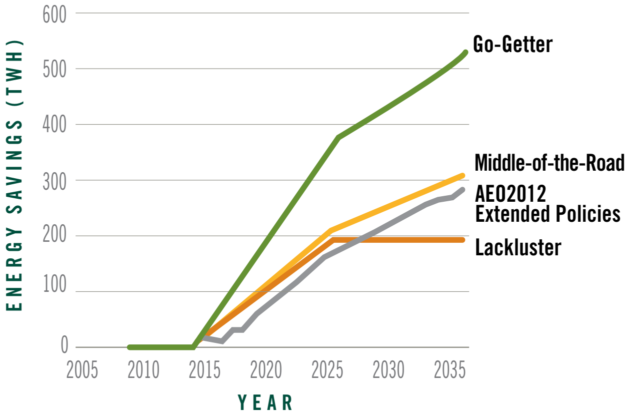
The third study we considered was the "extended policies" side case from AEO2012. This side case "examined updates to existing efficiency standards for residential and commercial products as well as the creation of efficiency standards for products not currently covered." Energy savings in this side case reach about 164 TWh in 2025 and nearly 280 TWh in 2035 from the residential and commercial sectors.

For the lackluster scenario, we chose the lowest range of energy efficiency improvements from all of the studies over the entire study period, which was the IEE moderate scenario. This scenario estimated 192 TWh of electricity savings in 2025 from the AEO2011 reference case in the residential and commercial sectors, and an additional 36 TWh of savings from the industrial sector. Applying these savings to the AEO reference case in 2025 results in a 5 percent reduction in electric demand. For this analysis, we assumed that standards commence in 2015 and result in a constant increase in savings between 2015 and 2025. Unfortunately, 2035 results were not provided. In order to develop intentionally conservative results, we hold the reported reductions achievable in 2025 constant through 2035. We do this even though stock turnover continues, in part because the AEO2012 reference case continues to increase appliance efficiency through 2035. While this study compares its savings to those modeled in AEO2011, we assumed that the potential energy savings reported in these studies can be applied to the base case, which utilizes AEO2012.[40]

3. Middle-of-the-Road Scenario for Appliance and Equipment Efficiency Standards (Electric)

The middle-of-the-road scenario is based on the middle range of energy efficiency improvements from the studies. Specifically, we use *The Efficiency Boom: Cashing In on the Savings from Appliance Standards*, which concluded that the 34 standards considered would save residential and commercial consumers 212 TWh in 2025 and 306 TWh in 2035. These savings amount to a 5 percent and 7 percent reduction in electric demand in 2025 and 2035, respectively, compared to the AEO2012 reference case. These results are comparable to those found by EIA in their side case. We relied on *The Efficiency Boom* because it lists specific product standards and dates, so that future actions can be easily compared. The EIA side case also included updated standards as well as new standards for products not yet covered by efficiency standards. AEO did not provide this same level of detail. For purposes of this analysis, we assumed that standards commence in 2015 and result in a constant increase in savings between 2015 and 2025 and from 2025 to 2035. The middle-of-the-road scenario for GHG performance standards for industry, as detailed in Section XI, includes considerable efficiency gains. Therefore, to avoid double counting, we do not assume any additional industrial efficiency gains are obtained as a result of appliance and equipment efficiency standards for industry. This does not mean that equipment efficiency standards would not be beneficial, just that we do not consider them here to ensure the development of conservative emissions reduction estimates.

FIGURE A-1.5 Energy Savings (TWh) from Residential and Commercial Appliance Efficiency Standards



4. Go-Getter Scenario for Appliance and Equipment Efficiency Standards (Electric)

The go-getter scenario is based on the highest level of reductions reported in the three reports, which was the aggressive scenario in the IEE study. IEE's aggressive scenario resulted in energy savings from equipment standards in the residential and commercial sectors of 364 TWh in 2025 from the AEO2011 reference case. It also resulted in 63 TWh of savings from industrial consumers in 2025. For the reasons outlined in the middle-of-the-road scenario for appliance and equipment efficiency standards, above, we did not include savings from industrial equipment standards.

We assumed that standards commence in 2015 and result in a constant increase in savings between 2015 and 2025. This study did not provide 2035 results. However, the other study we relied on—*The Efficiency Boom*—found that electricity savings increased between 2025 and 2035 due to stock turnover. We also note that additional standards are possible after 2020. Therefore, in our go-getter scenario, we take a less conservative approach to estimating savings in 2035 than we do in the lackluster scenario. We assume that annual energy savings increase between 2025 and 2035 at an annual rate consistent with the middle-of-the-road scenario (3.7 percent per year). This results in 525 TWh of savings in 2035. These savings amount to a 9 percent and 11 percent reduction in electric demand in 2025 and 2035, respectively, compared to the AEO2012 reference case.

5. Modeling Notes for Appliance and Equipment Efficiency Standards (Electric)

The energy savings from increased appliance and equipment efficiency standards in each of the three scenarios was fed into the electric demand module, which incorporates the full range of changes to electricity demand due to factors such as increased energy demand from electrification of light-duty and off-highway vehicles, and reduced demand for electricity as a result of increased deployment of combined heat and power (CHP) in the industrial sector. For more information about the electric demand model, see Section III.C.

Because we relied on EIA's AEO2012 $25 carbon tax scenario for the go-getter power sector generation projections, we had to make further adjustments to these efficiency savings. EIA's scenario predicts that the carbon price will increase electric rates and that this will lead to additional energy savings beyond the AEO2012 reference case. We assume that these savings will overlap with those resulting from increased appliance and equipment efficiency standards, and therefore discount them in the model. In 2035, for example, though the standards are predicted to result in 525 TWh of savings, we only model 270 TWh of incremental efficiency savings because the carbon price scenario already included 255 TWh of efficiency savings.

C. ELECTRICITY DEMAND

1. Lackluster Scenario for Electricity Demand

In order to provide a conservative estimate of the benefit of policies that reduce electricity demand, we begin by preventing the building of the "average" unplanned fossil-fired unit (i.e., new units that have not yet commenced construction). Through most years this is natural gas. In later years this affects the small amount of new coal plants that do not have carbon capture and storage in the AEO reference case (less than 0.5 GW). Next, we turn off the "average" existing fossil-fired unit. We reduce CO_2 emissions according to the average emissions rate because it is challenging to predict what the marginal emissions rate will be nationwide throughout the time frame considered. Furthermore, while marginal units tend to be natural gas in some regions of the country (such as New England),[41] they are coal in other regions. Due to the predominance of coal in the system, this results in the retirement of about 1.5 MW of electricity from coal plants for every 1 MW of electricity from every gas plant. We do not turn off existing renewable or nuclear sources, as we assume that the bulk of the capital costs are already sunk, and the operational costs are lower than fossil units.

Depending on the specific combination of state and federal action, we account for four types of measures, which have slightly different impacts on the generation mix:

- Those that reduce overall electricity demand (e.g., appliance standards and building codes);
- Those that generate electricity that does not get put onto the grid (e.g., CHP programs where the electricity used is predicted to be behind-the-meter);
- Those that increase demand (e.g., vehicle electrification); and
- Those that generate electricity that is put onto the grid from other clean sources (e.g., renewable programs).

Policies that reduce demand or that generate electricity that does not get put onto the grid reduce the total amount of electricity sold onto the grid. This can reduce renewable generation driven by state renewable mandates because those mandates are typically set as a percentage of total electricity sales. Most of the renewable energy built through 2030 in the lackluster scenario (which is modeled off of the AEO2012 reference case) appears to be due to renewable standards. Therefore, we reduce new renewable generation in a manner that is proportional to the predicted reduction in electricity sales due to electricity demand reduction and programs and policies that generate electricity that does not get put onto the grid.

Policies that increase demand offset the impact of programs that reduce demand or that generate electricity that is not sold on the grid. In none of the modeled scenarios do we predict that demand reductions will be outstripped by electricity demand increase due to various policies considered.

Policies that generate electricity that is put onto the grid from other clean sources do not reduce total sales, and thus do not impact the renewable mandates. They do, however, reduce the demand for other sources of electricity, and thus affect the construction of new units and the operation of existing fossil units in a manner that is similar to policies that reduce electricity demand.

None of the scenarios shut down the lone carbon capture and storage project that is predicted to be built as this demonstration project is hardwired into the AEO, and is not the result of economic factors.

2. Middle-of-the-Road Scenario for Electricity Demand

To evaluate the middle-of-the-road scenario for electricity demand, we had to consider the dynamics of the middle-of-the-road scenario for performance standards for existing power plants, which is an amalgamation of a number of proposals being considered at the federal level. There are currently no detailed sector outputs for any of those proposals that display the predicted generation, consumption, and emissions from existing and new units by type. Therefore, we cannot readily turn off discrete types of new or existing units in response to changes in electricity demand. However, this may be less problematic than would otherwise appear. Several of the proposals under discussion establish a target emissions rate for fossil-fired power plants. Under such an approach, demand reductions could provide a benefit that is proportional to the emissions rate for regulated sources. In this scenario, the emissions rates ranged from 0.67 tons of CO_2/MWh in 2021 to 0.5 tons of CO_2/MWh in 2035.

3. Go-Getter Scenario for Electricity Demand

The go-getter approach is based on the $25 carbon tax scenario from EIA's AEO2012. Thus we have detailed sector outputs that allow us to follow a very similar process as the lackluster scenario, with one key difference. In this scenario renewable projects become cost competitive with fossil plants, and thus there is a three-fold increase in renewable energy development. Therefore, we treat new renewables the same as other new non-renewable resources, and prevent their construction on a proportional basis in response to reductions in demand, as long as the residual renewable generation meets the appropriate set of state renewable standards. This causes any change in demand to have a lower impact in terms of GHG emissions than it does in the lackluster and middle-of-the-road scenarios.

EIA's AEO2012 $25 carbon tax scenario predicts lower electric demand compared to their reference case due to higher electricity prices. We assume that much of that reduction will be driven by the purchase of more efficient appliances, and thus discount electricity demand savings otherwise predicted by new efficiency standards for appliances and equipment.

4. Additional Modeling Notes for Electricity Demand

The state action scenarios result in a mixture of states with and without carbon policies for the electric sector and potentially a different mix of states with and without state-specific policies that affect electricity demand. Since we do not predetermine which states might pursue each of these policies, and since the scenarios assume that up to 50 percent of states pursue any particular policy, we assume for modeling purposes that the impact of policies that affect demand will be shared across all states.

Because we consider increases and decreases in electric demand associated with a number of activities (e.g., electrification of light-duty vehicles and improved industrial energy efficiency), we do not separately determine CO_2 emissions reductions associated with appliance efficiency standards. Instead, those reductions are included in the overall emissions reductions for electric generation.

IV. Transportation

A. LIGHT-DUTY VEHICLES

1. Base Case for Light-Duty Vehicles

In August 2012 EPA and the National Highway Traffic Safety Administration (NHTSA) finalized new GHG emissions standards and CAFE standards for light-duty vehicles.[42] EPA's GHG emissions standards affect vehicles sold from model years 2017 through 2025. Due to statutory limitations, NHTSA only finalized CAFE standards for vehicles of model years 2017 through 2021. NHTSA also announced possible CAFE standards for model year 2021 through 2025 vehicles, though finalization of those standards will require additional rulemaking. EPA's standards establish a CO_2 emissions standard of 163 grams per mile in model year 2025, which is equivalent to a fuel economy standard of 54.5 mpg (if met solely through fuel economy improvements). This is equivalent to a CAFE standard of 49.7 mpg because NHTSA considers only drive train improvements and does not consider improvements in air conditioning leakage of HFCs for purposes of establishing CAFE standards.[43] To avoid double counting, we account for the HFC benefits in the HFC module and do not account for them in the figures that follow.

For the analysis, we used Argonne National Laboratory's VISION model,[44] which relies on the EIA *Annual Energy Outlook 2012* and does not include the latest EPA and NHTSA standards for light-duty vehicles.[45] Thus, we developed our own base case scenario by inputting the new federal standards into the VISION model. We note that EPA has the ability to revisit the standards for model years 2022 to 2025, and adjust them based on the best and most current information available at that time. In the base case scenario, however, we assumed that the standards through model year 2025 are achieved as outlined in the most recent rulemaking, and are not revised upwards or downwards. We further assume that the 2025 model year standards remain constant through 2035.

The recently finalized emissions standards for model years 2017 through 2025 include incentives for electric vehicles (EVs), plug-in hybrid electric vehicles (PHEVs), fuel cell vehicles (FCVs), and compressed natural gas (CNG) vehicles. The incentives include a temporary per-vehicle multiplier that allows EVs, PHEVs, FCVs, and CNG vehicles to "count" as more than one vehicle in the manufacturer's compliance calculation for model years 2017 through 2021. The standards also provide for the temporary use of an increased fuel economy value and a reduced GHG emissions compliance value in order to spur deployment of vehicles that consume less gasoline and emit fewer GHG emissions.[46] We incorporate each of these credits into the model.

2. Lackluster Scenario for Light-Duty Vehicles

For all of the scenarios, we relied on the *Interim Joint Technical Assessment Report* (TAR) produced by EPA, NHTSA, and the California Air Resource Board (CARB).[47] The agencies analyzed four scenarios of future stringency for model years 2020 and 2025, starting with a 250 gram/mile estimated fleet-wide level in model year 2016 and four different levels of CO_2 standard improvement rates: 3 percent per year, 4 percent per year, 5 percent per year, and 6 percent per year. For reference, the 4 percent improvement rate results in a 51 mpg standard by model year 2025, while the 6 percent improvement rate results in a 62 mpg standard by model year 2025. For each of these rates of increased stringency, the agencies considered the effects of the industry following four potential "technology pathways." Each of these rely on varying market penetrations of different sets of technology, including HEV, PHEV, EVs, and mass reduction. The agencies'

TABLE A-1.3 Vehicle Emissions and Efficiency Standards Scenarios, Light-Duty Vehicles

LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
August 2012 Joint EPA-DOT Standards: 54.5 mpg by model year 2025 (Included in the base case)		
Standards continue to improve from 2026–2035 at roughly half the rate of the 2017–2025 standards (2 percent). This results in a 131 grams per mile emissions standard and a 61 mpg CAFE standard by 2035. Under this scenario, 9 percent of the miles traveled by MY 2035 vehicles are powered by electricity.	Standards continue to improve from 2026–2035 at roughly the same rate as the 2017–2025 standards. This equates to about a 4 percent annual improvement through 2035, and results in a 104 gram per mile emissions standard and a 74.6 mpg CAFE standard. Under this scenario, 12 percent of the miles traveled by MY 2035 vehicles are powered by electricity.	Six percent annual improvement rate in emissions standards. This results in a 81 grams per mile emissions standard and a 92 mpg CAFE standard. Under this scenario, 34 percent of the miles traveled by MY 2035 vehicles are powered by electricity.

Note: CAFE standards do not include benefits from HFC emissions reductions, which EPA projects to result in credits amounting to 14.3 grams CO_2 per mile in 2025. Also note that the rate of change for the standards is applied to the GHG emissions standards (grams per mile) and fuel consumption rate (gallons per mile).

results illustrate that a variety of technologies can be used to meet each of the standards.

Our lackluster scenario assumes vehicle standards achieve a 131 gram per mile emissions standard in 2035, and a 61 mpg CAFE standard.[48] This is equivalent to a 2 percent annual improvement rate from 2026 through 2035, which is about half the rate required in the finalized standards for model years 2017 through 2025. The 2 percent rate of improvement is only applied to vehicle efficiency improvements and not HFCs because the opportunities to achieve incremental HFC benefits beyond those driven by the current round of standards are more limited. Consistent with EPA and NHTSA's *Interim Joint Technical Assessment Report*, in all of our scenarios the rate of change is applied to the GHG emissions standards (grams per mile) and fuel consumption rate (gallons per mile).

We assume that under this scenario, 9 percent of the miles traveled by MY 2035 vehicles are powered by electricity. We made this assumption because we are unable to predict exactly how these alternative vehicles will penetrate the market and wanted to account for a range of possible outcomes. However, for modeling purposes, we assume that EVs reach 4 percent of sales by 2025. This is consistent with one of the technology pathways the agencies found could achieve a set of standards with similar stringency to those finalized in August. We assumed that sales would escalate over time, so that in 2035 EV's accounted for 8 percent of total sales and PHEVs accounted for 1.5 percent of total sales. This is consistent with the average penetration rates assumed in the four scenarios analyzed by the agencies that achieve 62 mpg in their *Interim Joint Technical Assessment Report*.

3. Middle-of-the-Road Scenario for Light-Duty Vehicles

We assume that vehicle standards continue to improve though 2035 at roughly the same rate as the 2017–2025 standards (4 percent), and achieve an emissions standard of 104 grams of CO_2 per mile traveled and a fleet-wide CAFE standard of 74.6 mpg in 2035. Like the lackluster scenario, the middle-of-the-road scenario assumes that EVs reach 4 percent of new vehicle sales by 2025. Consistent with the lackluster scenario, we only apply the rate of improvement to vehicle efficiency improvements, and do not include HFC emissions in those calculations because there are limited opportunities to achieve incremental HFC benefits beyond those driven by the current round of standards.

Under this scenario, the light-duty fleet achieves approximately 63 mpg in 2031. The TAR considered a scenario where roughly the same fuel economy was achieved in 2025, and examined several technology pathways for achieving that standard. For modeling purposes, we assumed that EV and PHEV penetration would follow the average of these pathways. This results in EV and PHEV penetration of 8 percent and 1.5 percent of sales in 2031, respectively, when the light-duty fleet reaches 62 mpg. We assume that EV and PHEV sales continue to increase at a constant rate so that in 2035, EV's reach 10.7 percent and PHEV's reach 2.5 percent of vehicle sales. In order to account for a wider range of possible outcomes, we assume that 12 percent of the miles travelled by MY 2035 vehicles are powered by electricity.

4. Go-Getter Scenario for Light-Duty Vehicles

Our go-getter scenario assumes that the EPA GHG emissions standard improves 6 percent per year between 2025 and 2035. This is the highest improvement rate EPA and NHTSA considered in the proposed model year 2017–2025 standards. Consistent with the other scenarios, we only apply the rate of improvement to vehicle efficiency improvements, and do not include HFC emissions in those calculations because there are limited opportunities to achieve incremental HFC benefits beyond those driven by the current round of standards.

This would lead to a greenhouse gas emissions standard of 81 grams of CO_2 per mile traveled and a CAFE standard of 92 mpg in 2035. For modeling purposes, we assume that EVs reach 14 percent of new vehicle sales by 2025 and 31.5 percent by 2035, and that PHEVs reach 2 percent of new vehicle sales by 2025 and 4.5 percent by 2035. These rates were determined in a manner consistent with the middle-of-the-road scenario. However, instead of applying the average EV and PHEV penetration rate from the TAR, we applied the highest EV and PHEV penetration rate in 2025 and assumed that penetration rates continued through 2035 at a continuous rate.[49] In order to account for a wider range of possible outcomes, we assume that 34 percent of the miles traveled by MY 2035 vehicles are powered by electricity.

5. Modeling Notes for Light-Duty Vehicles

The VISION model allows users to edit the default fuel economies of light-, medium-, and heavy-duty vehicle categories between 2000–2100. We estimated fuel economies (mpg) for each major vehicle technology (e.g., internal combustion vehicles, EVs, PHEVs) using each vehicle technology's annual sales, applicable incentives for EVs and PHEVs, and VISION's assumed relative efficiency of vehicle types (e.g., EVs versus internal combustion engines).

In addition, for purposes of this analysis we made the following assumptions for all scenarios:

- We assume that the incentives and credits for electric vehicles (EVs), plug-in hybrid electric vehicles (PHEVs), fuel cell vehicles (FCVs), and compressed natural gas (CNG) vehicles expire, or wind down, as scheduled. This results in the evaluation of EV and PHEV emissions on the basis of the GHG emissions associated with electricity generation, which relates to the GHG performance standards in place for the power sector.
- PHEVs on average drive 50 percent of their miles using electricity, which is consistent with the assumptions in EPA's *Analysis of the Transportation Sector: Greenhouse Gas and Oil Reduction Scenarios,*[50] as well as the upper estimate in Argonne National Laboratory's VISION 2012 AEO base case. The emissions from electricity associated with the operation of these vehicles are accounted for in the electric sector through increased demand.
- Any differences in driving habits between EVs and internal combustion vehicles were not incorporated into the model because these trends are not considered in the VISION model.
- GHG benefits from reduced HFC emissions were not included in tailpipe emissions estimates, and instead were calculated separately in the HFC module.
- On-road mpg remains approximately 80 percent of the test mpg in accordance with standard practice and VISION model design.
- Consistent with common accounting practice and EIA's *Annual Energy Outlook*, we do not include emissions associated with the combustion of biofuels in emissions estimates for light-duty vehicles. This is commonly done due to an assumption that such fuels are carbon neutral. While recent studies suggest that this is not actually the case, for purposes of our analysis we do not include those emissions here.

FIGURE A-1.6 **Fuel Economy Improvements Modeled for Light-Duty Vehicles**

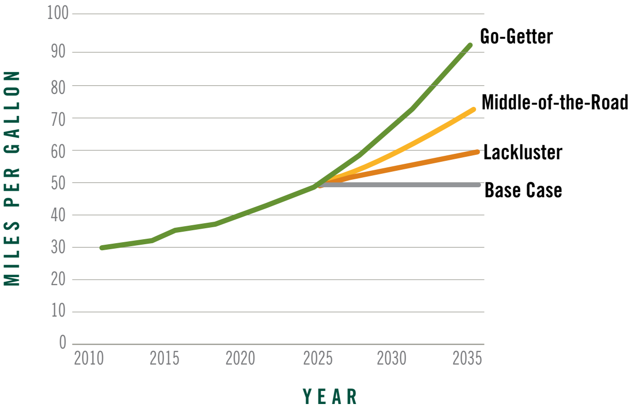
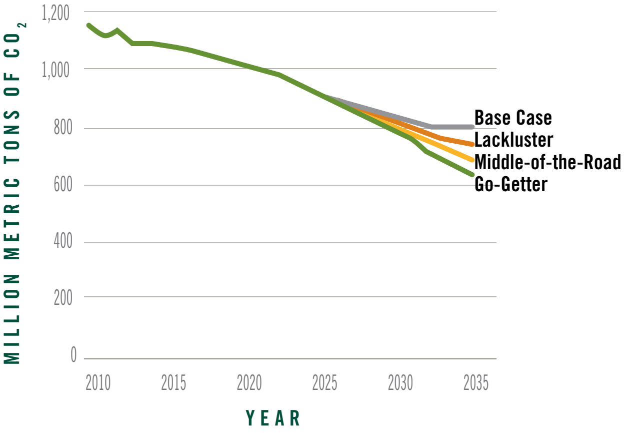


FIGURE A-1.7 **Tailpipe Carbon Dioxide Emissions from Light-Duty Vehicles**



B. MEDIUM- AND HEAVY-DUTY VEHICLES

1. Base Case for Medium- and Heavy-Duty Vehicles

In August 2011 EPA and NHTSA finalized a joint rulemaking that established the first-ever standards for GHG emissions and fuel consumption for medium- and heavy- duty vehicles.

Medium-duty vehicles (class 2b-6) are defined as those with a gross vehicle rate between 8,500 and 26,000 pounds, while heavy-duty vehicles (class 7-8) have a gross vehicle rate above 26,000 pounds. These vehicles are commonly divided into the following categories:

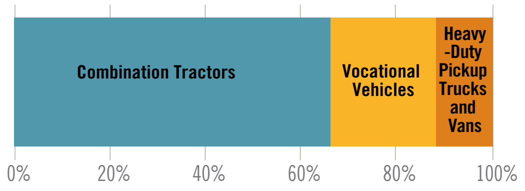
- **Combination tractors** (class 7-8): used for freight transportation and usually pull one or more trailers and emit about two-thirds of medium- and heavy-duty CO_2 emissions (Figure A-1.8);[51]
- **Vocational vehicles** (class 2b-8): used for a wide range of purposes, including fire trucks, dump trucks, refuse trucks, and others;[52] and
- **Heavy duty pick-up trucks and vans** (class 2b-3): used mainly for work purposes, as well as shuttle vehicles.[53,54]

The EPA and NHTSA standards, however, divide these medium- and heavy-duty vehicle categories into 13 subcategories, and establish vehicle GHG emissions and fuel consumption standards for each. Because the manufacturer of the vehicle can differ from the manufacturer of the engine, in some cases EPA and NHTSA established separate engine standards. However, these engine standards are built into the vehicle standards, and thus we do not separately consider them in our scenario development or modeling.

The rule covers vehicles sold from model years 2014 through 2018. EPA's standards are mandatory for model years 2014–2018. NHTSA's fuel consumption standards, however, are voluntary for model years 2014 and 2015 and don't become mandatory until model year 2016.[55] This is due to the regulatory lead-time requirements built into the Energy Independence and Security Act of 2007 (EISA), which cites a need for "regulatory stability."[56]

EPA established a separate standard for HFC leakage from AC systems in heavy-duty pickup trucks and vans as well as class 7 and 8 tractors, based on the

FIGURE A-1.8 **Carbon Dioxide Emissions from Medium- and Heavy- Duty Vehicles by Type, 2005**



Source: *Final Rulemaking to Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles: Regulatory Impact Analysis,* U.S. EPA and NHTSA, August 2011.

refrigerant capacity of the installed AC system. For purposes of this analysis, we applied EPA's estimated GHG benefits from this standard to base case emission projections for HFCs. Thus HFC benefits are not reflected in the GHG emissions projections from this sector shown in the figures that follow.

In the base case scenario, we assumed that the standards are not updated after the current regulatory period and thus the 2018 model year standards remain unchanged through 2035.

2. Lackluster Scenario for Medium- and Heavy-Duty Vehicles

Our lackluster scenario assumes that improvement in the standards continues at a rate consistent with half the rate of improvement achieved by the recent standards, or on average, 1.3 percent annually.[57] This would lead to an average fuel economy of 11 mpg and a GHG emissions standard of 949 grams CO_2 per mile across all medium- and heavy-duty vehicles in 2035.[58] As a result of the standards, we estimate that medium and heavy-duty vehicles sold in 2035 will consume 21 percent less fuel than vehicles sold in 2010.

The Energy Independence and Security Act of 2007 (EISA) requires at least three years of "regulatory stability" whereby standards for medium- and heavy-duty vehicles remain fixed. Therefore, in all three of the scenarios, we assume that CAFE standards are updated as frequently as possible, and that updates to the GHG emissions standards occur at the same time interval—once every three years.

3. Middle-of-the-Road Scenario for Medium- and Heavy-Duty Vehicles

In the middle-of-the-road scenario, we assume that the standards increase at the same rate as the standards for model years 2014–2018 (roughly 2.6 percent annually). This would lead to an average fuel economy of 13.3 mpg and a GHG emissions standard of 781 grams CO_2 per mile across all medium- and heavy-duty vehicles in 2035. As a result of the standards, medium- and heavy-duty vehicles sold in 2035 will consume 35 percent less fuel than vehicles sold in 2010.

4. Go-Getter Scenario for Medium- and Heavy-Duty Vehicles

The go-getter scenario for medium-duty and most heavy-duty vehicles assumes that the GHG emissions standards improve by an average 42 percent in 2023 across all vehicle categories compared to 2010 vehicles. This magnitude of improvement is likely only possible if EPA begins to regulate trailers, which are not covered by current standards. We assume standards for 2020 to 2022 split the difference between the standards set in 2019 and 2023 for each vehicle category, which results in an average improvement rate of 26 percent across all vehicle types. We assume that emissions standards increase by 3 percent every three years (1 percent annually) thereafter. This would lead to an average fuel economy of 16.0 mpg (657 grams CO_2 per mile) across all medium- and heavy-duty vehicles in 2035. As a result of the standards, medium- and heavy-duty vehicles sold in 2035 will consume 46 percent less fuel than vehicles sold in 2010.

TABLE A-1.4 Vehicle Emissions and Efficiency Standards, Medium- and Heavy-Duty Vehicles

LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Joint EPA-DOT Standards from August 2011 will improve the GHG emissions rate for vehicles by approximately 2.6 percent per year from 2013–2019		
Standards continue to improve through 2035 at half the rate of the 2014–2018 standards by vehicle category. This equates to an average annual improvement of 1.3 percent across all medium- and heavy-duty vehicles.	Standards continue to improve through 2035 at the same rate as the 2014–2018 standards by vehicle category. This equates to an average annual improvement of 2.6 percent across all medium- and heavy-duty vehicles.	By 2020–2022, the medium- and heavy-duty fleet reduces its emissions rate by an average 26 percent and by 42 percent in 2023–2025 compared to 2010. Standards continue to improve annually by 1 percent through 2035.

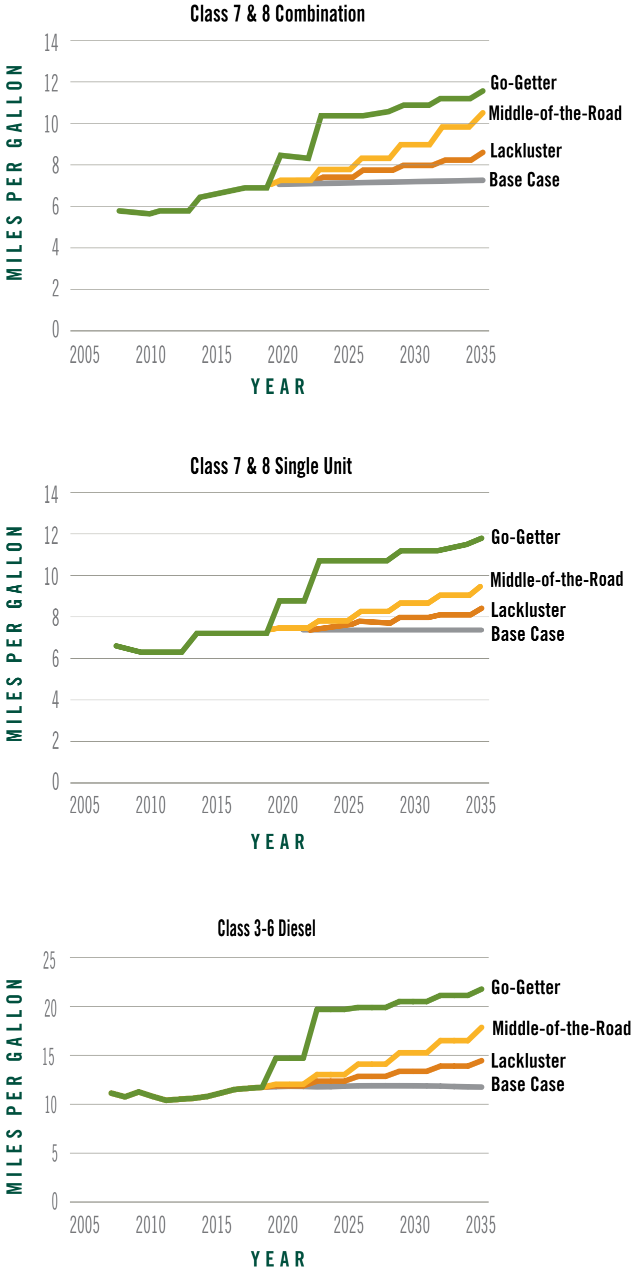
The go-getter scenario for medium- and heavy-duty vehicles was derived from the National Academy of Sciences *Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.*[59] That study examines several types of medium- and heavy-duty vehicles, and determines that they can reduce fuel consumption between 32 and 51 percent in the 2015–2020 timeframe by utilizing different technologies, depending on the vehicle class and purpose.[60] These ranges were used to develop average improvement rates for each of the major vehicle classes.

The 2020–2022 standards would reduce fuel consumption by an average 28 percent from 2008 levels. This is slightly higher than the potential fuel savings described in the Presidential Memorandum Regarding Fuel Efficiency Standards from May 21, 2010.[61,62]

5. Modeling Notes for Medium- and Heavy-Duty Vehicles

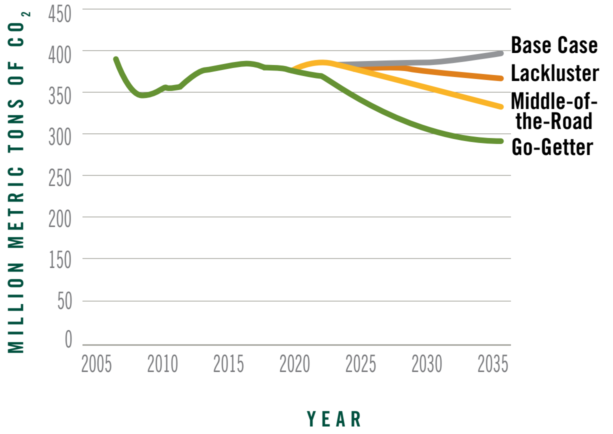
Our analysis relies on Argonne National Laboratory's VISION 2012 model,[63] which includes the latest EPA and NHTSA standards. The VISION model allows users to edit the default fuel economies of new light-, medium-, and heavy-duty vehicles sold from 2000 to 2100. However, VISION breaks the fleet up into different categories than those used by EPA and NHTSA. We therefore relied on EPA's estimated fleet-wide fuel efficiency for model years 2010–2018 under the finalized standards for heavy-duty pickups and vans, vocational vehicles, and combination tractors to help inform the average improvement in fuel efficiency in each of the VISION vehicle categories.[64] Similar to our approach for light-duty vehicles, we applied the improvement rates to the GHG emissions standards (grams per mile) and fuel consumption standards (gallons per ton-mile). These values were converted to fuel economy (miles per gallon) for modeling purposes. Figure A-1.9 shows fuel economy improvements for the three largest vehicle categories, which together account for roughly 94 percent of total GHG emissions from medium- and heavy-duty vehicles in 2010 and 2035.

FIGURE A-1.9 **Efficiency Improvements Modeled for Medium- and Heavy-Duty Vehicles**



Note: Fuel economy for class 3-6 gasoline, natural gas, and LPG vehicles, as well as class 7-8 single unit natural gas and LPG vehicles, are not shown here. Together, they account for only 6 percent of total GHG emissions in 2010.

FIGURE A-1.10 Tailpipe Carbon Dioxide Emissions from Medium- and Heavy-Duty Vehicles



C. OFF-HIGHWAY MOBILE SOURCES

1. Base Case for Off-Highway Mobile Sources

Off-highway mobile sources include a variety of emissions sources such as engines and equipment used for agriculture (tractors and combines), construction (cranes and bulldozers), lawn and garden, and mining. There is no specific off-highway category in the AEO, and it is beyond the scope of this analysis to reconstruct this sector's emissions from the ground-up. Therefore, we relied on the business-as-usual projections from the *EPA Analysis of the Transportation Sector: Greenhouse Gas and Oil Reduction Scenario*s for the base case, which projects that emissions from these sources will rise from roughly 200 mmtCO$_2$e in 2012 to roughly 275 mmtCO$_2$e in 2030.

2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for Off-Highway Sources

The EPA *Analysis of the Transportation Sector* concludes that there are significant opportunities to reduce GHG emissions from this sector.[65] In the report, EPA posits two greenhouse gas emissions reductions scenarios that are technically achievable. In this analysis, EPA was clear that the "illustrative example scenarios do not imply that EPA considers these to be the appropriate levels or dates for standards."[66] However, we were unable to identify other studies to complement EPA's work, and thus based all three of the scenarios on EPA's study. Therefore, we made the lackluster scenario more conservative by modeling one-half the reductions achieved by EPA's least ambitious scenario, scenario A. The middle-of-the-road scenario was modeled to match EPA's scenario A. The go-getter scenario was modeled to match EPA's most ambitious scenario, scenario B.

Unlike the reductions for light-, medium-, and heavy-duty vehicles, off-highway mobile sources were not independently modeled for this analysis, as sufficient information about the sources and policies is not available. Instead, reductions were taken directly from EPA's study. These reductions were adjusted to remove the contribution from operational improvements because EPA has not mandated such operational improvements to date in these standards. Therefore, for the lackluster, middle-of-the-road, and go-getter scenarios, we assumed that new standards can achieve an additional 0.9 percent, 1.8 percent, and 2.4 percent annual improvement, respectively, in the emissions rate for new equipment and engines from 2018 to 2035.

3. Modeling Notes for Off-Highway Sources

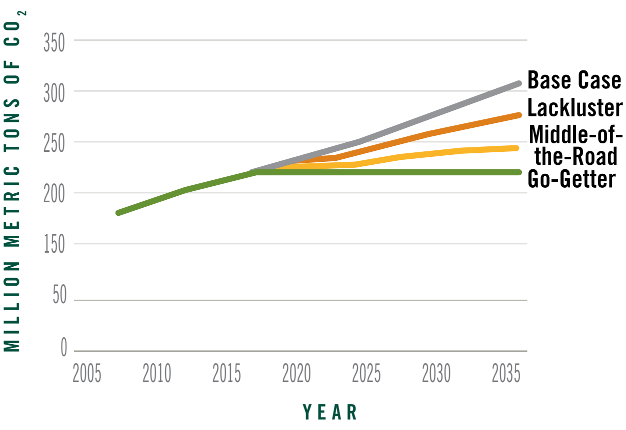
EPA's scenarios result in emissions reductions through increased equipment electrification. We therefore estimated increased electric demand and fed that into the electricity demand module to capture the resulting increases in electricity emissions. For off-highway electrification, the increase in electricity demand in 2035 is 12, 23, and 80 TWh for the lackluster, middle-of-the-road, and go-getter scenarios, respectively. These increases represent 0.3 percent to 1.8 percent of total electricity demand in 2035 under the AEO2012 reference case.

TABLE A-1.5 Vehicle Emissions and Efficiency Standards Scenarios, Off-Highway

LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
0.9 percent annual improvement in the emissions rate for new equipment and engines from 2018 to 2035	1.8 percent annual improvement in the emissions rate for new equipment and engines from 2018 to 2035	2.4 percent annual improvement in the emissions rate for new equipment and engines from 2018 to 2035

EPA's analysis was based on AEO2009. We were unable to adjust these results to account for any differences between AEO2012 and AEO2009 because the analyses do not clearly break out emissions from off-highway mobile sources.

FIGURE A-1.11 **Carbon Dioxide Emissions from Off-Highway Mobile Sources**



D. AVIATION

1. Base Case for Aviation

The emissions base case for aviation emissions was developed using projected energy use as found in the AEO2012 table, *Transportation Sector Key Indicators and Delivered Energy Consumption*. AEO2012 builds in a steady improvement in energy efficiency. Nevertheless, emissions are expected to increase through 2035 due to increased miles traveled; in 2035, aircraft CO_2 emissions are about 11 percent higher than 2010 levels.

2. Lackluster & Middle-of-the-Road Scenarios for Aviation

The FAA can 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.[67]

Operational improvement scenarios were developed using the *EPA Analysis of the Transportation Sector.*[68] In this report, EPA concluded that it was possible to achieve operational improvements in the range of 0.7 percent to 1.4 percent per year, but noted that the FAA thought that operational improvements realized through NextGen would only reach between 0.17 and 0.4 percent per year. To remain conservative in the lackluster scenario, we modeled a 0.17 percent annual improvement starting in 2014. This results in emissions that are 3 percent below base case levels in 2035, but which are 7 percent greater than 2010 levels. In the middle-of-the-road scenario, we use the higher range reported by FAA, 0.4 percent per year. This results in an 8 percent reduction in emissions compared to the base case in 2035, which is 2 percent above 2010 levels.

3. Go-Getter Scenario for Aviation

In the go-getter scenarios, we relied on the most ambitious estimates from the *EPA Analysis of the Transportation Sector* (scenario B), which concludes that it is possible to achieve a 1.4 percent annual operational improvement. We assume that this rate of change remains constant through 2035.

In addition, we assume that EPA implements GHG emissions standards for airplanes under Title II of the Clean Air Act in 2018. (Note that while EPA may

TABLE A-1.6 **Vehicle Emissions, Efficiency Standards, and Operational Improvements Scenarios, Aviation**

LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
0.17 percent annual emissions reduction through 2035 via operational improvements through the FAA NextGen program.	0.4 percent annual emissions reduction through 2035 via operational improvements through the FAA NextGen program.	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 2035.

implement GHG emissions standards, FAA enforces those standards.) This also comes from EPA's transportation analysis, which concludes that by 2030, it may be possible to see engine improvements around 20 percent, and airframe weight and drag reductions between 5 and 20 percent. They model this as a 2.3 percent per year annual improvement in aircraft efficiency.

EPA's estimates are comparable to the International Civil Aviation Organization (ICAO) *Report of the Independent Experts of Fuel Burn Reduction Technology Goals*, which suggests efficiency gains of 19–25 percent (in fuel-burn) could be achieved by 2020, and efficiency gains between 26 and 41 percent could be achieved by 2030.[69] In addition, the *International Air Transport Association Technology Roadmap Report* concludes that it might be possible to reduce emissions 23–30 percent in the 2020 time frame, and 25–50 percent in later years.[70] FAA's Continuous Lower Emissions, Energy, and Noise (CLEEN) program has a near-term goal of a 33 percent reduction in fuel burn relative to current technology.[71]

We acknowledge that EPA has never before established aircraft emissions standards for any air pollutant that are more stringent than those set by ICAO, and therefore do not include aircraft standards in the lackluster or middle-of-the-road scenarios. However, the ability to establish aircraft emissions standards lies soundly within their authority under Title II of the Clean Air Act. It is worth noting that there may be other paths forward to achieve these improvements in new aircraft standards. ICAO's Committee on Aviation Environmental Protection is also in the process of developing a new international standard for aircraft carbon dioxide emissions levels and is aiming for a 2013 completion date for the standard.[72]

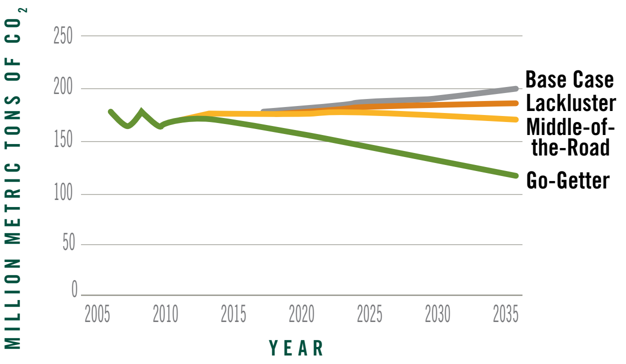
As a point of comparison, the European Union's (EU's) Emission Trading System (ETS) for aircraft requires a 3 percent reduction in 2005 emission levels starting in 2012 and a 5 percent reduction from the same base year from 2013 through 2020. This is comparable to the results for the middle-of-the-road scenario. In November 2012, the EU ETS proposed deferring participation in these emissions reductions for flights to and from Europe in anticipation of progress toward an international market-based approach to regulating GHG emissions from aviation by ICAO in 2013. The legislation still applies to all flights within and between the 30 participating European countries within the EU ETS.[73]

4. Model Uncertainty for Aviation

There are uncertainties regarding projected unit turnover, aircraft efficiency, and demand. In addition, based on EPA's analysis there appear to also be considerable uncertainties about the actual benefits from FAA's NextGen program. All of these will impact actual CO_2 emissions in the future.

There is no guarantee that the level of efficiency improvements (and thus emissions reductions) built into the AEO2012 will occur without regulations. Emissions standards on aircraft may therefore be necessary to capture efficiency improvements assumed by AEO2012, and thus in the base case as well as lackluster and middle-of-the-road scenarios.

FIGURE A-1.12 Carbon Dioxide Emissions from Aircraft



V. Non-Energy CO_2 and Non-CO_2 Emissions

A. BASE CASE FOR NON-ENERGY EMISSIONS

According to EPA's latest emissions inventory, non-energy emissions accounted for roughly 20 percent of 2010 emissions. Due to data limitations and an evolving understanding of natural gas systems, the base case projections for non-energy CO_2 emissions and non-CO_2 gases come from several different sources. We project that non-energy emissions will increase roughly 18 percent above 2005 levels by 2020 and 36 percent above 2005 levels by 2035, even after accounting for recently finalized regulations that affect natural gas systems and HFCs emissions from vehicles (based on HFC emissions, not consumption).[74]

Non-CO_2 gas projections for all sources except for natural gas systems and HFCs came from EPA's *Draft*

Global Non-CO$_2$ Emissions Projections Report: 1990-2030.[75] In this report, EPA developed country-specific emission projections using assumptions about economic activity, technology development, emissions reductions from well-established programs or international sector agreements, and other factors. Results were provided in five-year intervals. We estimated emissions between the five-year intervals by applying a linear rate of change. Emissions for 2030 through 2035 were estimated by applying the same rate of change observed from 2025 to 2030.

The technical understanding of emissions from natural gas systems is continually evolving, particularly with regard to shale gas. Therefore, historical emission levels and base case projections utilized analysis conducted for a forthcoming working paper by WRI, *Clearing the Air on Shale Gas Emissions: Assessing and Reducing the Carbon Footprint of Natural Gas.*[76] This report builds on the synthesis of recent lifecycle analyses by Weber and Clavin, *Life Cycle Carbon Footprint of Shale Gas: Review of Evidence and Implications,*[77] EPA's Inventory of Greenhouse Gas Emissions and Sinks 2012,[78] and AEO2012.

Because EPA's *Draft Global Non-CO$_2$ Emissions Projections Report: 1990–2030* lumped natural gas systems with petroleum systems, we projected methane emissions from petroleum systems separately using historical emissions,[79] historical production data,[80] as well as projected production data.[81]

For the base case, we rely on projections of HFC consumption estimated by EPA in *Benefits of Addressing HFCs under the Montreal Protocol.*[82] Consumption is roughly equal to life-cycle emissions due to low rates of HFC reclamation and destruction. The main difference is that emissions for some products can be delayed many years after their production. As discussed below, annual emissions estimates could be developed using more detailed models of equipment and products. However, those models and underlying data are proprietary.

Non-energy CO$_2$ emissions projections were not provided in EPA's *Draft Global Non-CO$_2$ Emissions Projections Report: 1990–2030,* and so instead come from the Applied Dynamic Analysis of the Global Economy (ADAGE) reference scenario of EPA's modeling of the American Clean Energy and Security Act of 2009 (ACES).[83] ADAGE is a dynamic computable general equilibrium model run by RTI International.[84] ADAGE projects emissions in five-year intervals from 2010 to 2050. To estimate emissions between those intervals, we applied a linear rate of change between intervals.

The sources of the base case projections do not present the same level of detail as does the AEO reference case for energy-related CO$_2$ emissions. Therefore, in the sections that follow we simply describe the reported output for each of the base case emissions projections and where appropriate, describe any steps we took to adjust these projections.

B. NATURAL GAS SYSTEMS

1. Base Case for Natural Gas Systems

Natural gas production has increased by over 20 percent over the past five years[85] on account of rapid development of shale gas resources. Technology advancements in horizontal drilling and hydraulic fracturing have enabled access to vast supplies of natural gas deposits in shale rock formations.[86] The climate implications of shale gas development have been a point of particular controversy due to uncertainty around the methane emissions associated with development of shale gas wells and other portions of the natural gas system.

Our base case emissions projections come from analysis conducted for *Clearing the Air on Shale Gas Emissions,* a forthcoming WRI working paper that examines emissions and abatement opportunities for natural gas systems. Their base case projections were developed using EPA's 2012 *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010,*[87] shale gas production projections from AEO2012, and fugitive emissions rates from *Life Cycle Carbon Footprint of Shale Gas: Review of Evidence and Implications.*[88]

Our base case includes a suite of standards finalized by EPA in April 2012, including New Source Performance Standards (NSPS)[89] for volatile organic compound (VOC) emissions and National Emissions Standards for Hazardous Air Pollutants (HAP) from U.S. natural gas systems.[90] 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.[91] The NSPS will result in further reductions of GHGs and VOCs from high-bleed

TABLE A-1.7 Performance Standards for Natural Gas Systems

LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
EPA performance and emissions standards achieve 21-29 percent reduction in CH_4 emissions compared to projections without standards through the use of green completions and dry seal processors		
Emissions reductions of 26 percent from base case starting in 2019. Assumes implementation of plunger lift systems to reduce emissions from liquids unloading at new and existing wells, and leak monitoring and repair to reduce fugitive emissions from production, processing, and compressor stations.	Emissions reductions of 37 percent from base case in 2019. Assumes implementation of measures in lackluster scenario and conversion of existing high-bleed pneumatic controllers to low-bleed or no-bleed controllers to reduce emissions from production, processing, and transmission.	Emissions reductions of 67 percent from base case starting in 2019. Assumes implementation of measures in middle-of-the-road scenario as well as: 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.

compressors. The NSPS and emission standards for HAPs from storage tanks will also reduce GHGs and VOCs, though to a lesser extent.[92]

Clearing the Air on Shale Gas Emissions projects that the new standards will reduce methane emissions by approximately 65 $mmtCO_2e$ in 2020 and 85 $mmtCO_2e$ in 2035, and as a result total base case emissions (methane and carbon dioxide) will be 240 $mmtCO_2e$ in 2020 and 250 $mmtCO_2e$ in 2035.

2. Lackluster Scenario for Natural Gas Systems

Our lackluster scenario assumes that EPA implements regulations that require natural gas systems to employ:

1. Plunger lift systems to reduce emissions from liquids unloading at new and existing wells; and
2. Leak monitoring and repair to reduce fugitive emissions from production, processing, and compressor stations.[93]

These emissions control technologies are projected to pay for themselves within one to two years, even without a price on carbon.[94] *Clearing the Air on Shale Gas Emissions* projects that widespread adoption of these technologies would reduce methane emissions 26 percent below base case projections.[95] We assume that reductions commence in 2019.

3. Middle-of-the-Road Scenario for Natural Gas Systems

Our middle-of-the-road scenario assumes that EPA implements regulations that require natural gas systems to employ the above emissions control technologies—as well as conversion of existing high-bleed pneumatic controllers to low-bleed or no-bleed controllers—to reduce emissions from processing and transmission. This technology is predicted to have a payback period of less than two years with a $20 price on carbon, and is projected to pay for itself within three years even without a price on carbon. Clearing the Air on Shale Gas Emissions projects that widespread adoption of these three technologies would reduce methane emissions roughly 37 percent below base case projections.[96] We assume that these reductions commence in 2019.

4. Go-Getter Scenario for Natural Gas Systems

Our go-getter scenario assumes that EPA implements regulations that require natural gas systems to employ all of the emission control technologies identified in the lackluster and middle-of-the-road scenarios, as well as:

1. Hot taps to reduce emissions from pipeline maintenance and repair during transmission;
2. Desiccant dehydrators to reduce emissions during dehydration of wet gas;
3. Improved compressor maintenance to reduce emissions during processing; and
4. Vapor recovery units to reduce emissions during storage.

The technologies were identified by the Natural Resource Defense Council's Leaking Profits report as being both technically feasible and profitable, each with a payback period of less than three years under NRDC's assumptions.[97] Using the same methodology and conservative assumptions as were employed in the WRI working paper Clearing the Air on Shale Gas Emissions, these emission control technologies are found to achieve 67 percent reduction in emissions from the base case projections.[98] We assume that the standards lead to reductions beginning in 2019.

5. Modeling Notes for Natural Gas Systems

Emissions from natural gas systems are related to the amount of natural gas produced. While the AEO2012 reference case shows the U.S. going from being a net importer to a net exporter of natural gas by the early 2020s, consumption and production levels remain within 5 percent of each other through most of our study period.[99] Based on this observation, in this analysis we employ the simplifying assumption that changes in natural gas demand will result in equivalent changes in natural gas production in the United States. In each of the scenarios, methane and carbon dioxide emissions levels were adjusted to account for changes in natural demand from electricity generation, residential and commercial appliances, and industry.

We do not attempt to sort out the relative change in conventional and unconventional production. This is not expected to significantly impact the results, as we project the emissions rate for conventional and unconventional sources to be within 5 to 30 percent of one another across all scenarios.[100] Across all scenarios, natural gas demand is not expected to change by more than 12 percent,[101] and changes in upstream emissions of natural gas are estimated to be less than 0.1 percent of total economy-wide GHG emissions reductions.

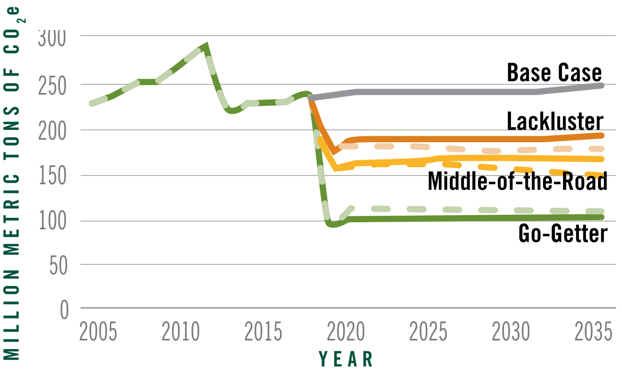
6. Uncertainties for Natural Gas Systems

WRI analysis of greenhouse gas emissions from natural gas systems relies in large part on activity data from EPA's 2012 Inventory, as well as on lifecycle analyses that utilize data from that inventory. However, The American Petroleum Institute (API) and America's Natural Gas Alliance (ANGA) published a joint study in September, 2012 that calls into question some of EPA's assumptions and methodologies in the agency's calculations for the largest sources of leaked and vented methane from natural gas systems. This industry-led study is noteworthy because it presents measurement data from 19 of the 21 largest basins across the U.S. Additional measurement data will be published over the course of the next year – including a study led by Environmental Defense Fund[102] and measurement data provided to the EPA under Subpart W of the Greenhouse Gas Reporting Program[103] – that will help clarify the still-murky picture of natural gas systems emissions.

Specifically, the API and ANGA study reports a much lower frequency of liquids unloading, and a much lower emissions factor for the venting associated with this process, than does EPA in the 2012 Inventory. API and ANGA also estimate a much lower refracture rate for hydraulically fractured wells than is used in the 2012 Inventory.

Using the results from the API/ANGA study in place of the activity data from EPA's 2012 Inventory would reduce historical estimates of methane and carbon dioxide emissions from natural gas systems, the base case projection of those emissions, and the reductions from that baseline from EPA's existing standards and from our three reduction scenarios. The baseline projections would be reduced by 14-21 percent from 2020-2035. The EPA performance and emissions standards finalized in 2012 would achieve a 21-26 percent reduction in methane emissions starting in 2013 compared to projections without standards, compared to 21-29 percent using the 2012 Inventory. Likewise, implementing regulations consistent with our lackluster, middle-of-the-road, and go-getter scenarios

FIGURE A-1.13 Total Methane and Carbon Dioxide Emissions from Natural Gas Systems (Federal)



Solid lines indicate changes in base case emissions due to new emissions standards for natural gas systems.

Dashed lines indicate changes in emissions after accounting for changes in demand.

Note: Carbon dioxide emissions range from around 30MMtCO$_2$e to 43MMtCO$_2$e across all scenarios.

described above would lead to reductions in methane emissions from the base case between 2019 and 2035 that are equivalent to roughly 22 percent, 35 percent, and 51 percent, respectively. These compare to 26, 37, and 67, respectively, using the 2012 Inventory. Using the results from the API/ANGA study, the federal go-getter scenario only reduces emissions 16.3 percent below 2005 levels, and thus additional state (or legislative) action would be needed to achieve the 17 percent reduction target.

C. HYDROFLUOROCARBONS (HFCS)

1. Base Case Scenario for Hydrofluorocarbons

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, HCFCs, are also phased out as they are currently being replaced with gases that have a high global warming potential.[104] EPA's *Draft Global Non-CO_2 Emissions Projections Report: 1990-2030* projects that if current trends continue, hydrofluorocarbons (HFCs) emissions will increase from 143 mmtCO_2e in 2010 to roughly 411 mmtCO_2e in 2035.[105]

EPA's projections were developed using the Vintaging model, a proprietary bottom-up model of "ozone-depleting substances (ODS) and ODS-substitute-containing equipment and products to estimate the use and subsequent emissions of ODS substitutes in the U.S."[106] Without this model, we were unable to develop robust estimates of actual emissions due to changes in consumption. Therefore, we relied on projections of HFC consumption estimated by EPA in *Benefits of Addressing HFCs under the Montreal Protocol* for the base case.[107] In this report, EPA projects that HFC consumption in the U.S. will increase from 300 mmtCO_2e in 2010 to roughly 580 mmtCO_2e in 2035. These projections do not, however, account for the HFC benefits projected from EPA's GHG emissions standards for light-, medium-, and heavy-duty vehicles. For light-duty vehicles, EPA offers a credit to manufacturers that reduce HFC leakage from AC systems. The emissions standards for medium- and heavy-duty vehicles, on the other hand, establish specific standards for HFC leakage from heavy-duty pickup trucks and vans as well as combination tractors. We adjusted these projections using estimated HFC abatement from light-duty vehicles as reported in EPA's OMEGA model outputs[108] and from medium- and heavy-duty vehicles using EPA and NHTSA's regulatory impact analysis (RIA).[109] We assumed that reported lifetime reductions in HFC emissions for each vehicle model year corresponded to the same level of reductions in consumption. After accounting for these new regulations, we project in the base case that HFC consumption will only increase to 543 mmtCO_2e in 2035 (37 mmtCO_2e less than the 580 mmtCO_2e predicted in *Benefits of Addressing HFCs under the Montreal Protocol*).

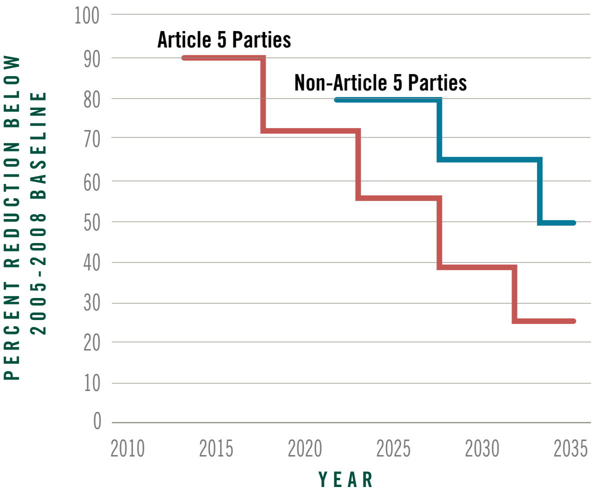
2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for Hydrofluorocarbons

On May 9, 2012, the U.S. filed a joint proposal with Canada and Mexico to amend the Montreal Protocol. That proposal calls for a ramp-down of emissions of high global warming potential (GWP) HFCs, so that in 2033 production and consumption of HFCs on a GWP-weighted basis are 15 percent of base case emissions in the U.S. and other developed countries (specifically, non-Article 5 Parties). The baseline is defined as the average of 2005–2008 HFC consumption plus 85 percent of the average 2005–2008 HCFC consumption. The proposal puts forth a separate, slightly less aggressive reduction schedule for developing countries listed under Article 5 of the Montreal Protocol (see Figure A-1.14).

TABLE A-1.8 Emissions Reduction Schedule for Hydrofluorocarbons

LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Consumption ramp-down occurs three years later than the schedule detailed in the joint North American Proposal.	Consumption is ramped-down in a manner consistent with the joint North American Proposal, which calls for an 85 percent reduction below 2005–2008 levels by 2033.	Consumption is ramped-down more rapidly than in the joint North American Proposal, achieving the 85 percent reduction target in 2028, five years earlier than detailed in the joint North American Proposal.

FIGURE A-1.14 HFC Reduction Schedules



Source: *Benefits of Addressing HFCs under the Montreal Protocol,* U.S. EPA, June 2012.

EPA's authority for regulating emissions of ozone-depleting substances comes from Title VI of the Clean Air Act. The phasedown of HFCs could be implemented through its Significant New Alternatives Policy (SNAP) program. The SNAP program implements section 612 of the Clean Air Act, which calls for the replacement of ozone-depleting substances with substitutes that reduce the overall risk to human health and the environment. Under the SNAP program, EPA may restrict or prohibit the use of unacceptable substitutes and classify substitutes that are acceptable.[110] In its report, *Benefits of Addressing HFCs under the Montreal Protocol*,[111] EPA notes that the most promising options for reducing HFC consumption through the SNAP program include:

- "Substituting HFCs with low-GWP or no-GWP substances in a variety of applications (where safety and performance requirements can be met);
- Implementing new technologies that use, at installation and/or over the lifetime of the equipment, no or significantly lower amounts of HFCs; and,
- Various process and handling options—including the principles of refrigerant recovery and management implemented during the CFC phaseout—that reduce consumption during the manufacture, use, and disposal of products that contain or use HFCs."

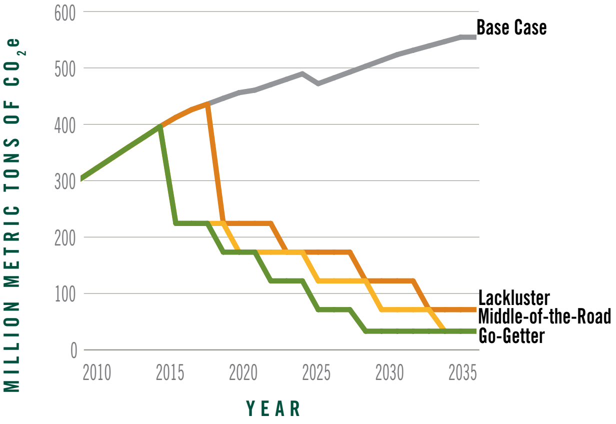
We note that Title VI provides additional authority to EPA to reduce HFCs beyond the SNAP program, including sections 608 and 609. We assume that EPA will either implement the ramp-down schedule after it is included in an international agreement, or will seek to achieve similar reductions through existing authority absent such an agreement. Because the reduction schedule proposed by the United States achieves relatively large reductions from the base case, and because they have signaled a strong intention to pursue this long-term path, in the middle-of-the-road scenario we assume that EPA takes action to achieve the reduction schedule proposed for non-Article 5 Parties.[112] In the lackluster scenario, we assume that a similar reduction schedule is followed, except that the reductions commence beginning in 2019 instead of 2016.

Our go-getter scenario assumes that EPA sets standards that result in a more aggressive reduction schedule so that an 85 percent reduction in consumption is achieved five years before the middle-of-the-road scenario. This results in a 61 percent reduction in consumption in 2020 compared to the base case projections in the same year. The full schedules are detailed in Figure A-1.14.

3. Modeling Notes for Hydrofluorocarbons

Using these HFC consumption-based estimates, we find that go-getter action for HFCs and other sectors will result in economy-wide U.S. GHG emissions that are 17 percent below 2005 levels in 2020. As noted above, we did not have access to the Vintaging model or similar models that would have allowed us to develop robust estimates of actual emissions due to changes in consumption. However, we developed a basic emissions model to provide rough estimates of 2020 emissions. This was only possible due to the relatively short time considered (i.e., 2020 as opposed to emissions through 2035), as it allowed us to minimize the variables of

FIGURE A-1.15 HFC Consumption



equipment turnover and recharging. The results of this analysis, showing economy-wide reductions in the range of 15 to 19 percent, were generally consistent with the consumption-based estimates we used in this study.[113]

D. COAL MINES

1. Base Case for Coal Mines

The base case utilizes EPA's *Draft Global Non-CO$_2$ Emissions Projections Report: 1990–2030*, which projects methane emissions will increase from 70 mmtCO$_2$e in 2010 to 87 mmtCO$_2$e in 2035.

2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for Coal Mines

All scenarios assume that EPA establishes performance standards for new and existing coal mines in a manner that results in abatement of methane emissions consistent with the cost-effective reductions identified in EPA's marginal abatement cost curves. For example, reductions from coal mines can be achieved through degasification and pipeline injection and through oxidation of ventilation air methane. For simplicity, we assumed that relatively few new coal mines would come online between 2012 and 2017, and thus do not model any reductions until 2019, the earliest expected date that performance standards could be in place for existing coal mines. Table A-1.9 shows the level of GHG emissions reductions achieved under the three scenarios, and the corresponding cost per ton from EPA analysis.

We based our assessment of achievable emissions reductions using these measures on the marginal abatement cost curves found in EPA's *Preliminary Draft Global Mitigation of Non-CO$_2$ Greenhouse Gases Report (March 2012).*[114] Marginal abatement cost curves can serve as a useful point of reference because EPA will consider the cost of abatement when setting prescribed emissions rates for new and existing coal mines. EPA's marginal abatement curves provide cost information per ton of emissions reduced, and have been used by EPA with ADAGE emissions forecasts in various analyses. EPA's *Preliminary Draft Global Mitigation of Non-CO$_2$ Greenhouse Gases Report (March 2012)* represents an update to their 2006 report. Their 2012 analysis incorporates updated mitigation technologies, labor and energy costs, and emissions baselines with an updated modeling approach.

We based the lackluster scenario on the reductions achievable at a cost of $5 per ton of CO$_2$e. The middle-of-the-road scenario was based on the reductions achievable at a cost of $20 per ton of CO$_2$e. The go-getter scenario was based on the reductions achievable at a cost of $61 per ton of CO$_2$e.

The selected costs cover the range of prices that were considered at the federal and state level in cap-and-trade program design.[115] They also cover the range of prices considered in the report— *Technical Support Document: Social Cost of Carbon Regulatory Impact Analysis Under Executive Order 12866*, released in February 2010—prepared by the Interagency Working Group on the Social Cost of Carbon.[116] The social cost of carbon is meant to provide an estimate of the monetized damages associated with the incremental emissions of greenhouse gases. The estimates contained in the 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 $6–$73 in 2015 and $10–$100 in 2030.

It bears noting that there may be barriers to achieving the full technical reduction potential for emissions reductions through direct regulation as compared to a voluntary offsets program. According to EPA's inventory of coal mines for 2010, abandoned coal

TABLE A-1.9 **Methane Emissions from Coal Mines**

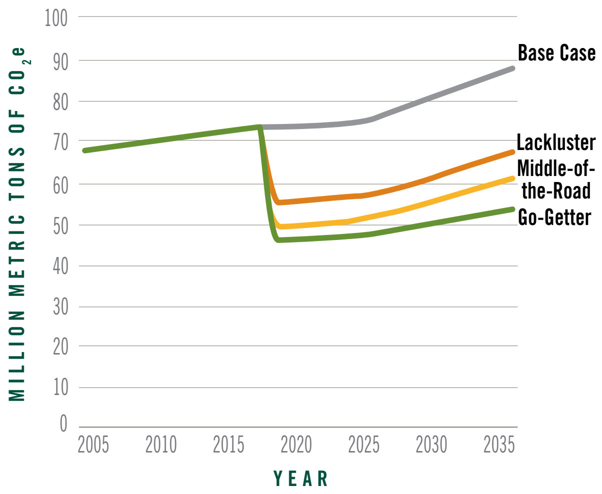
	ABATEMENT COST ($/TON CO$_2$e)	PERCENT REDUCTION FROM BASE CASE IN 2020 (PERCENT)	EMISSIONS (MMTCO$_2$e) 2010	2020	2035
Base Case	-	-	70	73	87
Lackluster	5	24 percent	-	55	66
Middle-of-the-Road	20	32 percent	-	50	59
Go-Getter	61	39 percent	-	44	53

mines (i.e., those that are not producing coal) account for approximately 6 percent of coal mine emissions.[117] Abandoned mines pose significant challenges to enforcement of standards. Therefore, we assume that only the 94 percent of coal mine methane that comes from active mines is abated in response to NSPS. This is consistent with EPA's P*reliminary Draft Global Mitigation of Non-CO_2 Greenhouse Gases Report (March 2012)*, which derives the abatement curves based on reductions of methane emissions from active mines only.

3. Uncertainties for Coal Mines

Our scenarios establish new standards for new and existing coal mines. EPA's marginal abatement cost curves, however, do not differentiate between new and existing mines. They also do not show significant changes in abatement over time (from 2020 to 2030). This means that the rate that new mines come into production should not significantly affect the abatement rate. Emissions will change, however, if production increases or decreases differently than is predicted by EPA. There is also uncertainty about what percentage of mines will be abandoned in future years. If that percentage increases above 6 percent, then emissions from this sector may increase beyond what is modeled here.

FIGURE A-1.16 **Methane Emissions from Coal Mines**



E. NITRIC AND ADIPIC ACID MANUFACTURING

A. Base Case for Nitric and Adipic Acid Manufacturing

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 according to the IPCC's *Fourth Assessment* has a global warming potential 298 times that of carbon dioxide over a 100-year timeframe.[118] For the base case we relied on EPA's *Draft Global Non-CO_2 Emissions Projections Report: 1990-2030*, estimating emissions for 2030 through 2035 by applying the same rate of change from 2025 to 2030. We project that N_2O emissions from nitric and adipic acid production will increase from 28 mmtCO_2e in 2010 to 38 mmtCO_2e in 2035.

2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for Nitric and Adipic Acid Manufacturing

All three scenarios assume that EPA establishes performance standards for new and existing nitric acid manufacturers in a manner that results in abatement of N_2O emissions consistent with the cost-effective reductions identified in EPA's marginal abatement cost curves. This generally would require some form of catalytic reduction for nitric acid manufacturers. For adipic acid manufacturers, this would likely require thermal destruction using reducing flame burners with premixed methane or natural gas.[119]

TABLE A-1.10 **Nitrous Oxide Emissions from Nitric Acid and Adipic Acid Manufacturing**

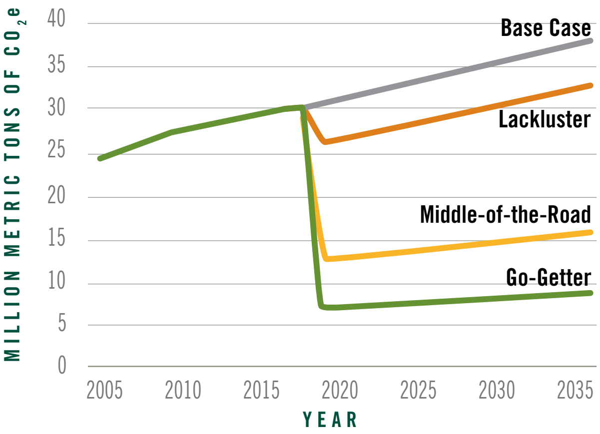
	ABATEMENT COST ($/TON CO_2e)	PERCENT REDUCTION FROM BASE CASE IN 2020 (PERCENT)	EMISSIONS (MMTCO_2e)		
			2010	2020	2035
Base Case	-	-	28	31	38
Lackluster	5	13 percent	-	27	33
Middle-of-the-Road	20	56 percent	-	14	16
Go-Getter	61	75 percent	-	8	9

For simplicity, we assumed that relatively few new production facilities would come online between 2012 and 2017, and thus do not model any reductions until 2019, the earliest expected date that performance standards could be in place for existing production facilities. Table A-1.10 shows the level of GHG emissions reductions achieved for both nitric and adipic acid facilities under the three scenarios, and the corresponding cost per ton from EPA analysis as discussed above in the coal mine section.

3. Uncertainties for Nitric and Adipic Acid Manufacturing

In this section, we model the impact of performance standards on new and existing units. EPA's marginal abatement cost curves do not differentiate between new and existing units, and do not predict significant changes in abatement over time (from 2020 to 2030). This means that the rate that new units come into production should not affect the abatement rate. However, if production increases or decreases differently than predicted by EPA, then emissions will change accordingly.

FIGURE A-1.17 **Nitrous Oxide Emissions from Nitric and Adipic Acid Manufacturing**



F. LANDFILLS

1. Base Case for Landfills

For the base case, we relied on EPA's D*raft Global Non-CO_2 Emissions Projections Report: 1990-2030*, which projects that methane emissions from landfills will remain relatively constant between 2010 (154 mmtCO_2e) and 2035 (152 mmtCO_2e).

2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for Landfills

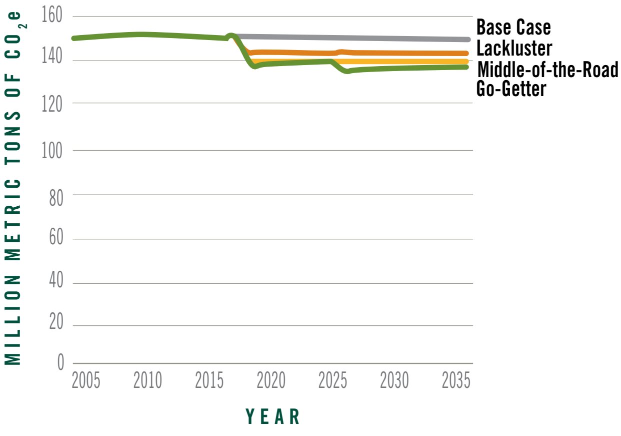
All three scenarios assume that EPA establishes performance standards for new and existing landfills in a manner that results in methane abatement consistent with the cost-effective reductions identified in EPA's marginal abatement cost curves. Abatement at landfills is accomplished through methane capture and destruction. For simplicity, we assumed that relatively few new landfills would come online between 2012 and 2018, and thus do not model any reductions until 2019, the earliest expected date that performance standards could be in place for existing landfills. Table A-1.11 shows the level of GHG emissions reductions achieved under the three scenarios, and the corresponding cost per ton from EPA analysis, as discussed above in the coal mine section.

Our previous analysis suggested that 44 to 74 percent of methane emissions from landfills could be abated under the three scenarios, based on data from EPA's 2006 release of its *Global Mitigation of Non-CO_2 Greenhouse Gases* report.[120] EPA's updated analysis, *Draft Global Non-CO_2 Emissions Projections Report: 1990-2030*, is thought to be more accurate as it includes more information on gas capture rates, mitigation options and costs, and labor costs. It also projects decreased prices for landfill methane gas, which reduces the benefit for methane capture.

TABLE A-1.11 **Methane Emissions from Landfills**

	ABATEMENT COST ($/TON CO_2e)	PERCENT REDUCTION FROM BASE CASE IN 2020 (PERCENT)	EMISSIONS (MMTCO_2e)		
			2010	2020	2035
Base Case	-	-	154	152	152
Lackluster	5	5 percent	-	145	144
Middle-of-the-Road	20	9 percent	-	139	138
Go-Getter	61	9 percent	-	138	135

FIGURE A-1.18 **Methane Emissions from Landfills**



3. Uncertainties for Landfills

EPA's marginal abatement cost curves do not differentiate between new and existing units, and predict minimal changes in abatement over time (from 2020 to 2030). This means that changes in the percentage of emissions attributable to new landfills (as opposed to older landfills) should not affect the abatement rate. However, if methane production increases or decreases due to changes in the quantities of waste going to landfills or landfill management practices, then emissions will change accordingly.

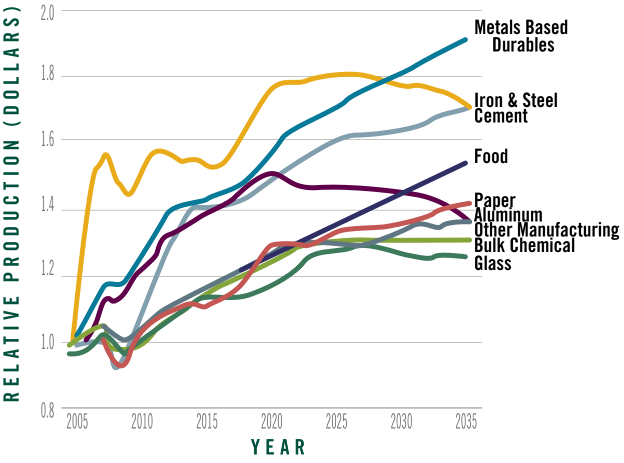
VI. Industry

A. MANUFACTURING

1. Base Case for Manufacturing

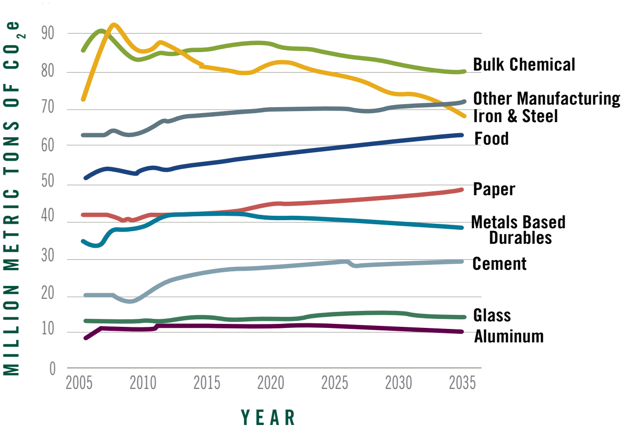
Baseline emissions for energy-related CO_2 emissions come from EIA's AEO2012. Under the AEO2012 reference scenario, each major manufacturing sector is projected to see an upward trend in production.[121] As a result, in 2035 total production exceeds production levels in 2009. The AEO reference case assumes that overall process efficiency will gradually improve over time. However, overall energy use and emissions are forecast to increase in most subsectors.[122] Due to mature technology and low turnover rates, boiler efficiency, however, remains relatively constant over time.[123]

FIGURE A-1.19 **Relative Changes in Production from 2009 for Major Manufacturing Sectors, Expressed in Inflation-adjusted Dollar Value of Shipments**



Source: *AEO2012,* U.S. EIA

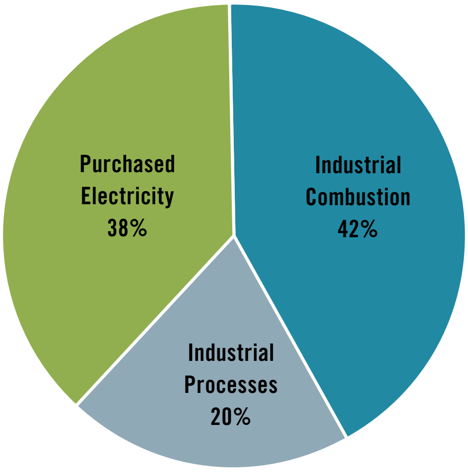
FIGURE A-1.20 **Base Case Carbon Dioxide Emissions from Fossil Fuel Combustion at Manufacturing Facilities**



Source: *AEO2012,* U.S. EIA

Emissions from onsite combustion and other industrial processes—such as those from limestone calcination in the cement production process—in the manufacturing sector are projected to grow from 527 mmtCO_2e in 2009 to 566 mmtCO_2e in 2035, amounting to a 7 percent increase in emissions over this time period (roughly three-quarters of these emissions result from onsite combustion, while the remainder are process emissions). Increases in emissions from the food, cement, and paper industries offset emissions reductions in the bulk chemical and iron and steel industries. More detailed sector breakdowns are depicted in Figure A-1.20. However, it is important to note that onsite combustion and other industrial processes account for only 62 percent of total emissions. The other 38 percent is due to emissions associated with purchased electricity (see Figure A-1.21).

FIGURE A-1.21 **Industrial Greenhouse Gas Emissions by Source, 2010**



Source: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010,* EPA.

2. Lackluster Scenario for Manufacturing

In its ANPR, EPA concluded that existing industrial boilers could achieve efficiency improvements of 1–10 percent, and that efficiency improvements of 10–33 percent could be obtained by replacing an existing boiler with a CHP unit.[124]

For the lackluster scenario, we assume that EPA establishes performance standards for new and existing industrial boilers. To simplify the modeling of this scenario, we assume that EPA establishes emissions limits for new and existing industrial boilers that achieve a 10 percent reduction in emissions beyond base case projections. This was modeled as a 10 percent reduction in fuel use across all boilers and fuel types in the manufacturing sector, which includes food, paper, bulk chemical, glass, cement, iron and steel,[125] aluminum, metals-based durables, and other manufacturing.[126] A comparable level of emissions reductions could be achieved through other combinations of new unit and existing unit standards.[127,128] Since in the early years few new units are expected, for simplicity we model these reductions starting in 2019 to account for the six-year time lag for developing performance standards for existing units.

3. Middle-of-the-Road Scenario for Manufacturing

According to NEMS support documentation for AEO2012, industrial boilers account for only 28 percent of manufacturing heat and power energy consumption, excluding byproduct fuels.[129] In the middle-of-the-road scenario, we therefore assume that EPA devises performance standards that account for the entire industrial facility and purchased electricity, instead of merely capturing boiler efficiency opportunities. This more holistic approach would capture efficiencies in the entire industrial process, thereby improving the rate of emissions per unit of output. This would require a slightly more expansive approach to performance standards than EPA has implemented in the past. However, it is worth noting that a similar approach was discussed by the Climate Change Working Group of the Clean Air Act Advisory Committee.[130] Such standards could take the form of output-based emissions rates, or (in the case of existing units) through a flexible compliance program for industry that rewards improvements in emissions per unit of output.

TABLE A-1.12 **Performance Standards to Reduce Industry Emissions**

	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Fossil-fuel Combustion in Manufacturing and Cement Kilns	Emissions reductions consistent with a 10 percent improvement in efficiency beyond base case levels starting in 2019.	Emissions reductions consistent with harnessing all cost-effective energy efficiency across the entire manufacturing facility. Emissions standards also drive reductions in process emissions from cement kilns.	Emissions reductions consistent with harnessing all cost-effective energy efficiency across the entire manufacturing facility; all new units must meet emissions rate equivalent to natural gas combustion. Emissions standards also drive reductions in process emissions from cement kilns.
Refineries	Emissions reductions consistent with a 1 percent improvement in efficiency.	Emissions reductions consistent with a 5 percent improvement in efficiency.	Emissions reductions consistent with a 10 percent improvement in efficiency.

In order to gauge the additional reductions achievable through process efficiency improvements beyond those included in AEO2012, we relied on a study commissioned by the Department of Energy (DOE), *Scenarios for the Clean Energy Future* (CEF).[131] The CEF study examines the effect of a suite of voluntary policies on reducing industrial emissions. In the CEF, two different policy implementation scenarios are analyzed: a moderate and advanced scenario. The CEF advanced scenario included voluntary sector agreements between government and industry and a suite of complementary policies, including expanded research and development and a domestic carbon dioxide emissions trading system with prices around $19 per ton of carbon dioxide.[132] This valuation of the impact of carbon dioxide emissions could be integrated into the development of sector-appropriate standards, whether they are in the form of source-specific emissions rates, or a more flexible compliance program.

The CEF study, which was completed in November 2000, was based on AEO1999. In *Real Prospects for Energy Efficiency in the United States,*[133] the National Academy of Sciences concluded that the percentage of reductions found in the CEF can be applied to more recent releases of the AEO. This was because "new energy efficiency opportunities arise each year as infrastructure and equipment ages, and as new and improved technologies are introduced into the marketplace."[134] For the middle-of-the-road scenario, we assumed that reductions commence in 2019 due to the time lag for establishing standards on existing units through section 111(d). We then assumed that industrial efficiency ramps up in a linear manner so that in 2025 it achieves the same percent improvement, relative to business-as-usual projections, as was found in the CEF study for 2010. We assumed that the relative energy efficiency benefits modeled in the CEF study for 2020 would be achieved in 2035. We also assume a linear rate of change between the reductions modeled in 2025 and 2035.

The built-in time lags are intended to provide the sector time to turn over stock and adopt improved efficiency measures at existing facilities. The precise amount of time needed to achieve these changes is uncertain, as the CEF analysis did not provide annual results, but instead presented findings at two separate intervals. For this scenario, we did not need to independently calculate unit turnover, as it is already built into the CEF reduction scenario. However, the CEF generally assumed a slightly higher unit retirement rate than is incorporated into the AEO, based on their own assessment of the retirement rates commonly observed across industrial classes. This level of efficiency and technology improvement leads to GHG emissions reductions of 16 mmtCO$_2$ in 2020 and 76 mmtCO$_2$ in 2035 from onsite combustion above what is projected in the base case. It also leads to reductions in purchased electricity of 28 TWh (3 percent) in 2020 and 168 TWh (21 percent) in 2035 compared to the base case.

4. Go-Getter Scenario for Manufacturing

In the go-getter scenario, we again assume that EPA captures efficiencies across the entire industrial process by establishing equipment efficiency standards, sector-wide benchmark standards, or some other flexible compliance program for industry. This is modeled using the CEF improvements in the same manner as the middle-of-the-road scenario. In the go-getter scenario, we also assume that EPA establishes emissions standards for all new combustion sources (not just boilers) equivalent to natural gas combustion. This could be accomplished through co-firing of biomass, use of natural gas, carbon capture and sequestration, or built into the reduction schedule of a flexible compliance program. Combined, these standards lead to reductions of 30 mmtCO$_2$e in 2020 and 97 mmtCO$_2$e in 2035 compared to the base case projections in the same years. Similar to the middle-of-the-road scenario, purchases of electricity are reduced by 28 TWh in 2020 and 168 TWh in 2035 compared to the base case.

5. Uncertainties for Manufacturing

The CEF's considerations of cost, unit turnover, and its direct comparison to projected efficiency improvements built into the AEO make it a particularly valuable study for incorporation into the model. Since this study was published, other analyses have been completed, but they do not provide these same features. Nevertheless, some of them warrant consideration for comparative purposes. Of note are the series of "bandwidth" studies sponsored by the Department of Energy's Industrial Technologies Program. These studies assess the amount of energy that can be saved from a particular industrial process and compare current average energy use to state-of-the-art practices and the practical minimum energy use. Since each of the bandwidth studies was conducted independently, there are some inconsistencies. The studies examine state of the art/best practice for each sector, which they generally define as the least energy-intensive option in current use. They also examine what they call the practical minimum, which varies somewhat between the energy required "assuming application of reasonable technologies such as heat recovery, batch preheating, etc,"[135] and the "energy required for a typical plant after deployment of new process technologies developed through applied research and development."[136]

Table A-1.13 compares the sector-specific findings of the bandwidth studies with energy savings modeled under this report's middle-of-the-road and go-getter scenarios. For instance, under our scenarios efficiency improvements from the paper and glass sectors are well below those that would be achieved if they employed the best practices identified in their respective bandwidth studies. Meanwhile, we predict that the GHG emissions reductions from the bulk chemical sector are between the energy savings identified from best practices and those identified with the practical minimum. Projected energy reductions from the iron and steel sector exceed the bandwidth's practical minimum by 3 percent[137] (the practical minimum is not expected to be technically feasible without additional research and development), raising questions about the feasibility of achieving the level of improvement modeled for the iron and steel industry in the CEF. However, in *Real Prospects for Energy Efficiency in the United States*, the National Academy of Sciences concludes that significant opportunities exist to reduce energy use in the iron and steel sector, pointing to a McKinsey and Company study that found 22 percent energy savings were obtainable by 2020 compared to 2007 levels, which is much greater than the 3 percent improvement the bandwidth study found for current best practices.[138] Furthermore, an American Iron and Steel Institute study, *Saving One Barrel of Oil per Ton*,[139] sets an industry-wide goal of reducing energy-use per ton of steel production by 39 percent in 2025 compared to 2003 levels. Due to this lack of consensus in the available literature in terms of potential efficiency improvements and a common baseline, we did not adjust the iron and steel numbers from those found in the CEF.

TABLE A-13 **Energy Savings and Energy-Related Carbon Dioxide Intensity Improvements in the Manufacturing Sector (percent)**

	ENERGY SAVINGS WITH BEST PRACTICE (BANDWIDTH)	ENERGY SAVINGS WITH PRACTICAL MINIMUM (BANDWIDTH)	TOTAL ENERGY SAVINGS IN 2035 WHEN COMBINE SAVINGS FROM CEF AND AEO2012	MODELED CO_2 INTENSITY IMPROVEMENT 2035 VS. 2012 (TONS CO_2 FROM COMBUSTION/VALUE OF SHIPMENT)			
				Base Case	Lackluster (10 percent efficiency gain all boilers)	Middle-of-the-Road (CEF)	Go-Getter (CEF + natural gas emissions rate for new units)
Food Products	NA	NA	33	20	26	37	40
Paper	26	39	11	19	25	38	42
Bulk Chemical	18	71	38	27	33	37	38
Glass	35	52	21	11	12	18	19
Cement	NA	NA	31	9	9	32	46
Iron & Steel	3	31	34	33	33	37	45
Aluminum	NA	NA	48	25	28	47	51

Note: The bandwidth study determined baseline energy consumption for paper manufacturing using 2002 Manufacturing Energy Consumption Survey (MECS) data, plus data collected for the report. The bandwidth study for glass was based on data collected through surveys collected for the report prior to publication in 2007. The bandwidth study for steel was based on energy-use data from 2000. The bandwidth study for bulk chemicals was based on energy data collected in 2004 for the report.[140]

Source: Steel Industry Energy Bandwidth Study. Energetics, Inc., U.S. Department of Energy, October 2004; Chemical Bandwidth Study Exergy Analysis: A Powerful Tool for Identifying Process Inefficiencies in the U.S. Chemical Industry. Dickson Ozokwelu, Joseph Porcelli, and Peter Akinjiola, U.S. Department of Energy, December 2006; Industrial Glass Bandwidth Analysis, David Rue, James Servaites, and Warren Wolf, U.S. Department of Energy, December 2006; Pulp and Paper Industry Energy Bandwidth Study, Jacobs Institute of Paper Science and Technology, American Institute of Chemical Engineers, August 2006.

There is considerable uncertainty in industrial unit turnover. Greater equipment turnover could lead to more significant reductions depending on the pace of new technology development and actual standards that are set for new units. Lower turnover would lead to fewer reductions.

There is also considerable uncertainty about the long-term production forecast for each manufacturing subsector. Increased production beyond what is modeled in the AEO2012 could increase emissions, but may also signal improved economics for domestic industry that would allow for greater investments in efficiency technologies and deeper cuts in GHG emissions.

Furthermore, this study relies heavily on the CEF to estimate the emissions reductions achievable if plant-wide efficiency opportunities were incorporated into GHG performance standards. The CEF study considers cost, unit turnover, and directly compares efficiency gains to those built into the AEO. More current assessments would be necessary before regulatory standards could be established for these sectors. New assessments would likely produce different estimates for each manufacturing sector than what we modeled here. Nevertheless, we believe that this analysis provides a sense of the range of reductions achievable through federal authority given the assessments currently available.

6. Modeling Notes for Manufacturing

Changes in purchases of electricity are accounted for in the electricity demand module. Because we relied on EIA's AEO2012 $25 carbon tax scenario for the go-getter power sector generation projections, we had to make adjustments to industrial efficiency savings. This is because the $25 carbon tax scenario includes industrial efficiency savings beyond those modeled in the AEO2012 reference case. Therefore, we incorporated only the benefits that occur beyond those included in the $25 carbon tax scenario, amounting to roughly 45 TWh of additional electricity savings in 2035.

Changes in natural gas consumption are accounted for in the natural gas demand module that adjusts upstream natural gas emissions to reflect downstream consumption patterns.

AEO2012 does not separate out new and older units in intermediary or final outputs for the industrial sector module. Therefore, we had to estimate unit turnover in order to account for the new unit standards in the go-getter scenario. Since the scenario is based on the CEF study, we employed the retirement rates found in the CEF, which are generally higher than those used in the AEO2012. In this analysis, modeling of new unit development is somewhat simplified and can lead to the overdeployment of new units if production rapidly changes for a very brief period of time. To prevent that from occurring, we smoothed the production curves upon which turnover was based. The model did not build out new units if it projected that sector production would result in a surplus supply within seven years of new unit construction. Seven years was chosen because it parallels the AEO2012 assumption that new units are not eligible to retire within the first seven years of construction.

B. CEMENT KILNS

1. Base Case for Cement Kilns

Base case emissions for energy-related CO_2 emissions are discussed above in Section VI.A. In 2010 CO_2 emissions from energy consumption accounted for 46 percent of total CO_2 from cement plants, while the remaining CO_2 emissions were the result of chemical processes (limestone calcination) associated with cement production.[141] In the analysis, we relied on ADAGE for the base case projections of non-energy CO_2 emissions. However, ADAGE does not include a separate line item for cement process emissions, but instead folds them into a broader category that includes process emissions from all energy-intensive manufacturing. Therefore, we developed our own projections. We determined the percentage of industrial process CO_2 emissions attributable to cement production in 2010 using EPA's *2012 Inventory of Greenhouse Gas Emissions and Sinks*,[142] and multiplied this by AEO2012 projections. We then multiplied 2010 emissions by the percent change in cement output for all subsequent years, as obtained from Table 30 of AEO2012, "Cement and Lime Industry Energy Consumption." Using this approach, we estimate that process emissions will increase from 36 mmtCO_2 in 2010 to 42.5 mmtCO_2 in 2035 under the base case. This methodology is viable because AEO2012 does not increase the use of blended cements. Even though section 108 of the Energy

Policy Act of 2005 requires federally funded projects to increase the recovered mineral fraction in cement (e.g., fly ash or blast furnace slag), AEO2012 does not include this requirement because the proportion of mineral component is not specified in the legislation or subsequent regulations.[143]

2. Lackluster Scenario for Cement Kilns

In the ANPR, EPA concluded that the range of effectiveness of individual efficiency measures for existing cement plants was less than 1 percent to 10 percent.[144] EPA also notes that benchmarking and other studies have demonstrated that the most efficient new plants can use 40 percent less energy than older plants using wet kilns. However, AEO2012 assumes that no new wet kilns are built and that all new cement plants are dry kilns,[145] making this comparison less relevant for purposes of this analysis. Therefore, for the lackluster scenario, we assume that EPA establishes performance standards for GHGs for new and existing boilers at cement plants that achieve a 10 percent reduction in emissions beyond business-as-usual projections, which is consistent with the manufacturing lackluster scenario above. Facilities could meet these standards through efficiency improvements or fuel switching.

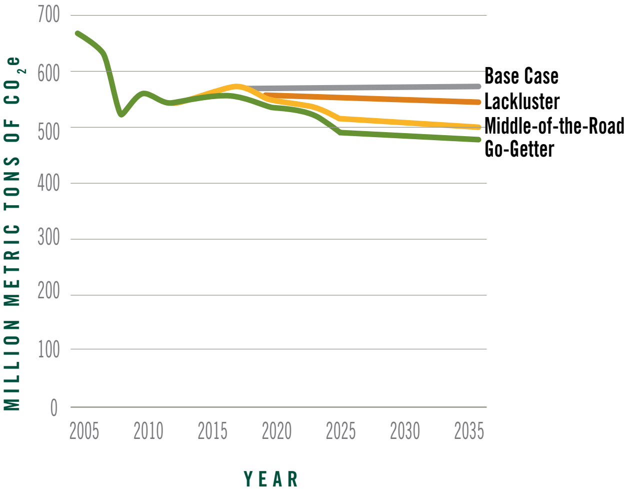
3. Middle-of-the-Road and Go-Getter Scenarios for Cement Kilns

According to AEO2012, boilers are projected to only account for 3 percent of total energy consumption at cement plants in 2012. Therefore, in the middle-of-the-road and go-getter scenarios, we assume that EPA requires facilities to capture emissions reduction opportunities in the entire industrial process that reduce emissions from onsite combustion and purchased electricity. This could be accomplished through output-based emission rate standards or through a more flexible compliance mechanism. In the go-getter scenario, we also assume that EPA establishes emissions standards for all combustion sources in new cement kilns (not just boilers) through New Source Performance Standards, and that those standards require an emissions rate equal to the emissions rate of natural gas combustion. This could be accomplished through co-firing of biomass, fuel switching, carbon capture and sequestration, or built into the reduction schedule of a flexible compliance program. We modeled the middle-of-the-road and go-getter scenarios for cement kilns using the same methodology that we employed for the manufacturing sector middle-of-the-road and go-getter scenarios. The only difference between the cement scenarios and the other manufacturing scenarios is that we also consider reductions in process emissions from the cement sector in our middle-of-the-road and go-getter scenarios. We assume that this is primarily accomplished through greater use of blended cements. Alternatively, cement kilns could comply through the employment of carbon capture and storage. Applying CEF reduction percentages based on more widespread use of blended cements leads to reductions in CO_2 process emissions of 2 percent in 2020 and 13 percent in 2035. CO_2 emissions reductions are detailed in Figure A-1.22 in the middle-of-the-road and go-getter scenarios

4. Uncertainties for Cement Kilns

The uncertainties detailed in the manufacturing sector also apply to the cement sector. We note, however, that there is also considerable uncertainty about the long-term production forecast for cement. Increased production beyond that modeled in AEO2012 could increase emissions, but may also signal improved economics for domestic industry that would allow for greater investments in efficiency technologies and deeper cuts in GHG emissions.

FIGURE A-1.17 Carbon Dioxide Emissions from Industrial Fossil Fuel Combustion and Processes



C. PETROLEUM REFINERIES

1. Base Case for Petroleum Refineries

Base case emissions start with the AEO2012 reference case, which predicts that CO_2 emissions from combustion at refineries will increase from 268 mmtCO_2 in 2012 to 323 mmtCO_2 in 2035. However, the AEO2012 reference case does not include the EPA and NHTSA extension of the national GHG emissions and CAFE standards for model year 2017 through 2025 light-duty vehicles, finalized in August 2012.[146] These standards are included in the base case, and thus we adjusted the base case projections for refineries to account for this reduced demand for refinery products. To calculate the refinery emissions reductions from decreased refinery product demand, we used the simplifying assumption of treating all refinery outputs as though their production required the same relative energy input. This resulted in comparable emissions per unit of production. We also assumed that imports and domestic production would decline at a similar rate, and thus a 10 percent reduction in demand would result in a 10 percent reduction in emissions at refineries located in the United States.

Using the above approach, we estimate that the existing standards will reduce refinery output by 5.2 percent by 2025 and 10.7 percent by 2035 in the base case. These projections are comparable to the AEO side case that considered the proposed vehicle standards.

Our base case assumptions for the projected relative contribution of each refinery product for years 2009–2035 comes from AEO2012.[147] The relative reduction in each refinery product was based on transportation scenario outputs and the relative contribution from each transportation sector in 2010, as reported in EPA's 2012 *Inventory of Greenhouse Gas Emissions and Sinks*.[148]

2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for Petroleum Refineries

In December 2010, U.S. EPA announced they would establish GHG performance standards for new and existing refineries using their authority under section 111 of the Clean Air Act. As part of this announcement they established a timeline to propose standards by December 2011 and finalize those standards by November 2012.[149] EPA has not met these deadlines, and has not yet issued proposed standards.

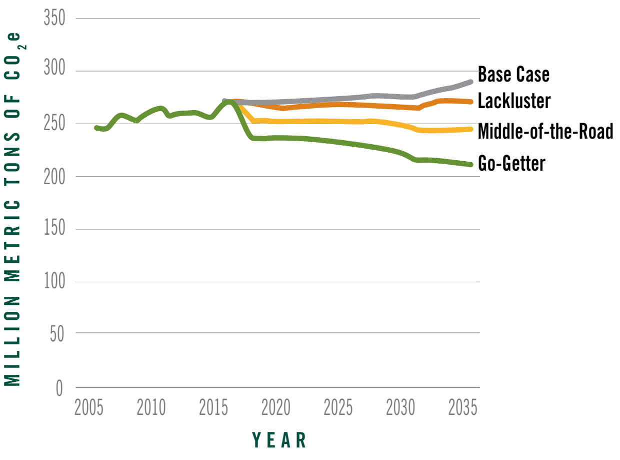
Therefore, in all scenarios, we assume that emissions from refineries are reduced by the establishment of performance standards for new and existing units. In the Advanced Notice of Proposed Rulemaking, EPA concludes that benchmarking data suggests that most existing refineries could economically improve energy efficiency by 10–20 percent, and that new refineries could be designed to be at least 20 percent more efficient than existing refineries.[150] One recent study, Energy Bandwidth for Petroleum Refining Processes, published in 2006 by industry experts for the DOE Industrial Technologies Program (ITP), reviewed five major industrial processes that account for roughly 70 percent of energy use in the refining sector. This study concluded that total energy savings of more than 35 percent are achievable using existing "best practices and state-of-the-art technologies under real-world conditions" for these five major processes, and that "plant-wide refinery energy savings potential is usually found to be around 30 percent."[151]

Also, according to a study by the National Academy of Sciences, *Real Prospects for Energy Efficiency in the United States*, identifying plant-wide energy savings of approximately 30 percent would be typical. However, the study also concludes that these gains will be offset by the use of increasingly heavier crude slates in the coming years, resulting in an overall increase in energy consumption per unit of refined product. To some extent these trends are being mitigated by recent production increases of light sweet crude oil from domestic shale plays.[152] The specific efficiency improvements built into the refinery module of AEO2012 are confidential, making it impossible to examine the specific efficiency improvements built into its projections. According to the AEO2012 table *Refining Industry Energy Consumption*, the total energy consumption per unit of refinery input remains relatively constant from 2010 through 2030. If crude slates become increasingly heavy, it may be challenging to get additional emissions reductions beyond those already included in AEO2012.

Given the lack of access to the data underlying AEO2012 projections and the limited inferences that can be drawn from available data, we take a conservative approach to modeling the refinery sector. All three of the reduction scenarios are derived from the lower range of estimates provided for existing units (i.e., 10 percent) by EPA in the ANPR. For the go-getter scenario, we assumed EPA would require existing units to reduce emissions 10 percent below future projected levels beginning in 2018 through GHG performance standards. For the middle-of-the-road scenario, we assumed that EPA would require existing units to reduce emissions 5 percent below future projected levels, and for the lackluster scenario, we assumed that EPA would require existing units to reduce emissions 1 percent below future projected levels. While we assume that EPA would establish standards for new and existing units, we only modeled reductions for existing sources. This is because AEO2012 does not predict significant deployment of new refineries after 2012,[153] and new development could be offset by reductions in demand caused by the transportation scenarios.

In addition, we examine GHG emissions reductions that result from decreased refinery operation. This is caused by further reductions in petroleum demand due to additional emissions standards for vehicles and industry, energy efficiency standards for home appliances, GHG performance standards for industry, and operational changes for aircraft. The model predicts a 4.8, 9.8, and 17.1 percent decrease in petroleum demand by 2035 compared to base case demand projections under the federal action-only scenarios (and even more when layering in state action). These demand reductions are thus major drivers of emissions reductions across the scenarios.

FIGURE A-1.23 Carbon Dioxide Emissions from Refineries



3. Uncertainties for Refineries Scenarios

The impact of changes in crude slates is uncertain. It is also not entirely clear what efficiency improvements have been built into the AEO2012 base case for refineries. Little unit turnover is projected and this could change, making the emissions reductions projections too low. Under the scenarios we considered, which were intentionally conservative, the primary source of emissions reductions in 2035 was reductions in demand, and not NSPS for refineries. Thus, actual refinery emissions will vary mostly based on actual fuel economy standards, fuel content standards, and changes in vehicle miles traveled.

VII. Appliance and Equipment Efficiency Standards (Heating)

A. MODELING APPROACH FOR APPLIANCE AND EQUIPMENT STANDARDS (HEATING)

Here we focus on opportunities to reduce GHG emissions by increasing the efficiency of appliances that use fossil fuel for purposes such as home heating, cooking, and water heating. We note that there are even greater opportunities to reduce direct combustion of fossil fuels in residential and commercial buildings through improved performance of the building envelope. However, building code policies directly affecting new and existing buildings have historically been controlled by U.S. states and municipalities. These policies are explored in the state scenarios.

Natural gas consumption accounts for the vast majority of onsite fuel consumption for residential and commercial buildings. According to AEO2012, natural gas is expected to account for about 78 to 80 percent of total onsite fuel consumption for residential and commercial buildings from 2012 through 2035. The next largest contributor is distillate fuel, which is only expected to account for about 6 to 9 percent of onsite fuel consumption. Due to this significant disparity, the energy savings primarily affect natural gas consumption.

B. LACKLUSTER, MIDDLE-OF-THE-ROAD, AND GO-GETTER SCENARIOS FOR APPLIANCE AND EQUIPMENT STANDARDS (HEATING)

We base our assumptions about the reductions achievable through increased federal standards for residential and commercial appliances that combust fossil fuels on the *Efficiency Boom* study, discussed in Section III.B. The Efficiency Boom analysis examines efficiency opportunities for the following residential appliances: boilers, clothes washers, dishwashers, and faucets, as well as commercial clothes washers, warm-air furnaces, pre-rinse spray valves, and unit heaters. The study concludes that standards for those sources could reduce gas demand by 126 TBtu in 2025 and 235 TBtu in 2035. For purposes of this analysis, we assumed that standards commence in 2015, and result in a constant increase in savings between 2015 and 2025, and from 2025 through 2035. The net result of the standards is a reduction in CO_2 emissions of 6.7 mmtCO_2 in 2025 and 12.5 mmtCO_2 in 2035.

Opportunities for improving efficiency are also detailed in the AEO2011 expanded standards side case, which found 110 TBtu of savings in 2025 and 230 TBtu of savings in 2035. We rely exclusively on *Efficiency Boom,* however, as it lists specific product standards upon which future actions can be easily compared. No such list is provided for the EIA side case.

Endnotes

1. *Draft Global Non-CO2 Emissions Projections Report: 1990–2030.* Office of Atmospheric Programs, Climate Change Division, U.S. Environmental Protection Agency, EPA 430-D-11-003, August 2011. Accessible at: <http://www.epa.gov/climatechange/EPAactivities/economics/nonco2projections.html>.

2. To download data annex, see: <http://www.epa.gov/climatechange/economics/economicanalyses.html>.

3. *Clearing the Air on Shale Gas Emissions: Assessing and Reducing the Carbon Footprint of Natural Gas.* James Bradbury, Michael Obeiter, Laura Draucker, Wen Wang, and Amanda Stevens. World Resources Institute, Working Paper, forthcoming.

4. *Draft Global Non-CO2 Emissions Projections Report: 1990–2030.* Office of Atmospheric Programs, Climate Change Division, U.S. Environmental Protection Agency, EPA 430-D-11-003, August 2011. Accessible at: <http://www.epa.gov/climatechange/EPAactivities/economics/nonco2projections.html>.

5. To download data annex, see: <http://www.epa.gov/climatechange/economics/economicanalyses.html>.

6. *RTI Applied Dynamic Analysis of the Global Economy (ADAGE) Model.* RTI International-Scientific Research Development Institute. Accessible at: <http://rti.org/page.cfm?objectid=DDC06637-7973-4B0F-AC46B3C69E09ADA9>.

7. *Clearing the Air on Shale Gas Emissions: Assessing and Reducing the Carbon Footprint of Natural Gas.* James Bradbury, Michael Obeiter, Laura Draucker, Wen Wang, and Amanda Stevens.World Resources Institute, Working Paper, forthcoming.

8. For more information, see: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

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10. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010.* U.S. Environmental Protection Agency, April 2012. Accessible at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

11. *Annual Energy Review,* Table 5.1b Petroleum Overview, Selected Years, 1949–2011. U.S. Energy Information Administration. Accessible at: <www.eia.gov/totalenergy/data/annual/pdf/sec5_7.pdf>.

12. *Annual Energy Outlook 2012.* U.S. Energy Information Administration, June 25, 2012. Accessible at: <http://www.eia.gov/forecasts/aeo/>.

13. *Benefits of Addressing HFCs under the Montreal Protocol.* Office of Atmospheric Programs, U.S. Environmental Protection Agency, June 2012. Accessible at: <http://www.epa.gov/ozone/downloads/Benefits%20of%20Addressing%20HFCs%20Under%20the%20Montreal%20Protocol,%20June%202012.pdf>.

14. *VISION 2012 AEO Base Case.* Argonne National Laboratory. Accessible at: <http://www.transportation.anl.gov/modeling_simulation/VISION/>.

15. *Annual Energy Outlook 2012.* U.S. Energy Information Administration, June 25, 2012. Accessible at: <http://www.eia.gov/forecasts/aeo/>.

16. This emissions level is lower compared to past AEO projections. The previous year's projections, AEO2011, estimated that 2035 emissions from the power sector would be over 8 percent higher (2.5 billion metric tons) than current projections. This is part of a larger trend of declining projections in the AEO going back to 2005. The change in outlook is due to a variety of factors, such as an assumed slow growth in electricity demand, growing use of renewable technologies and fuels, improved efficiency, and increased use of natural gas.

17. Note that AEO2012 includes the impact of AB32 on power sector emissions only.

18. In its initial announcement, EPA committed to issuing these proposed regulations by July 26, 2011 and finalizing the standards and guidelines by May 26, 2012. EPA has not kept to this timeline. For more information, see: <http://www.epa.gov/carbonpollutionstandards/settlement.html>.

19. In setting NSPS, EPA prescribes emissions limitations based on the "best demonstrated technology" (BDT) for new and modified existing source categories it designates. EPA must consider technological feasibility, cost, lead time, and energy and non-air environmental impacts.

20. EPA is conducting a review of the role biomass may play in meeting regulatory requirements for GHGs. No final determinations have emerged from that review. For more information, see: <http://www.epa.gov/NSR/ghgdocs/McCarthytoMartella.pdf>.

21. *The Power to Reduce CO2 Emissions, The Full Portfolio.* 2009 Technical Report, Electric Power Research Institute, Research Update, Oct. 2009.

22. *New "Flexible" Power Plant from GE Breaks Efficiency Record; Nearly $1.2 Billion in Orders.* GE, September 25, 2012. Accessed December 10, 2012. Accessible at: <http://www.gereports.com/new-flexible-power-plant-from-ge-breaks-efficiency-record/>.

23. *Regulating Greenhouse Gas Emissions Under the Clean Air Act.* 73 Register §147 (2008). Accessible at: <http://www.epa.gov/climatechange/emissions/downloads/ANPRPreamble5.pdf>.

24. I*mproving the Efficiency of Coal-Fired Power Plants for Near Term Greenhouse Gas Emissions Reductions.* Phil DiPetro and Katrina Krulla. National Energy Technology Laboratory, Office of Systems, Analyses and Planning, DOE/NETL-2010/1411, April 16, 2010. Accessible at: <http://www.netl.doe.gov/energy-analyses/pubs/ImpCFPPGHGRdctns_0410.pdf; http://www.netl.doe.gov/energy-analyses/pubs/NETL%20Power%20Plant%20Efficiency%20Workshop%20Report%20Final.pdf>. Analyses Show Benefits of Improving Unit Heat Rate as Part of a Carbon Mitigation Strategy. Lehigh Energy Update, Vol. 28, No. 1, February 2010. Accessible at: <http://www.lehigh.edu/~inenr/leu/leu_65.pdf>. Opportunities to Improve the Efficiency of Existing Coal-fired Power Plants. J. Eisenhauer and R. Scheer. National Energy Technology Laboratory, July 15, 2009. *Regulating Greenhouse Gases from Coal Power Plants under the Clean Air Act.* Joshua Linn, Erin Mastrangelo, and Dallas Burtraw. Resources for the Future, January 2012 (revised February 2012). Accessible at: <http://www.rff.org/documents/RFF-DP-11-43-REV.pdf>.

25. For comparative purposes, we note that the National Energy Technology Laboratory (NETL) has set a vision of improving the generation-weighted average efficiency from 32.5 percent to 36 percent based on improvements to existing units, retirement of lower efficiency units, and increased generation from higher efficiency units. This would improve the average heat rate of existing coal units by 10 percent. Researchers at Lehigh University also found that a 10 percent improvement in the heat rate at existing coal-fired units can be achieved through several technological upgrades. Resources for the Future found that after controlling for a variety of technical features across the boiler fleet—such as design, size, and pollution control equipment—a 5 percent reduction in the fleet-wide emissions rate may be technically feasible.

26. Personal communication with Laura Martin, Energy Information Administration, June 27, 2012.

27. *Retail Electricity Price Savings from Compliance Flexibility in GHG Standards for Stationary Sources.* Dallas Burtraw, Matt Woerman, and Anthony Paul. Energy Policy 42: 67–77. RFF Discussion Paper, 11-30, 2012.

28. *Regulating Greenhouse Gases from Coal Power Plants under the Clean Air Act.* Joshua Linn, Dallas Burtraw, and Erin Mastrangelo. RFF Discussion Paper 11-43,2012.

29. *The Consequences of Subcategorization in a GHG Tradable Performance Standard Policy.* Dallas Burtraw and Matt Woerman. Presentation at the annual meeting of the Association of Environmental and Resource Economists, Asheville TN, June 4, 2012.

30. *Closing the Power Plant Carbon Pollution Loophole: Smart Ways the Clean Air Act Can Clean Up America's Biggest Climate Polluters.* Daniel Lashof, Starla Yeh, David Doniger, Sheryl Carter, and Laurie Johnson. Natural Resources Defense Council, December 2012. Accessible at: <http://www.nrdc.org/air/pollution-standards/files/pollution-standards-report.pdf>.

31. AEO2012 predicts that natural gas combined cycle units will remain at 40 to 48 percent capacity through 2035.

32. Note that the Clean Air Act does not permit trading or averaging when complying with performance standards for new sources.

33. *Annual Energy Outlook 2012.* U.S. Energy Information Administration, June 25, 2012. Accessible at: <http://www.eia.gov/forecasts/aeo/>.

34. *The Efficiency Boom: Cashing In on the Savings from Appliance Standards.* Amanda Lowenberger, Joanna Mauer, Andrew deLaski, Marianne DiMascio, Jennifer Amann, and Steven Nadel. American Council for an Energy-Efficient Economy, Appliance Standards Awareness Project, ASAP-8/ACEEE-A123, March 2012. Accessible at: <http://www.aceee.org/sites/default/files/publications/researchreports/a123.pdf>.

35. 42 U.S.C. Sections 6291 to 6309.

36. See, e.g., 42 U.S.C. Section 6292(b).

37. *The Efficiency Boom: Cashing In on the Savings from Appliance Standards.* Amanda Lowenberger, Joanna Mauer, Andrew deLaski, Marianne DiMascio, Jennifer Amann, and Steven Nadel. American Council for an Energy-Efficient Economy, Appliance Standards Awareness Project, ASAP-8/ACEEE-A123, March 2012. Accessible at: <http://www.aceee.org/sites/default/files/publications/researchreports/a123.pdf>.

38. IEE is an affiliate of the Edison Electric Institute.

39. *Assessment of Electricity Savings in the U.S. Achievable through New Appliance/Equipment Efficiency Standards and Building Efficiency Codes (2010–2025).* Institute for Electric Efficiency, May 2011. Accessible at: <http://www.edisonfoundation.net/iee/Documents/IEE_CodesandStandardsAssessment_2010-2025_UPDATE.pdf>.

40. Even though the study utilized AEO2011, we believe the study's findings can be applied to our base case, which relies on AEO2012, as conversations with EIA staff indicated that there were no substantive differences in equipment standards between the AEO2011 and AEO2012 reference case.

41. *2010 ISO New England Electric Generator Air Emissions Report.* System Planning Department, ISO New England, Inc., March 2012. Accessible at: <http://www.iso-ne.com/genrtion_resrcs/reports/emission/final_2010_emissions_report_v2.pdf>.

42. *2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards.* U.S. Environmental Protection Agency and National Highway Traffic Safety Administration, 2011. Accessible at: <http://www.gpo.gov/fdsys/pkg/FR-2011-12-01/pdf/2011-30358.pdf>.

43. This follows a rulemaking in May 2010 that required model year 2016 vehicles to meet an emissions standard of 250 grams of carbon dioxide-equivalent emissions per mile, which is equivalent to a fuel economy standard of 35.5 mpg if the automobile industry were to meet those standards solely through fuel economy improvements. The accompanying NHTSA standard was set at 34.1 mpg. At the time, NHTSA considered only drive train improvements and did not consider air conditioning leakage or efficiency improvements for purposes of establishing CAFE standards.

44. *VISION 2012 AEO Base Case.* Argonne National Laboratory. Accessible at: <http://www.transportation.anl.gov/modeling_simulation/VISION/>.

45. While the VISION model relies on EIA's *Annual Energy Outlook* (AEO) projections as much as possible, there are some differences and so VISION's base case does not match EIA's AEO reference case results.

46. *2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards.* U.S. Environmental Protection Agency and National Highway Traffic Safety Administration, 2011. Accessible at: <http://www.gpo.gov/fdsys/pkg/FR-2011-12-01/pdf/2011-30358.pdf>.

47. Interim Joint Technical Assessment Report: Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards for Model Years 2017–2025. Office of Transportation and Air Quality, U.S. Environmental Protection Agency, Office of International Policy, Fuel Economy, and Consumer Programs; National Highway Traffic Safety Administration, U.S. Department of Transportation; California Air Resources Board, September 2010. Accessible at: <http://www.epa.gov/otaq/climate/regulations/ldv-ghg-tar.pdf>.

48. CAFE standards do not include benefits from HFC emissions reductions. EPA projected that these benefits would result in credits amounting to 14.3 grams CO_2 per mile in 2025. We deduct these credits when converting from the EPA CO_2 standards to the equivalent CAFE standard.

49. This level of EV penetration will likely require significant infrastructure development and advances in battery technology, both of which would benefit from additional policy interventions.

50. *Analysis of the Transportation Sector: Greenhouse Gas and Oil Reduction Scenarios.* U.S. Environmental Protection Agency, March 2010. Accessible at: <http://www.epa.gov/oms/climate/GHGtransportation-analysis03-18-2010.pdf>.

51. *Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles.* U.S. Environmental Protection Agency and National Highway Traffic Safety Administration, 2011. Accessible at: <http://www.gpo.gov/fdsys/pkg/FR-2011-09-15/pdf/2011-20740.pdf>.

52. *Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles.* U.S. Environmental Protection Agency and National Highway Traffic Safety Administration, 2011. Accessible at: <http://www.gpo.gov/fdsys/pkg/FR-2011-09-15/pdf/2011-20740.pdf>.

53. *Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles.* U.S. Environmental Protection Agency and National Highway Traffic Safety Administration, 2011. Accessible at: <http://www.gpo.gov/fdsys/pkg/FR-2011-09-15/pdf/2011-20740.pdf>.

54. Class 2b vehicles designed as passenger vehicles (medium-duty passenger vehicles, MDPVs) are covered by the light-duty GHG and fuel economy standards and not addressed in this rule.

55. Both EPA and NHTSA also provide manufacturers with optional alternative implementation schedules, but for purposes of our analysis we assume that all manufacturers comply with EPA's standards under the primary implementation schedule.

56. The Energy Independence and Security Act of 2007 (EISA) requires at least three years of "regulatory stability" whereby fuel efficiency standards for medium- and heavy-duty vehicles remain fixed.

57. The rate of improvement in the standards for our lackluster and middle-of-the-road scenarios was calculated as the annual improvement rate between model year 2013 vehicles and the model year 2018 vehicle standard across the medium- and heavy-duty fleet for each of our scenarios.

58. Average fleet-wide fuel economy was weighted using the projected sales for each vehicle category in VISION.

59. *Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.* Committee to Assess Fuel Economy Technologies for Medium- and Heavy-Duty Vehicles, Board on Energy and Environmental Systems Division on Engineering and Physical Sciences, Transportation Research Board, Washington, DC, National Academies, 2010.

60. The major technologies that the National Academies study found necessary to achieve the highest level of reductions are hybridization, advanced diesel engines, and aerodynamics. Other technologies that could help reduce fuel consumption include low-rolling-resistance tires, improved transmissions, idle-reduction technologies, and weight reduction. While the study included energy reductions resulting from driver management and coaching for combination trucks, we did not include these savings in our analysis because EPA has not mandated such operational improvements to date in these standards.

61. In President Obama's May 2010 memorandum, he directed EPA and NHTSA to begin working on a joint rulemaking to establish fuel efficiency and greenhouse gas emissions standards for medium- and heavy-duty vehicles beginning with model year 2014. The memorandum noted that preliminary estimates indicate that large tractor trailers can reduce greenhouse gas emissions by as much as 20 percent and increase their fuel efficiency as much as 25 percent.

62. *Presidential Memorandum Regarding Fuel Efficiency Standards.* May 21, 2010. Accessible at: <http://www.whitehouse.gov/the-press-office/presidential-memorandum-regarding-fuel-efficiency-standards>.

63. *VISION 2012, New Auto Fuel Economy Ratio to Base ICE* (using gasoline equivalent gallons). Argonne National Laboratory. Accessible at: <http://www.transportation.anl.gov/modeling_simulation/VISION/>.

64. *Final Rulemaking to Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles: Regulatory Impact Analysis.* Table 6-11: Estimated Fleet-Wide Fuel Efficiency by Model Year for Alternative 3 [gallons/100 miles]. U.S. Environmental Protection Agency and National Highway Traffic Safety Administration, August 2011. Accessible at: <http://www.epa.gov/oms/climate/documents/420r11901.pdf>.

65. *EPA Analysis of the Transportation Sector.* U.S. Environmental Protection Agency, March 2010.

66. *EPA Analysis of the Transportation Sector.* U.S. Environmental Protection Agency, March 2010.

67. *Next Gen Implementation Plan.* Federal Aviation Administration, 2012. Accessible at: <http://www.faa.gov/nextgen/implementation/media/NextGen_Implementation_Plan_2012.pdf.

68. *EPA Analysis of the Transportation Sector.* U.S. Environmental Protection Agency, March 2010.

69. *Doc 9963 Report of the Independent Experts on the Medium and Long Term Goals for Aviation Fuel Burn Reduction from Technology.* ENGLISH ISBN 978-92-9231-765-2 Order No. 9963,2010.

70. *Factsheet: Technology Roadmap for Environmental Improvement.* International Air Transport Association, June 2012. Accessible at: <http://www.iata.org/pressroom/facts_figures/fact_sheets/Pages/technology.aspx>.

71. *U.S. Aviation Greenhouse Gas Emissions Reduction Plan.* Federal Aviation Administration, June 2012. Accessible at: <http://www.faa.gov/about/office_org/headquarters_offices/apl/environ_policy_guidance/policy/media/Aviation_Greenhouse_Gas_Emissions_Reduction_Plan.pdf>.

72. *Next Gen Implementation Plan.* Federal Aviation Administration, 2012. Accessible at: <http://www.faa.gov/nextgen/implementation/media/NextGen_Implementation_Plan_2012.pdf>.

73. *Reducing emissions from the aviation sector.* European Commission. For more information, see: <http://ec.europa.eu/clima/policies/transport/aviation/index_en.htm>.

74. It is expected that EPA's most recent rulemakings for light-, medium-, and heavy-duty vehicles will result in emissions savings from reduced HFC leakage. For light-duty vehicles, EPA is offering a credit for manufacturers that choose to reduce HFC leakage from air conditioning equipment, and projects that these benefits would result in credits amounting to 14.3 grams CO_2 per mile in 2025. EPA set a separate standard that requires a reduction in the amount of HFC leakage from AC systems in heavy-duty pickup trucks and vans as well as class 7 and 8 tractors, based on the refrigerant capacity of the installed AC system. Since these regulations have been finalized, we account for these savings in our adjusted base case emission projections for HFCs.

75. *Draft Global Non-CO2 Emissions Projections Report: 1990-2030.* Office of Atmospheric Programs, Climate Change Division, U.S. Environmental Protection Agency, EPA 430-D-11-003, August 2011. Accessible at: <http://www.epa.gov/climatechange/EPAactivities/economics/nonco2projections.html>.

76. *Clearing the Air on Shale Gas Emissions: Assessing and Reducing the Carbon Footprint of Natural Gas.* James Bradbury, Michael Obeiter, Laura Draucker, Wen Wang, and Amanda Stevens. World Resources Institute, Working Paper, forthcoming.

77. *Life Cycle Carbon Footprint of Shale Gas: Review of Evidence and Implications.* Christopher Weber and Christopher Clavin. Environ Sci Technol,2012,doi:10.1021/es300375n.Available at: <http://pubs.acs.org/doi/abs/10.1021/es300375n> (with supplemental document).

78. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010.* U.S. Environmental Protection Agency, April 2012. Accessible at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

79. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010.* U.S. Environmental Protection Agency, April 2012. Accessible at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

80. *Annual Energy Review.* Table 5.1b: Petroleum Overview, Selected Years, 1949–2011, U.S. Energy Information Administration. Accessible at: <www.eia.gov/totalenergy/data/annual/pdf/sec5_7.pdf>.

81. *Annual Energy Outlook 2012.* U.S. Energy Information Administration, June 25, 2012. Accessible at: <http://www.eia.gov/forecasts/aeo/>.

82. *Benefits of Addressing HFCs under the Montreal Protocol.* Office of Atmospheric Programs, U.S. Environmental Protection Agency, June 2012. Accessible at: <http://www.epa.gov/ozone/downloads/Benefits%20of%20Addressing%20HFCs%20Under%20the%20Montreal%20Protocol,%20June%202012.pdf>.

83. To download data annex, see: <http://www.epa.gov/climatechange/economics/economicanalyses.html>.

84. *RTI Applied Dynamic Analysis of the Global Economy (ADAGE) Model.* RTI International-Scientific Research Development Institute. Accessible at: <http://rti.org/page.cfm?objectid=DDC06637-7973-4B0F-AC46B3C69E09ADA9>.

85. *Annual Energy Review.* Table 6.2: Natural Gas Production, Selected Years, 1949–2011. U.S. Energy Information Administration, September 2012. Accessible at: <http://www.eia.gov/totalenergy/data/annual/pdf/aer.pdf>.

86. *Clearing the Air on Shale Gas Emissions: Assessing and Reducing the Carbon Footprint of Natural Gas.* James Bradbury, Michael Obeiter, Laura Draucker, Wen Wang, and Amanda Stevens. World Resources Institute, Working Paper, forthcoming.

87. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010.* U.S. Environmental Protection Agency, April 2012. Accessible at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

88. *Life Cycle Carbon Footprint of Shale Gas: Review of Evidence and Implications.* Weber, Christopher and Christopher Clavin,Environ Sci Technol,2012,doi:10.1021/es300375n. Available at: http://pubs.acs.org/doi/abs/10.1021/es300375n (with supplemental document).

89. For more information, see: http://www.epa.gov/airquality/oilandgas/actions.html.

90. For more information, see: http://www.epa.gov/airquality/oilandgas/pdfs/20120417finalrule.pdf.

91. *How The EPA's New Oil and Gas Standards Will Reduce Greenhouse Gas Emissions.* Michael Obeiter, World Resources Institute Insights Blog, May 9, 2012. Accessible at: http://insights.wri.org/news/2012/05/how-epas-new-oil-and-gas-standards-will-reduce-greenhouse-gas-emissions.

92. Specifically, the regulations require that high-bleed pneumatic controllers, employed during the processing stage of the natural gas lifecycle to maintain gas pressure, need to meet a new leakage rate of six cubic feet of gas per hour. This results in small reductions in methane emissions, according to emissions data from the EPA GHG inventory. More significant reductions will come from compressors used in gas production and processing, as they are a much larger sources of emissions and they will need to reduce VOC emissions by 95 percent. The new rule should reduce methane emissions from compressors by a similar amount, and can be achieved by converting wet seal compressors to dry seals. Additionally, a new performance standard for storage tanks at well sites will primarily address VOC emissions, with limited GHG co-benefits, as storage tanks are not a major source of GHG emissions, according to the GHG inventory.

93. While leak monitoring and repair can apply to the entire transmission life-cycle stage, it is less cost-effective outside of compressor stations since there are hundreds of thousands of miles of pipeline.

94. The payback period for these technologies assumes natural gas prices from the AEO2012 reference case, which range from $4.59/Mcf in 2019 to $7.58/Mcf in 2035.

95. *Clearing the Air on Shale Gas Emissions: Assessing and Reducing the Carbon Footprint of Natural Gas.* James Bradbury, Michael Obeiter, Laura Draucker, Wen Wang, and Amanda Stevens. World Resources Institute, Working Paper, forthcoming.

96. *Clearing the Air on Shale Gas Emissions: Assessing and Reducing the Carbon Footprint of Natural Gas.* James Bradbury, Michael Obeiter, Laura Draucker, Wen Wang, and Amanda Stevens. World Resources Institute, Working Paper, forthcoming.

97. *Leaking Profits: The U.S. Oil and Gas Industry Can Reduce Pollution, Conserve Resources, and Make Money by Preventing Methane Waste.* Natural Resource Defense Council, March 2012. Accessible at: <http://www.nrdc.org/energy/files/Leaking-Profits-Report.pdf>.

98. These conclusions are based on unpublished analysis conducted for this report by the authors of *Clearing the Air on Shale Gas Emissions.*

99. *Annual Energy Review.* Figure 6.0: Natural Gas Flow 2011. U.S. Energy Information Administration, September 2012. Accessible at: <http://www.eia.gov/totalenergy/data/annual/pdf/sec6_3.pdf>.

100. The relative difference largely depends on the actual impact of plunger lifts.

101. Specifically, we predict that demand for natural gas will decrease by 7 percent and 10 percent in 2035 in our lackluster and middle-of-the-road scenarios, respectively. Meanwhile, we predict that demand for natural gas will increase by 12 percent in our go-getter scenario. Across all of the scenarios, power plant standards and residential and commercial appliance and equipment standards were the primary drivers of changes in natural gas demand.

102. W*hat will it take to get sustained benefits from natural gas?* Examining the climate impacts of methane leakage from natural gas, Environmental Defense Fund. Accessible at: http://www.edf.org/methaneleakage

103. *Greenhouse Gas Reporting Program,* U.S. Environmental Protection Agency. Accessible at: http://www.epa.gov/climate/ghgreporting/index.html

104. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010.* U.S. Environmental Protection Agency, April 2012. Accessible at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

105. *Draft Global Non-CO2 Emissions Projections Report: 1990–2030.* Office of Atmospheric Programs, Climate Change Division, U.S. Environmental Protection Agency, EPA 430-D-11-003, August 2011. Accessible at: <http://www.epa.gov/climatechange/EPAactivities/economics/nonco2projections.html>.

106. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010.* U.S. Environmental Protection Agency, April 2012. Accessible at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

107. *Benefits of Addressing HFCs under the Montreal Protocol.* Office of Atmospheric Programs, U.S. Environmental Protection Agency, June 2012. Accessible at: <http://www.epa.gov/ozone/downloads/Benefits%20of%20Addressing%20HFCs%20Under%20the%20Montreal%20Protocol,%20June%202012.pdf>.

108. *Optimization Model for reducing Emissions of Greenhouse gases from Automobiles (OMEGA).* U.S. Environmental Protection Agency, August 2012. Accessible at: <http://www.epa.gov/oms/climate/models.htm>.

109. *Final Rulemaking to Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles: Regulatory Impact Analysis.* Table 6-11: Estimated Fleet-Wide Fuel Efficiency by Model Year for Alternative 3 [gallons/100 miles]. U.S. Environmental Protection Agency and National Highway Traffic Safety Administration, U.S. Department of Transportation, August 2011. Accessible at: <http://www.epa.gov/oms/climate/documents/420r11901.pdf>.

110. 40 CFR Part 82, Subpart A

111. *Benefits of Addressing HFCs under the Montreal Protocol.* Office of Atmospheric Programs, U.S. Environmental Protection Agency, June 2012. Accessible at: <http://www.epa.gov/ozone/downloads/Benefits%20of%20Addressing%20HFCs%20Under%20the%20Montreal%20Protocol,%20June%202012.pdf>.

112. *Benefits of Addressing HFCs under the Montreal Protocol.* Office of Atmospheric Programs, U.S. Environmental Protection Agency, June 2012. Accessible at: <http://www.epa.gov/ozone/downloads/Benefits%20of%20Addressing%20HFCs%20Under%20the%20Montreal%20Protocol,%20June%202012.pdf>.

113. These calculations assume that emissions from the five main end uses for HFCs were equivalent to the midpoint of their emissions range, as described in EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010.* For each of the five main end uses, reported annual emissions rates are as follows: refrigeration and air conditioning (1–28 percent), aerosols (100 percent), foams (100 percent), solvents (90 percent), and fire protection (5–8 percent). Note that if average emissions are more consistent with the lower range of the reported emissions rates for the five major end uses, then total U.S. GHG emissions in 2020 will be 15 percent below 2005 levels. If average emissions are consistent with the upper-bound emissions rate, then total U.S. GHG emissions in 2020 will be 19 percent below 2005 levels.

114. *Draft Global Non-CO2 Emissions Projections Report: 1990–2030.* Office of Atmospheric Programs, Climate Change Division, U.S. Environmental Protection Agency, EPA 430-D-11-003, August 2011. Accessible at: <http://www.epa.gov/climatechange/EPAactivities/economics/nonco2projections.html>.

115. *Appendix B: Economic Modeling Results, Design Recommendations for the WCI Regional Cap-and-Trade Program.* Western Climate Initiative, September 23, 2008. Accessible at: <http://www.westernclimateinitiative.org/component/remository/func-startdown/18/>. *Cap-and-Trade Modeling: Policy Run Results.* Presentation to the GHG Accord Advisory Group, Midwestern Greenhouse Gas Reduction Accord, Minneapolis, May 11, 2009. *EPA Analysis of the American Clean Energy and Security Act of 2009, H.R. 2454 in the 111th Congress.* U.S. Environmental Protection Agency, Office of Atmospheric Programs, June 23,2009. Accessible at: <http://www.epa.gov.climatechange/economics/pdfs/HR2454_Analysis.pdf>. *Energy Market and Economic Impacts of H.R. 2454, the American Clean Energy and Security Act of 2009.* Office of Integrated Analysis and Forecasting, U.S. Energy Information Administration, 2009. Accessible at: <http://www.eia.doe.gov/oaif/servicerpt/hr2454/pdf/sroiaf(2009)05.pdf>. *Economic Impacts of S. 1733: The Clean Energy Jobs and American Power Act of 2009 in the 111th Congress.* U.S. Environmental Protection Agency, Office of Atmospheric Programs, October 23, 2009.

116. Participants in the Interagency Working Group on the Social Cost of Carbon included the White House Council of Economic Advisers, White House Council on Environmental Quality, Department of Agriculture, Department of Commerce, Department of Energy, Department of Transportation, Environmental Protection Agency, National Economic Council, Office of Energy and Climate Change, Office of Management and Budget, Office of Science and Technology Policy, and Department of the Treasury. For more information, see: <http://www.epa.gov/oms/climate/regulations/scc-tsd.pdf>.

117. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010.* U.S. Environmental Protection Agency, April 2012. Accessible at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

118. *N_2O Emissions from Adipic Acid and Nitric Acid Production.* Heike Mainhardt, ICF Incorporated, Contribution of Working Group 1 to the *Fourth Assessment Report of the Intergovernmental Panel on Climate Change*(S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller, eds). Accessible at: <http://www.ipcc-nggip.iges.or.jp/public/gp/bgp/3_2_Adipic_Acid_Nitric_Acid_Production.pdf>.

119. *Global Mitigation of Non-CO2 Greenhouse Gases.* Micke Gallaher, Deborah Ottinger, Dave Godwin, and Benjamin DeAngelo, Robert Beach, Jochen Harnisch, Sina Wartmann, William Salas, Changsheng Li, Stephen Del Grosso, and Timothy Sulser. U.S. Environmental Protection Agency, EPA Technical Report, June 2005. Accessible at: <http://www.ars.usda.gov/research/publications/publications.htm?seq_no_115=197768>.

120. *Global Mitigation of Non-CO2 Greenhouse Gases.* Micke Gallaher, Deborah Ottinger, Dave Godwin, and Benjamin DeAngelo, Robert Beach, Jochen Harnisch, Sina Wartmann, William Salas, Changsheng Li, Stephen Del Grosso, and Timothy Sulser. U.S. Environmental Protection Agency, EPA Technical Report, June 2005. Accessible at: <http://www.ars.usda.gov/research/publications/publications.htm?seq_no_115=197768>.

121. Here, production levels are defined in terms of the dollar value of shipments. These values are adjusted for inflation.

122. *Assumptions to the AEO2012.* U.S. Energy Information Administration, June 2012. Accessible at: <http://www.eia.gov/forecasts/aeo/assumptions/pdf/0554(2012).pdf>.

123. AEO2012 is built using the National Energy Modeling System (NEMS). NEMS assumes that gas and oil burners meet the standards set by the Energy Policy Act of 1992, which requires gas burners to have heat rates of 1.25 (80 percent efficiency) and oil burners have heat rates of 1.22 (82 percent efficiency). AEO2012 assumes that cogeneration units experience a steady increase in their efficiency through 2035.

124. *Regulating Greenhouse Gases from Coal Power Plants under the Clean Air Act.* Joshua Linn, Erin Mastrangelo, and Dallas Burtraw. Resources for the Future, January 2012 (revised February 2012). Accessible at: <http://www.rff.org/documents/RFF-DP-11-43-REV.pdf>.

125. For the iron and steel sector we assumed that boiler efficiency gains only reduce combustion of main fuel sources (natural gas, residual oil, steam coal, etc.), and not intermediary fuels that are the byproduct of direct combustion in coke ovens and blast furnaces.

126. Refineries were modeled separately. Therefore, for purposes of this analysis, we consider the following categories to be included in the manufacturing sector: food and kindred projects, paper and allied products, bulk chemicals, glass and glass products, cement, iron and steel, aluminum, fabricated metal products, machinery, computer and electronic products, transportation equipment, electrical equipment, appliances and components, wood products, and plastic and rubber products. The remaining manufacturing facilities are grouped into a single subcategory, called balance of manufacturing.

127. EPA finalized new standards for emissions of air toxics from industrial boilers (Boiler MACT) in December 2012.Those standards require boiler tune-ups, which according to EPA have been shown to improve efficiency between 1 and 5 percent. Those standards will lower the marginal improvement from the GHG standards we model. However, we note that the upper range of the efficiency improvements identified by EPA fall well short of those modeled in the lackluster scenario, suggesting that GHG emissions standards could drive additional reductions from industrial boilers.

128. *Regulatory Impact Results for the Reconsideration Proposal for National Emission Standards for Hazardous Air Pollutants for Industrial, Commercial, and Institutional Boilers and Process Heaters at Major Sources.* U.S. Environmental Protection Agency, December 1, 2011. Accessible at: <http://www.epa.gov/ttn/atw/boiler/boilersriaproposalrecon111201.pdf>.

129. *Model Documentation Report: Industrial Sector Demand Module of the National Energy Modeling System, DOE/EIA-M064(2011).* U.S. Energy Information Administration, Office of Integrated Analysis and Forecasting, May 2011. Accessible at: <http://www.eia.gov/FTPROOT/modeldoc/m064(2011).pdf>.

130. See the reports of the Climate Change Working Group at: <http://www.epa.gov/air/caaac/climatechangewg.html>.

131. *Scenarios for a Clean Energy Future.* Interlaboratory Working Group and Lawrence Berkeley National Laboratory, Oak Ridge, TN, Berkeley, CA, ORNL/CON-476 and LBNL-44029, November 2000.

132. We converted the study's listed price ($50 per ton of carbon) into a carbon dioxide price and 2011 dollars using the consumer price index. For more information, see Consumer Price Index, All Urban Consumers, at: <ftp://ftp.bls.gov/pub/special.requests/cpi/cpiai.txt>.

133. *Real Prospects for Energy Efficiency in the United States.* Panel on Energy Efficiency Technologies, Washington, D.C., National Academy Press, 2009. *The Untapped Energy Efficiency Opportunity in the U.S. Industrial* Sector: Details of Research, 2008. McKinsey and Company, 2008.

134. Note that the CEF projects sector-specific fuel-use patterns that were developed before the recent boom in shale gas extraction and consumption.

135. *Industrial Glass Bandwidth Analysis.* David Rue, James Servaites, and Warren Wolf. U.S. Department of Energy, December 2006. Accessible at: <http://www1.eere.energy.gov/manufacturing/industries_technologies/glass/pdfs/industrial_bandwidth.pdf>.

136. *Chemical Bandwidth Study Exergy Analysis: A Powerful Tool for Identifying Process Inefficiencies in the U.S. Chemical Industry.* Dickson Ozokwelu, Joseph Porcelli, and Peter Akinjiola. U.S. Department of Energy, December 2006. Accessible at: <http://www1.eere.energy.gov/industry/chemicals/pdfs/chemical_bandwidth_report.pdf>.

137. This comparison is based on the middle-of-the-road scenario, which only includes efficiency improvements. The go-getter scenario includes fuel switching, leading to greater emissions reductions.

138. *Real Prospects for Energy Efficiency in the United States.* Panel on Energy Efficiency Technologies, Washington, D.C., National Academy Press, 2009. *The Untapped Energy Efficiency Opportunity in the U.S.* Industrial Sector: Details of Research, 2008. McKinsey and Company, 2008.

139. *Saving One Barrel of Oil per Ton.* American Iron and Steel Institute, October 2005.

140. *Steel Industry Energy Bandwidth Study.* Energetics, Inc., U.S. Department of Energy, October 2004. Accessible at: <http://www1.eere.energy.gov/industry/steel/pdfs/steelbandwidthstudy.pdf>. *Chemical Bandwidth Study Exergy Analysis: A Powerful Tool for Identifying Process Inefficiencies in the U.S. Chemical Industry.* Dickson Ozokwelu, Joseph Porcelli, and Peter Akinjiola. U.S. Department of Energy, December 2006. Accessible at: <http://www1.eere.energy.gov/industry/chemicals/pdfs/chemical_bandwidth_report.pdf>. *Industrial Glass Bandwidth Analysis.* David Rue, James Servaites, and Warren Wolf. U.S. Department of Energy, December 2006. Accessible at: <http://www1.eere.energy.gov/manufacturing/industries_technologies/glass/pdfs/industrial_bandwidth.pdf>. *Pulp and Paper Industry Energy Bandwidth Study.* Jacobs Institute of Paper Science and Technology, American Institute of Chemical Engineers, August 2006. Accessible at: <http://www1.eere.energy.gov/industry/forest/pdfs/doe_bandwidth.pdf>.

141. Energy-CO_2 emissions from *Annual Energy Outlook 2012.* U.S. Energy Information Administration, June 25, 2012. Accessible at: <http://www.eia.gov/forecasts/aeo/>. Process CO_2 emissions from *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010.* U.S. Environmental Protection Agency, April 2012. Accessible at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

142. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010.* U.S. Environmental Protection Agency, April 2012. Accessible at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

143. *Model Documentation Report: Industrial Sector Demand Module of the National Energy Modeling System, DOE/EIA-M064(2011).* U.S. Energy Information Administration, Office of Integrated Analysis and Forecasting, May 2011. Accessible at: <http://www.eia.gov/FTPROOT/modeldoc/m064(2011).pdf>.

144. For more information, see: <http://www.epa.gov/climatechange/Downloads/anpr/ANPRFactSheet.pdf>.

145. *Model Documentation Report: Industrial Sector Demand Module of the National Energy Modeling System, DOE/EIA-M064(2011).* U.S. Energy Information Administration, Office of Integrated Analysis and Forecasting, May 2011. Accessible at: <http://www.eia.gov/FTPROOT/modeldoc/m064(2011).pdf>.

146. *2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards.* U.S. Environmental Protection Agency and National Highway Traffic Safety Administration, 2011. Accessible at: <http://www.gpo.gov/fdsys/pkg/FR-2011-12-01/pdf/2011-30358.pdf>.

147. *Annual Energy Outlook 2012.* U.S. Energy Information Administration, June 25, 2012. Accessible at: <http://www.eia.gov/forecasts/aeo/>.

148. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010.* U.S. Environmental Protection Agency, April 2012. Accessible at: <http://www.epa.gov/climatechange/emissions/usinventoryreport.html>.

149. For more information, see: <http://www.epa.gov/airquality/cps/pdfs/refineryghgsettlement.pdf>.

150. *Regulating Greenhouse Gases from Coal Power Plants under the Clean Air Act.* Joshua Linn, Erin Mastrangelo, and Dallas Burtraw. Resources for the Future, January 2012 (revised February 2012). Accessible at: <http://www.rff.org/documents/RFF-DP-11-43-REV.pdf>.

151. *Energy Bandwidth for Petroleum Refining Processes.* Energetics Inc., U.S. Department of Energy, October 2006. Accessible at: <http://www1.eere.energy.gov/industry/petroleum_refining/pdfs/bandwidth.pdf>.

152. Personal communication, U.S. Energy Information Administration, October 29, 2012.

153. *Annual Energy Outlook 2012.* Table 59: Domestic Refinery Distillation Base Capacity and Expansion. U.S. Energy Information Administration, June 25, 2012. Accessible at: <http://www.eia.gov/forecasts/aeo/>.

Appendix II: State Methods

I. State Action

This analysis seeks to understand the impact state actions can have on U.S. greenhouse gas emissions. It has two components: the first considers the impact of states taking action in the absence of federal action; the second considers the impact of states taking action in the presence of varying levels of federal action. In both components we examine the implication of states implementing the same types of policies modeled for the federal government, as well as more traditional state-level actions in the transportation, energy efficiency, and renewables areas.

This approach is based on the observation that the Constitution grants states broad authority to regulate their energy sources and emissions. Thus, states have the ability to implement many of the same policies as federal agencies. We also note that states are more likely to pursue these options when federal action falls short.

State-level actions generally complement federal authorities in transportation, energy efficiency, and renewable energy. Regarding transportation, the state scenarios consider measures to encourage low-carbon fuels and reduce vehicle miles traveled to complement federal vehicle efficiency measures. In the energy efficiency area, actions modeled include reduced energy consumption through end-use energy efficiency for electricity and natural gas, improved building performance, and increased deployment of combined heat and power. For renewables, the analysis adds new and additional renewable energy deployment across a certain number of states.

Unlike the federal analysis, many of the state actions modeled would require new legislation at the state level. Also unlike the federal scenario, the categorization of state action—whether "lackluster," "middle-of-the-road," or "go-getter"—is partially a function of how many states adopt the actions modeled. Thus a lackluster state trajectory does not necessarily mean that individual states have failed to take ambitious action. Instead, it can represent a scenario where a limited number of states have taken action and the result is that the combination of state actions has affected the national trajectory in a lackluster manner.

In the state scenarios, we do not identify specific states that take action. Rather, we identify percentages of the relevant sector that are subject to a new or expanded action, thus accounting for a variety of possible combinations of states and policies that can result in a similar level of GHG benefits. For example, to model the middle-of-the-road scenario for low-carbon fuels, we assume that states that account for 25 percent of energy consumption from transportation fuels reduce the carbon intensity of fuels by 1 percent per year beginning in 2015. This scenario, however, is not meant to be limited to this specific set of assumptions. Other combinations of numbers of states and levels of stringency could achieve this same "middle-of-the-road" result. For example, the same level of reductions could be achieved if states that accounted for 12.5 percent of energy consumption from transportation fuels reduced the carbon intensity of fuels by 2 percent per year. In this way, we capture a variety of possible combinations of policy ambition and state adoption levels under the same scenario.

II. Transportation

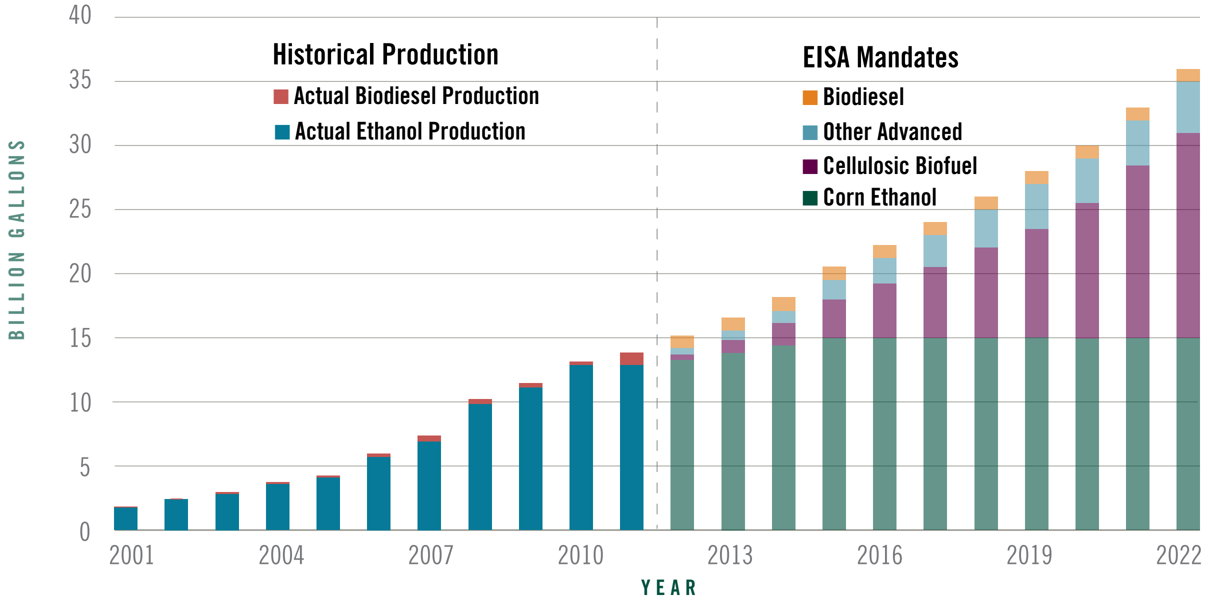
A. DIVERSIFICATION OF FUEL MIX REDUCES THE AVERAGE CARBON CONTENT OF FUELS

1. Base Case for Diversification of Fuel Mix

As described in Appendix I (Sections VII.A and VII.B), we developed our base case assumptions for light-, medium-, and heavy- duty vehicles from Argonne National Laboratory's "VISION 2012 AEO base case," which is calibrated to the *Annual Energy Outlook 2012.* However, we updated the base case to reflect new standards for light-duty vehicles sold through the 2025 model year.

The Energy Independence and Security Act of 2007 (EISA 2007) increases the volume of renewable fuel required to be blended into transportation fuel sold in the U.S. from nine billion gallons in 2008 to thirty-six billion gallons in 2022 (See Figure A-2.1). The law requires that the vast majority of the increase from current production levels come from cellulosic biofuel and other advanced biofuels. EISA 2007 requires EPA to annually estimate projected biofuel capacity for the following year, and if necessary adjust the production

FIGURE A-2.1 **Biofuel Production Required by the Energy Independence and Security Act of 2007**



Sources: Figure created using data from U.S. EIA's Annual Energy Review 2011 and U.S. EIA's Annual Energy Outlook 2012.

mandates downward. In each of the past three years, EPA determined it was not possible to meet the annual cellulosic biofuel target and adjusted the target downward compared to the level mandated in the initial rule.[1,2,3] Based on this recent history, and their own assessment of financial and technological barriers, the AEO 2012 assumes that the advanced biofuel targets will not be met until 2033.[4]

To qualify for credit under EISA 2007, transportation fuels sold in the U.S. must meet specified life-cycle emissions thresholds, which are lower than the life-cycle GHG emissions of conventional gasoline or diesel.[5] The statute requires EPA to account for the direct and indirect life-cycle emissions implications of qualifying biofuel production, considering all stages of fuel and feedstock production and distribution, including those emissions associated with direct and indirect land-use change. EPA has found that there are always life-cycle emissions associated with the production of biofuels. In contrast, AEO assumes that all biofuels are carbon neutral. When quantifying GHG emissions associated with the combustion of fuels, AEO assumes that biofuel emissions are offset by carbon sequestration that occurs during growth of the feedstock and does not consider emissions from land use and land-use change.[6] We did not adjust AEO's treatment of biofuel emissions in developing our base case.

2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for Diversification of Fuel Mix

Enhanced fuel mix diversity can reduce the average carbon intensity of fuels, thereby reducing GHG emissions associated with transportation. Fuel-mix diversification can be promoted by programs that promote alternative fuel production and/or consumption, or through the development of fueling station infrastructure.

Seven states have already set minimum requirements on the amount of renewable fuel that must be blended into gasoline, diesel, or both. However, these programs do not specify what types of renewable fuels must be used, thus allowing for the use of a wide range of biofuel feedstock, with uncertain net emissions implications. Louisiana and Pennsylvania have blend mandates for ethanol and diesel that will be triggered once state production reaches specified levels.[8]

To date, twenty-eight states offer biofuel tax incentives for ethanol, biodiesel, or both.[9] Idaho, North Dakota, South Dakota, and Wisconsin are among several states that offer tax incentives for development of biofuel infrastructure.[10] In addition, Louisiana, Minnesota, Nebraska, North Dakota, and Virginia have already begun to offer programs supporting research and development of advanced biofuels.[11] Rhode Island is

TABLE A-2.1 Low-carbon Transportation Fuel Scenarios

ACTION	POLICIES AND PROGRAMS DRIVING ACTION	SCENARIOS		
		Lackluster	Middle-of-the-Road	Go-Getter
Diversity in fuel mix resulting in lower average carbon content of fuels	• Low-carbon fuel standard • Clean fuel standard • Advanced biofuels standard • Infrastructure incentives	States that account for 15 percent of energy consumption from transportation fuels reduce carbon intensity of fuels by 1 percent per year beginning in 2015 through 2035.	States that account for 25 percent of energy consumption from transportation fuels reduce carbon intensity of fuels by 1 percent per year beginning in 2015 through 2035.	States that account for 35 percent of energy consumption from transportation fuels reduce carbon intensity of fuels by 1 percent per year beginning in 2015 through 2035.

actively researching and developing plans to expand advanced biofuel production.

Life-cycle GHG emissions intensity can vary considerably depending on the fuel type, sources, and production methods. In the Renewable Fuel Standard Regulatory Program Analysis completed in February 2010, EPA found that advanced biofuels can reduce life-cycle GHG emissions 40 to 90 percent below conventional gasoline, whereas corn ethanol from typical new facilities can only reduce life-cycle GHG emissions between 0 and 40 percent below conventional gasoline.[12,13]

In order to guarantee a reduction in the carbon intensity of fuels, some states have begun to pursue a clean fuel standard or a low-carbon fuel standard. The first such standard was issued by the California Air Resources Board in 2009. It requires the carbon intensity of fuels sold in California to be reduced 10 percent by 2020.[14] Initiatives under way in the Pacific Northwest and Northeast and Mid-Atlantic are evaluating the implications of implementing similar types of standards.[15]

In our scenarios we assume that states pursue a range of actions such as those described above, and that those policies further reduce the average carbon intensity of transportation fuels by 1 percent per year between 2015 and 2035. This rate is generally consistent with targets being considered in the Northeast, Washington, and Oregon, as well as the targets required under California's Low Carbon Fuel Standard.[16] If a similar target was adopted nationwide, this would reduce the carbon intensity of fuels an additional 6 percent in 2020 and 21 percent in 2035. In the lackluster scenario, we assume this annual reduction is achieved by states accounting for 15 percent of energy consumption from transportation fuels. In the middle-of-the-road and go-getter scenarios, we assume that these policies are pursued by states accounting for 25 percent and 35 percent of fuel consumption, respectively. We assume these state actions affect both gasoline and diesel consumption.

Table A-2.2 is intended to help put these numbers into context. It shows that California alone accounts for 10 percent of U.S. on-road fuel consumption, and that the Northeast and Pacific Northwest account for 17 percent and 3 percent of on-road fuel consumption, respectively. Meanwhile, the top five biofuel producing states (IA, NE, IL, MN, and IN) account for 10 percent of on-road fuel consumption.

TABLE A-2.2 Motor Fuel Consumption, 2010

	PERCENT OF TOTAL U.S. MOTOR FUEL CONSUMPTION
California	10
Northeast (New England, Mid-Atlantic, DE, MD)	17
Pacific Northwest	3
Top 5 Biofuel Producers (IA, NE, IL, MN, IN)	10

Source: State Energy Data System, U.S. EIA, 2012.

The 2007 EISA established a national renewable fuel standard that requires increasing renewable fuel production through 2022, with required production levels in later years to be established by the EPA in a future rulemaking. In the scenarios that we consider, biofuel production does not meet or exceed those standards through 2022. Under all of the state scenarios, biofuel consumption continues to rise until 2035, and over time even the lackluster scenario could lead to biofuel production levels in excess of the 2022 standards sometime before 2035. Note that the precise date the EISA's 2022 standards are exceeded and the total level of biofuel consumption will depend on assumptions about federal agency actions and the impact of fuel economy standards on biofuel consumption. The EISA 2022 standard represents 22 percent of total fuel consumed by light-, medium-, and heavy-duty vehicles in 2022 under our base case.

3. Modeling Notes for Diversification of Fuel Mix

In our model we assume that all of the GHG reductions from fuel diversification are the result of increased biofuel consumption and are not due to state policies and programs promoting use of PHEVs, EVs, and natural gas vehicles. Deployment of PHEVs, EVs, and natural gas vehicles provide credit for manufacturers to meet their national emissions and CAFE standards. This means that increased deployment of these vehicles in one state can help a manufacturer meet the standards and therefore will not necessarily result in nationwide emission reductions.[17] It is true that the current CAFE standards contain an incentive for biofuel vehicles. However, no such credit is provided under EPA's GHG emissions standards, and thus increased consumption of biofuels is expected to lead to additional reductions in GHG emissions.

Biofuels present a modeling challenge due to the uncertainty about the GHG benefits they provide. EPA's *Renewable Fuel Standard Regulatory Program Analysis* finds that in some cases corn ethanol consumption could be worse than traditional gasoline consumption—for instance, if the ethanol is produced in a dry mill fueled by coal.[18]

It is beyond the scope of our analysis to directly model emissions from the fuel production process. Instead, we avoid modeling these impacts by considering only those state policies that are directly or indirectly responsive to the life-cycle impacts of fuel production (e.g., clean fuel standard, advanced biofuel standard).

We assume that the same states that pursue fuel diversification policies also pursue VMT reduction policies. This results in a conservative estimate of the benefits of these policies, since the relative impact of each policy will be less in the presence of the other policy than it would on its own.

4. Uncertainties for Diversification of Fuel Mix

California's LCFS is currently being challenged in two separate lawsuits brought by ethanol producers, refineries, and truckers.[19] One of the rulings prevented California from enforcing the rule, but this injunction was lifted in April 2012 pending a decision on California's appeal. A three-judge panel of the Ninth Circuit Court of Appeals heard oral arguments in this case in October 2012.

For purposes of this analysis, we assume that state policies drive changes in the fuel mix beyond what is required nationally. If, however, state and federal policies are designed in a way that allows increased state consumption or production to count toward the federal fuel standards, then benefits of those policies would decrease.

B. VMT REDUCTION

1. Base Case for VMT Reduction

In these scenarios we only consider reductions in vehicle miles traveled (VMT) from light-duty vehicles. We use the same baseline for gasoline and diesel consumption for light-duty vehicles as our base case for diversity in fuel mix. The AEO2012 projects VMT to increase from 2,660 billion miles in 2010 to 3,583 billion miles in 2035. This is a slower rate of growth than has been projected in previous AEOs, which can be attributed to rising fuel costs and the effects of the economic recession.[20]

2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for VMT Reduction

A variety of growth and land-use strategies can reduce VMT and contribute to GHG emissions savings.[21] These include smart-growth strategies, such as targeting growth near public transportation, favoring infill, limiting sprawl, mixed-use development, and provision of affordable housing options. Growth strategies can be complemented by a variety of other tools to reduce VMT, including improving and expanding public transportation options, bike and pedestrian pathways, and car sharing, as well as through speed limit restrictions, intercity tolls, and strategies to limit driving within urban centers (such as parking restrictions).[22]

States play an important role in encouraging the development of smart-growth and related strategies. They can adopt VMT or GHG reduction targets, direct funding for smart growth, and work with regional

TABLE A-2.3 **Vehicle Miles Traveled (VMT) Scenarios**

ACTION	POLICIES AND PROGRAMS DRIVING ACTION	SCENARIOS		
		Lackluster	**Middle-of-the-Road**	**Go-Getter**
Vehicle miles traveled (VMT) reduction	• Smart growth • Improved public transit • Pedestrian and biking infrastructure • Improved traffic systems operation	States that account for 15 percent of GHG emissions from light-duty vehicles annually reduce VMT 0.5 percent below base case projections beginning in 2016	States that account for 25 percent of GHG emissions from light-duty vehicles annually reduce VMT 0.5 percent below base case projections beginning in 2016	States that account for 35 percent of GHG emissions from light-duty vehicles annually reduce VMT 1 percent below base case projections beginning in 2016

planning organizations to implement strategies that will achieve reduction goals.

Several states are in the process of implementing or developing smart-growth programs and policies. In Maryland, the Greenhouse Gas Reduction Act of 2009 required the Maryland Department of the Environment to develop a plan to reduce GHG emissions 25 percent below 2006 levels by 2020 and to allocate reduction targets to lead agencies by economic sector.[23] The Maryland Department of Transportation then developed a plan to meet its allocated goal by adopting VMT reduction strategies such as improved public transportation, bike and pedestrian infrastructure, and travel demand management. According to analysis by the Maryland Department of Transportation, plans that are already currently funded are expected to reduce VMT by roughly 5 percent by 2020 compared to business-as-usual projections, or just over 0.5 percent per year between 2012 and 2020.[24]

California is pursuing a similar strategy with its Sustainable Communities and Climate Protection Act of 2008. This law directs state agencies to set GHG emissions targets from smart growth and other VMT policies and to work with metropolitan planning organizations (MPOs) to implement strategies expected to help achieve these targets.[25] California's Air Resources Board worked with MPOs to develop regionally appropriate targets. In the MPOs with the greatest population densities, this process resulted in per capita GHG emissions reduction targets of 7 to 8 percent below 2005 levels by 2020 and 13 to 16 percent below 2005 levels by 2035. In lower density MPOs, this process resulted in targets around 5 percent below 2005 levels by 2020 and 10 percent below 2005 levels by 2035. In rural areas, targets are lower, and in some cases VMT growth will be allowed until after 2020. The state lacks the authority to require MPOs to adopt these targets or to require the jurisdictions therein to implement VMT strategies. The MPOs, however, have been able to get jurisdictions to participate by prioritizing transportation funding and streamlining administrative requirements for those jurisdictions implementing VMT reduction plans.[26]

Other states are moving forward as well. In Oregon, legislation directed the state Department of Transportation to set GHG reduction goals consistent with a statewide target of 10 percent below 1990 levels by 2020, and to work with MPOs to enact strategies to meet those goals.[27] Similar legislation in Washington established specific VMT reduction targets of 35 percent below 1990 levels by 2035, although later reevaluation of the target suggested 7 to 10 percent was more realistic.[28] Other states—including New York and Massachusetts—are developing smart-growth and VMT reduction strategies as part of broader climate initiatives.[29]

In our lackluster and middle-of-the-road scenarios, we assume that states implement policies and programs that reduce their VMT an additional 0.5 percent below business-as-usual projections per year beginning in 2016, leading to a 10 percent reduction below business-as-usual projections in 2035.[30] This is on the conservative end of the range found in current state programs. We assume that states accounting for 15 percent and 25 percent of GHG emissions from light-duty vehicles adopt programs or policies that lead to these annual savings in the lackluster and middle-of-the-road scenarios, respectively. In the go-getter scenario, we assume that states reduce their VMT 1 percent below business-as-usual projections per year beginning in 2016, leading to a 20 percent reduction in 2035.

We assume that such programs or policies are pursued by states accounting for 35 percent of GHG emissions from light-duty vehicles.

A VMT reduction of 1 percent per year is consistent with existing plans in California, Oregon, and New York. An analysis by the Urban Land Institute and Cambridge Systematics that looks at a similar set of policies finds that widespread adoption of land use and public transportation strategies results in GHG reductions of about 17 percent below baseline in 2030.[31] By comparison, if all states pursued go-getter-level ambition, reductions in 2030 would be 15 percent below baseline.

Note that the six states identified as already pursuing mandatory and voluntary policies above account for 22 percent of VMT. None of these state programs are directly included in the AEO2012 reference case. Additional state VMT profiles are provided in Table A-2.4.

TABLE A-2.4 Top 15 States According to Light-Duty Vehicle Miles Traveled (VMT), 2010

STATE	VMT (billions)	PERCENT OF TOTAL U.S. VMT
California*	323	11
Texas	234	8
Florida	196	7
New York*	131	4
Ohio	112	4
Georgia	112	4
Illinois	106	4
North Carolina	102	3
Pennsylvania	100	3
Michigan	98	3
Virginia	82	3
Indiana	76	3
New Jersey	73	3
Missouri	71	2
Tennessee	70	2
Washington*	57	2
Maryland*	56	2
Massachusetts*	54	2
Oregon*	33	1

Source: Bureau of Transportation Statistics, State Transportation Statistics, Table 5-3.
Note: Asterisks indicate states with VMT reduction plans. States shaded gray are not in the top 15 of light-duty VMT but are listed here for reference because they have existing reduction plans.

III. Energy Efficiency

A. ELECTRICITY SAVINGS

I. Base Case for Electricity Savings

Reducing electricity demand through improved end-use efficiency avoids the need to burn fossil fuel to generate electricity, thus reducing GHG emissions. A variety of state policies and programs already drive efficiency improvements, including energy efficiency resource standards, programs funded by system benefit charges, and least-cost procurement.[32] In addition, most states participating in the Northeastern and Mid-Atlantic Regional Greenhouse Gas Initiative (RGGI) also use auction revenue to fund electric efficiency programs.[33]

As described in detail in Appendix I, Sections III.A and IV.A, we utilized U.S. Energy Information Administration's (EIA) data for electricity demand in our base case. AEO2012 does not explicitly model state energy efficiency programs. However, programs in existence in 2011 and earlier are generally thought to be captured through recent regional electricity demand trends. Efficiency savings from new programs or existing programs that increase their incremental targets are generally expected to be additional to those modeled in the AEO reference case.[34]

Because AEO2012 does not model state-specific projections, we had to develop electricity demand projections for each U.S. state and the District of Columbia. This was done using historical electricity demand data for each state from EIA's State Energy Data System[35] and regional annual electricity demand growth rates from the AEO2012 reference case.

TABLE A-2.5 Electricity Savings Scenarios

ACTION	POLICIES AND PROGRAMS DRIVING ACTION	SCENARIOS		
		Lackluster	Middle-of-the-Road	Go-Getter
Electricity savings from states with EE targets	• Energy efficiency resource standards • System benefit charge funds or other funds • Least-cost procurement requirements	States responsible for 75 percent of electricity consumption that have existing annual energy efficiency targets below 1.5 percent achieve annual efficiency savings of 1.5 percent per year beginning in 2015 through 2035.	States responsible for 75 percent of electricity consumption that have existing annual energy efficiency targets below 2 percent achieve annual efficiency savings of 2 percent per year beginning in 2015 through 2035.	States responsible for 75 percent of electricity consumption that have an existing annual energy efficiency target below 2.5 percent achieve annual efficiency savings of 2.5 percent per year beginning in 2015 through 2035.
Electricity savings from states without EE targets		States responsible for 25 percent of electricity consumption achieve efficiency savings of 1 percent per year beginning in 2015 through 2035.	States responsible for 25 percent of electricity consumption achieve efficiency savings of 1.5 percent per year beginning in 2015 through 2035.	States responsible for 50 percent of electricity consumption achieve efficiency savings of 1.5 percent per year beginning in 2015 through 2035.

2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for Electricity Savings

Twenty-four states covering 60 percent of electricity demand currently have energy savings targets, which range from 0.3 to 2.4 percent savings per year.[36] An ACEEE analysis of twenty states with energy efficiency resource standards (EERS) in place in 2009 and 2010 found that states are generally on track toward meeting their efficiency goals.[37,38]

Under each scenario, we assume that some states without existing energy efficiency targets adopt policies and programs that lead to electricity savings beginning in 2015 (see FigureA-2.2). In the lackluster scenario, we assume that states accounting for 25 percent of electricity consumption not covered by an energy efficiency target achieve savings of 1 percent per year. In our middle-of-the-road scenario, we assume that states accounting for 25 percent of electricity consumption not covered by an energy efficiency target achieve savings of 1.5 percent per year. In our go-getter scenario, we assume that states accounting for 50 percent of electricity consumption not covered by an energy efficiency target adopt policies and programs that lead to electricity savings of 1.5 percent per year.

Under each scenario, we also assume that some states with existing energy efficiency targets adopt policies and programs that lead to additional electricity savings above these targets beginning in 2015. In our lackluster scenario, we assume that 75 percent of states with energy efficiency targets below 1.5 percent achieve electricity savings of 1.5 percent per year. In the middle-of-the-road scenario, we assume that 75 percent of states with energy efficiency targets below 2 percent achieve electricity savings of 2 percent per year. In the go-getter scenario, we assume that 75 percent of states with an energy efficiency target below 2.5 percent achieve electricity savings of 2.5 percent per year.

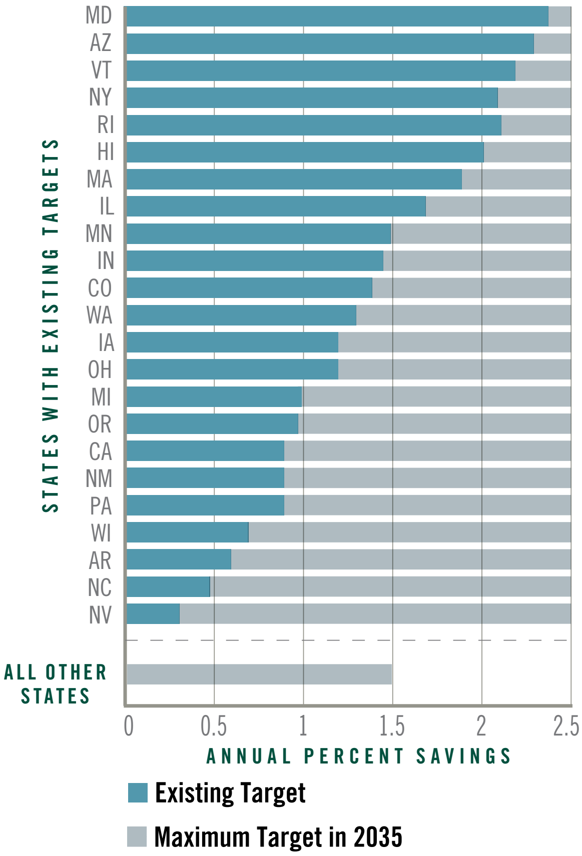
For additional context for these scenarios, see Table A-2.6, which provides a list of the top electricity consumers by state.

3. Modeling Notes for Electricity Savings

For purposes of our analysis we only examined the incremental benefit of new targets. A list of existing state targets was obtained from ACEEE's *2012 State Energy Efficiency Scorecard*.[39]

Typically, energy efficiency targets do not apply to all electricity sales within a state. In some states, targets apply only to investor-owned utilities (IOUs), in others

FIGURE A-2.2 Existing State Energy Efficiency Resource Standards and Scenario Assumptions (percent)



Source: Figure created using data from American Council for an Energy-Efficiency Economy's The 2012 State Energy Efficiency Scorecard, October 2012.

Note: We do not assume all the states pictured reach the scenario targets. Rather, we assume that only some states will take action. See Table A-2.5 for details. Texas had an electricity efficiency standard at the time of publication, but was treated as a state without a target for modeling purposes because its target is relatively low (about 0.2 percent of demand). This approach results in a more conservative estimate of total electricity savings than if Texas were treated as a state with an existing target.

targets apply only to utilities with large numbers of customers, while other states apply targets to varying combinations of IOUs, municipal utilities, and cooperatives.[40] On average, 13 percent of sales are not included by existing targets. To account for this, we adjusted the electricity savings by the percent of electricity sales covered. In the case of states with existing targets, we applied historical coverage percentages estimated by ACEEE (2012).[41] For those states without existing targets, we assumed that the percent of electricity sales covered was equal to the average percentage covered in states with existing targets.

We summed the incremental electricity savings for all states and incorporated the total savings into our electric demand module, which calculates the resulting greenhouse gas benefits (see Appendix I, Section V for more information).

For purposes of this analysis we assumed that these energy efficiency gains would be incremental to the other policies considered in our state and federal scenarios. Thus we assume that these benefits are in addition to savings from improved building codes and increased deployment of combined heat and power systems. We note that some states count combined heat and power (CHP) toward their energy efficiency standards,[42] and some states may allow other policies and programs to count under their energy efficiency goals. However, we believe our approach helps readers to more clearly identify the potential gains from any particular set of actions than would otherwise be possible.

B. NATURAL GAS EFFICIENCY

1. Base Case for Natural Gas Efficiency

Efficiency improvements in residential, commercial, and industrial systems provide GHG benefits by reducing demand for fossil fuels. As described in greater detail below, a number of states have efficiency programs in place that specifically target natural gas consumption.[43]

Our base case relies on U.S. Energy Information Administration's (EIA) data for natural gas demand. AEO2012 does not explicitly model state energy efficiency programs. However, programs in existence in 2011 and earlier are generally thought to be captured through recent regional natural gas demand trends.[44] Because AEO2012 does not model state-specific projections, we had to develop natural gas demand projections for each U.S. state and the District of Columbia. This was done using historical natural gas demand data for each state from EIA's State Energy Data System[45] and regional annual natural gas demand growth rates from the AEO2012 reference case.

2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for Natural Gas Efficiency

Eleven states covering 34 percent of natural gas demand currently have natural gas savings targets, most of which range from 0.5 to 1.5 percent savings of total natural gas demand per year (see Figure A-2.3).[46] 1 Under each scenario, we assume that some states

TABLE A-2.6 Largest Electricity Consumers, 2010

COVERED BY AN ELECTRIC EFFICIENCY STANDARD			UNCOVERED BY AN ELECTRIC EFFICIENCY STANDARD		
State	**Demand (trillion Btu)**	**Percent of covered sales**	**State**	**Demand (trillion Btu)**	**Percent of uncovered sales**
CA	882	14	TX	1223	19
OH	526	8	FL	789	12
PA	508	8	GA	480	8
IL	494	8	VA	388	6
NY	493	8	TN	353	6
NC	465	7	KY	319	5
IN	362	6	AL	310	5
MI	354	5	MO	294	5
WA	308	5	LA	290	5
AZ	249	4	SC	281	4
WI	235	4	NJ	270	4
MN	231	4	OK	197	3
MD	223	3	MS	170	3
MA	195	3	KS	138	2
CO	181	3	WV	109	2

Source: State Energy Data System, U.S. EIA, 2012.

TABLE A-2.7 Natural Gas Efficiency Scenarios

ACTION	POLICIES AND PROGRAMS DRIVING ACTION	SCENARIOS		
		Lackluster	**Middle-of-the-Road**	**Go-Getter**
Natural gas savings from states with EE targets	• Energy efficiency resource standards • System benefit charge funds or other funds	States responsible for 25 percent of natural gas consumption that have energy efficiency targets below 1 percent achieve savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 50 percent of natural gas consumption that have energy efficiency targets below 1 percent achieve savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 75 percent of natural gas consumption that have energy efficiency targets below 1.5 percent achieve savings of 1.5 percent of total demand per year from 2015 to 2035.
Natural gas savings from states without EE targets		States responsible for 10 percent of natural gas consumption achieve natural gas savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 25 percent of natural gas consumption achieve natural gas savings of 1 percent of total demand per year from 2015 to 2035.	States responsible for 50 percent of natural gas consumption achieve natural gas savings of 1.5 percent of total demand per year from 2015 to 2035.

without existing energy efficiency targets adopt policies and programs that lead to savings in natural gas demand beginning in 2015. In the lackluster scenario, we assume that states accounting for 10 percent of natural gas consumption not covered by an energy efficiency target achieve savings of 1 percent per year. In our middle-of-the-road scenario, we assume that states accounting for 25 percent of natural gas consumption not covered by an energy efficiency target achieve savings of 1 percent per year. In our go-getter scenario, we assume that states accounting for 50 percent of natural gas consumption not covered by an energy efficiency target adopt policies and programs that lead to savings of 1.5 percent per year.

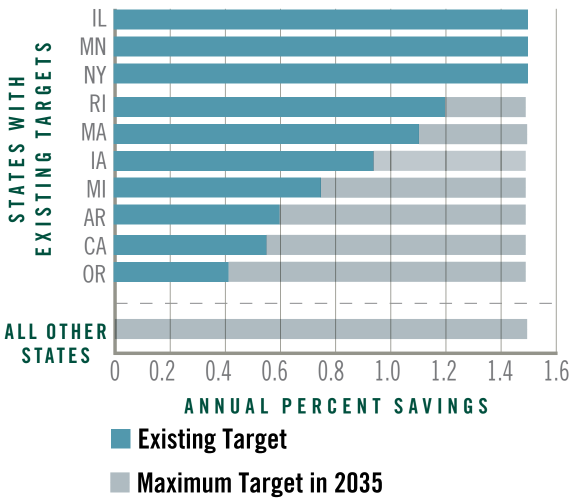
Under each scenario, we also assume that some states with existing energy efficiency targets adopt policies and programs that lead to additional natural gas savings above these targets beginning in 2015. In our lackluster scenario, we assume that 25 percent of states with energy efficiency targets below 1 percent achieve savings of 1 percent beginning in 2015. In the middle-of-the-road scenario, we assume that 50 percent of states with energy efficiency targets below 1 percent achieve savings of 1 percent. In the go-getter Scenario, we assume that 75 percent of states with an energy efficiency target below 1.5 percent achieve savings of 1.5 percent.

For additional context for these scenarios, see Table A-2.8, which provides a list of the top natural gas consumers by state.

3. Modeling Notes for Natural Gas Efficiency

While AEO2012 does not explicitly model state energy efficiency programs, programs in existence in 2011 and earlier are generally thought to be captured through recent regional natural gas demand trends. Efficiency savings from new programs or existing programs that increase their incremental targets are generally expected to be additional to those modeled in the AEO reference case.Therefore, we only modeled incremental benefits from new targets. We obtained the list of existing state targets from ACEEE's *2012 State Energy Efficiency Scorecard.*[48]

FIGURE A-2.3 Existing Natural Gas Efficiency Targets and Scenario Assumptions



Source: Figure created using data from American Council for an Energy-Efficiency Economy's *The 2012 State Energy Efficiency Scorecard,* October 2012.

Note: We do not assume all the states pictured reach the scenario targets. Rather we assume that only some states will take action. See Table A-2.7 for details. Wisconsin and Colorado had natural gas savings targets at the time of publication, but were treated as states without targets in order to generate more conservative modeling results. Wisconsin's targets were defunded in 2011. Colorado sets annual targets commensurate with funding levels and these targets have been historically low (approximately 0.1 percent of demand).

Typically, natural gas targets apply to all commercial, residential, and industrial sales within a state.[49] However, in our middle-of-the-road and go-getter scenarios, we already account for industrial efficiency gains through industrial standards. To avoid double counting of these benefits, we do not include natural gas savings from the industrial sector in either of these two scenarios. Rather, we apply the efficiency gains described in these scenarios to commercial and residential sales only, and assume that the programs will affect virtually all of those sales. The lackluster scenario for industrial policies only targets boiler efficiency improvements, and results in considerably less efficiency gains. Therefore we assume it would be possible to achieve additional efficiency improvements at industrial sources through natural gas efficiency programs in our lackluster scenario. We assume that the targets will affect nearly 100 percent of sales in the applicable customer class (i.e., residential, commercial, and in some cases industrial).

TABLE A-2.8 Largest Consumers of Natural Gas in Commercial, Residential, and Industrial Sectors, 2010

COVERED BY A NATURAL GAS EFFICIENCY TARGET			NOT COVERED BY A NATURAL GAS EFFICIENCY TARGET		
	Demand (trillion Btu)	Percent of sales covered by a target		Demand (trillion Btu)	Percent of sales not covered by a target
California	1546	31	Texas	2000	18
Illinois	869	17	Louisiana	1143	10
New York	772	15	Ohio	733	7
Michigan	618	12	Pennsylvania	587	5
Minnesota	375	8	Indiana	495	5
Iowa	256	5	New Jersey	460	4
Massachusetts	248	5	Colorado	397	3
Arkansas	167	3	Oklahoma	367	3
Oregon	125	3	Georgia	352	3
Rhode Island	36	1	Wisconsin	330	3

Source: State Energy Data System, U.S. EIA, 2012.

Note: Although Colorado and Wisconsin have natural gas savings targets in place, we treat them as though they do not have targets in order to generate more conservative modeling results. Wisconsin's targets were defunded in 2011. Colorado sets annual targets commensurate with funding levels and these targets have been historically low (approximately 0.1 percent of demand).

C. REDUCED ENERGY CONSUMPTION IN BUILDINGS

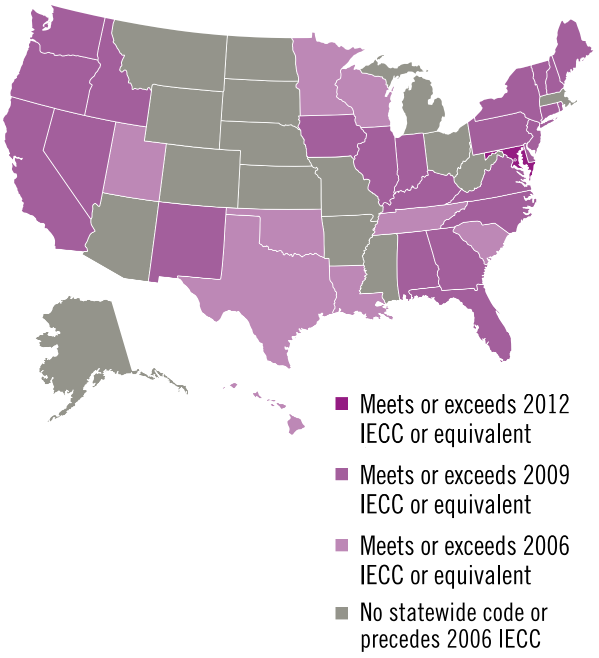
1. Base Case for Reduced Energy Consumption in Buildings

Our base case relies on the AEO2012 reference case. AEO2012 estimated that residential and commercial buildings accounted for 40 percent of total U.S. energy consumption and 73 percent of U.S. electricity use in 2010. These percentages rise to 41 percent of total U.S. energy consumption and 78 percent of U.S. electricity consumption in 2035. The majority of GHG emissions associated with buildings are the result of electricity use, which accounts for 78 percent of emissions in the commercial sector, and 74 percent of emissions in the residential sector. AEO2012 projects that even though population will increase 25 percent by 2035, energy use from buildings will only increase by 9 percent due to improvements in appliance and building shell efficiency.

Building codes provide a vehicle for establishing minimum efficiency standards for new buildings and major renovations. Building codes have historically been controlled by U.S. states and municipalities. As a result, the stringency of commercial and residential building codes they have adopted varies considerably (see Figures A-2.4 and A-2.5). It is also worth noting that the benefit of building codes varies to some extent from state to state depending on enforcement.[50]

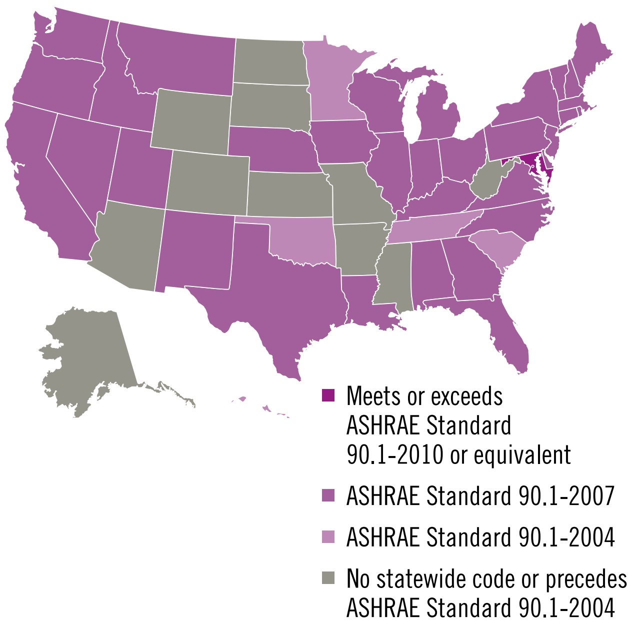
The American Recovery and Reinvestment Act of 2009 attempted to raise the level of standards across the United States by making state funding for the State Energy Program contingent upon states adopting the IECC 2009 codes for new residential buildings and ASHRAE 90.1-2007 for new commercial buildings. However, a number of states have not yet adopted these new codes. AEO2012 assumes that all states will adopt these new codes by 2017. The AEO2012 reference case does not model explicit adoption of additional building codes, although other economic and policy drivers (such as appliance standards) may lead to additional efficiency improvements.

FIGURE A-2.4 **Residential Building Codes**



Note: Building Code Maps adapted from the Online Code and Advocacy Network (OCEAN) (http://energycodesocean.org/code-status as of November 9, 2012).

FIGURE A-2.5 **Commercial Building Codes**



Note: Building Code Maps adapted from the Online Code and Advocacy Network (OCEAN) (http://energycodesocean.org/code-status as of November 9, 2012).

2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for Reduced Energy Consumption in Buildings

In our lackluster scenario, we assume that 10 percent of the electricity consumed by the building sector is covered by more ambitious building codes. In our middle-of-the-road and go-getter scenarios, we assume that 30 and 50 percent of the electricity consumed by the building sector is covered by more ambitious building codes.

Those building codes and the assumed electric energy savings achievable through their adoption are based on the Institute for Electric Efficiency's (IEE's) *Assessment of Electricity Savings in the U.S. Achievable through New Appliance/Equipment Efficiency Standards and Building Efficiency Codes (2010-2025).*[51] This paper quantifies reductions associated with "moderate" and "aggressive" scenarios of new building code adoption. Those scenarios are as follows:

- Residential buildings: The moderate scenario assumes that IECC 2012 goes into effect in 2015, followed by IECC 2015 in 2019, with savings of 25 percent and 45 percent compared to IECC 2006. The aggressive scenario uses the same assumptions as the moderate case until 2024, when it is assumed that a new code, with energy savings of 60 percent, goes into effect.

- Commercial buildings: The moderate scenario assumes the 2007 ASHRAE standards go into effect in 2013, followed by the 2010 ASHRAE in 2015, and 2013 ASHRAE in 2018, with savings of 15 percent, 20 percent, and 40 percent compared to the 2004 ASHRAE standards. The aggressive scenario uses the same assumptions until 2024, when it is assumed that a new ASHRAE standard with savings of 50 percent goes into effect.

Since IEE does not consider natural gas savings, we use the natural gas savings projected from building codes in the AEO2011 expanded standards and codes case. This equates to 210 trillion Btu of energy savings in 2025 (1 percent of total building consumption) and 450 trillion Btu of energy savings (2 percent of consumption) in 2035. The building code adoption

TABLE A-2.9 Building Code Scenarios

ACTION	POLICIES AND PROGRAMS DRIVING ACTION	SCENARIOS		
		Lackluster	**Middle-of-the-Road**	**Go-Getter**
Reduced energy consumption in buildings	• Commercial and residential building codes • Financial incentives	States that account for 10 percent of energy consumption in residential and commercial buildings phase in increasingly ambitious building codes through 2035. Generally, residential codes increase from IECC2009 to IECC2015 and commercial codes increase from 2004 ASHRAE 90.1 to 2013 ASHRAE 90.1.	States that account for 30 percent of energy consumption in residential and commercial buildings phase in increasingly ambitious building codes through 2035.	States that account for 50 percent of energy consumption in residential and commercial buildings phase in increasingly ambitious building codes through 2035.

schedule and associated energy savings in our analysis are considerably more ambitious than the AEO2011 expanded standards[52] and codes side case, driving roughly double the level of electricity savings.[53] This suggests that actual natural gas savings associated with adoption of the building code improvements assumed in our scenario would likely be considerably larger than we estimate here. We assume that there is minimal overlap between the natural gas savings due to improved building codes and energy efficiency programs for natural gas. This is because building codes affect new buildings and major renovations, while efficiency programs typically affect only existing buildings.

3. Modeling Notes for Reduced Energy Consumption in Buildings

The IEE report only provides electricity savings for 2025. We therefore estimated savings by assuming a linear rate of growth from 2015 through 2025. For years 2026–35, we extrapolated the national annual electricity savings by applying an assumed incremental benefit, based on the results of the moderate and aggressive scenarios of the IEE paper.[54]

We calculated electricity savings for each scenario by discounting the annual totals according to the percentage of states adopting the IEE building code schedule as described in Table A-2.9. We incorporated the total savings into our electric demand module, which incorporates changes in electricity demand resulting from a variety of federal regulations and state actions (see Appendix I, Section V, for more information).

D. INCREASED COMMERCIAL AND INDUSTRIAL COMBINED HEAT AND POWER (CHP) CAPACITY

1. Base Case for Increased Commercial and Industrial Combined Heat and Power (CHP)

Conventional electricity generation wastes one-half to two-thirds of the embodied energy of fuel, by releasing it as unused heat.[55] Combined heat and power (CHP) systems put that wasted heat energy to work, by simultaneously generating electricity and steam in a single system. This allows for considerable energy savings, thus reducing GHG emissions.[56]

Our base case relies on total electricity demand and energy CO_2 emissions projections from the AEO2012 reference case. AEO2012 projects 13 GW of new CHP capacity by 2020 and 36 GW of new capacity by 2035. This represents a growth of 144 percent from the 25 GW of CHP projected to be installed in 2012.

2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for Increased Commercial and Industrial Combined Heat and Power (CHP)

Annual additions of CHP have slowed since 2006 in part because of market uncertainty and the financial crisis, among other factors. However, there is emerging recognition of the environmental and economic benefits of CHP at the federal and state levels.[57] For instance, a recent executive order set an ambitious (but non-binding) national goal to deploy 40 GW of new CHP capacity by the end 2020.[58] The Department of Energy is currently working with states to realize this goal.

TABLE A-2.10 Combined Heat and Power (CHP) Scenarios

ACTION	POLICIES AND PROGRAMS DRIVING ACTION	SCENARIOS		
		Lackluster	**Middle-of-the-Road**	**Go-Getter**
Increased installation of industrial and commercial combined heat and power (CHP) systems	• Financial incentives, such as tax credits, loans, and loan guarantees • Standard interconnection rules • Reduced stand-by rates • Net metering policies • Output-based emissions regulations	State action results in deployment of an additional 10 GW of new CHP by 2025.	State action results in deployment of an additional 20 GW of new CHP by 2025.	State action results in deployment of an additional 40 GW of new CHP by 2025. When coupled with the new CHP modeled in AEO2012 (13 GW by 2020), this results in CHP deployment consistent with the Executive Order target of 40 GW of new CHP by 2020.

State policies and programs that can facilitate CHP deployment include standard interconnection rules, reduced stand-by rates, net metering policies, friendly air quality regulations such as output-based emissions regulations, feed-in tariffs, and technical assistance programs. Financial incentives—including tax credits, loans, and loan guarantees—can help ease financial uncertainty and encourage investment in CHP. These programs and incentives tend to be most effective, however, when paired with mechanisms that help overcome grid access issues such as developing interconnection standards for CHP.[59]

In a number of states, regulatory policies have not yet been revised to support distributed generation. High standby rates, which power consumers must pay in order to remain connected to the grid when they are not drawing power, offset otherwise positive economics for CHP systems. Net-metering policies that allow CHP operators to sell excess generation back to the grid can be very helpful, but are not yet widespread. In addition, utility acceptance of CHP interconnection varies widely across the states.

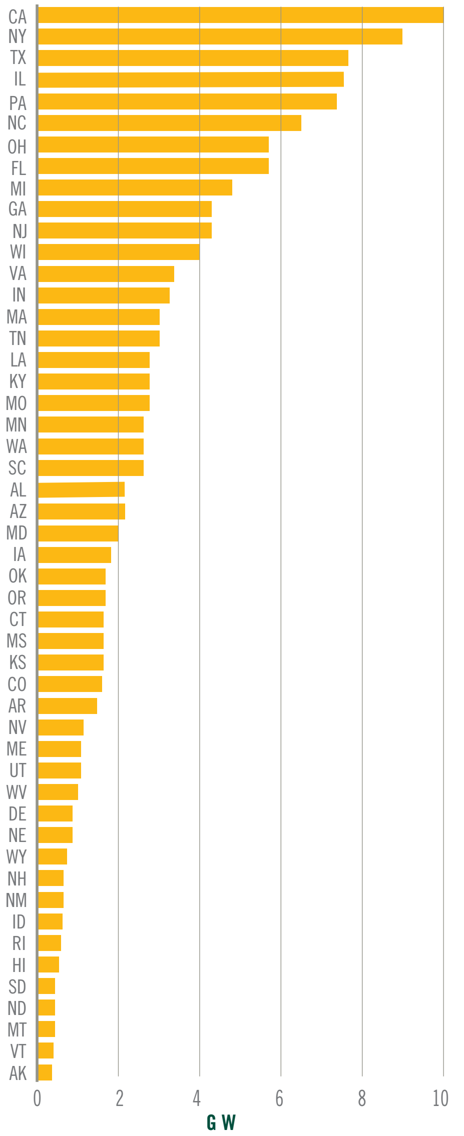
ICF International's *Effect of a 30 Percent Tax Credit on the Economic Potential for Combined Heat and Power* provides the most robust state-level assessment of the technical potential for CHP for all 50 states, and thus serves as the basis for all three of our scenarios. In generating these estimates, ICF limits CHP system size to the site's average electric demand, thus avoiding the need to deal with the challenges of selling electricity onto the grid.

In our lackluster, middle-of-the-road, and go-getter scenarios, we assume that state action results in deployment of an additional 10, 20, and 40 GW of new CHP by 2025. This is roughly 7.5, 15, and 30 percent of the technical potential identified by ICF. Such improvements could be achieved if states accounting for 15, 30, and 60 percent of total technical potential adopted policies that led them to develop new CHP units (above and beyond those modeled in AEO2012) that represent half of their technical potential. In the lackluster and middle-of-the-road scenarios, we assume that policies are implemented in 2015 and that CHP deployment phases in linearly through 2025. Thereafter it plateaus, so that no additional CHP is deployed between 2026 and 2035. In the go-getter scenario, we assume that this ramp-up occurs more rapidly so that 27 of the 40 GW are built by 2020. When coupled with the 13 GW of new CHP already predicted to be built in AEO2012, this enables the U.S. to meet the 40 GW target established by the August 2012 executive order. Figure A-2.6 shows technical potential by state, and is intended to help provide some context for these assumptions.

3. Modeling Notes for Increased Commercial and Industrial Combined Heat and Power (CHP)

We assume that all of the new CHP detailed in the scenarios above is in addition to what is modeled in the AEO2012 reference case. We note that even in our go-getter scenario we build 40 GW of additional CHP. When coupled with the 36 GW of new capacity AEO2012 predicts in 2035, this equates to 58 percent of the technical potential identified by ICF. However, we note that the AEO currently falls far short of recent ICF estimates of existing CHP capacity, estimating

FIGURE A-2.6 Combined Heat and Power Technical Potential



Source: *Effect of a 30 Percent Tax Credit on the Economic Potential for Combined Heat and Power,* ICF International, October 2010.

only 30 GW of capacity in 2011, compared to the 82 GW of CHP capacity estimated in the ICF study.[60]

CHP leads to electricity savings by providing on-site electric generation and displacing electricity that would otherwise be obtained from the grid. The impact of displacing that electricity is calculated by our electricity demand module, described in detail in Appendix I, Section V. Consistent with the ICF study, we assume that CHP units that produce cooling, heating, and power use half of their thermal output to displace electricity production for cooling and half to displace onsite fuel consumption.

CHP deployment tends to result in increased on-site fuel consumption. We estimate both the electricity savings and net increase in onsite fuel consumption using the documented assumptions and findings from ICF International's *Effect of a 30 Percent Tax Credit on the Economic Potential for Combined Heat and Power.*[61] We assume that all new CHP units and retired or refurbished units use 100 percent natural gas.[62] While a few industries are expected to increase use of coal and coal-to-liquid fuel, this will likely be offset by the greater amount of biomass, waste heat, and renewables used in other key industries.[63]

IV. Increased Generation from Renewable Sources

A. BASE CASE FOR INCREASED GENERATION FROM RENEWABLE SOURCES

Increased renewable generation can result from a variety of state programs, such as renewable portfolio standards, alternative energy standards, feed-in or other special tariffs, and other types of financial incentives. Renewable portfolio standards (RPS) specify a percentage of electricity generation (or sales) that must be met by renewable or other alternative sources. Such standards are in place in twenty-nine states and the District of Columbia, which together account for approximately 64 percent of electricity demand.

RPSs have successfully driven renewable development in those states that have adopted them. Analysis by Lawrence Berkeley National Laboratory found that all but three states were within 90 percent of their targets in 2009 and 2010.[64] Most states—including those without RPSs—encourage renewable development through tax incentives, grants and loans, and technical assistance programs.[65]

Our electricity demand projections rely on EIA's AEO2012, which includes all existing mandatory renewable electricity targets. AEO2012 projects that 340 TWh of new renewable electric generation will be built between 2009 and 2035, with an average growth rate of 2 percent in renewables per year, so that renewables account for approximately 14 percent of generation in 2020.

TABLE A-2.11 **Renewable Uptake Scenarios**

ACTION	POLICIES AND PROGRAMS DRIVING ACTIONS	SCENARIOS		
		Lackluster	**Middle-of-the-Road**	**Go-Getter**
Increased renewables from states with renewables targets	• Renewable portfolio standards • Alternative energy standards • Feed-in tariffs • Financial incentives	States responsible for 25 percent of electricity consumption increase their renewable generation by 1 percent annually after the last year for which a standard is set.	States responsible for 50 percent of electricity consumption increase their renewable generation by 1 percent annually after the last year for which a standard is set.	States responsible for 75 percent of electricity consumption increase their renewable generation by 1 percent annually after the last year for which a standard is set.
Increased renewables from states without renewables targets		States responsible for 10 percent of electricity consumption increase their renewable generation 0.5 percent annually beginning in 2015.	States responsible for 25 percent of electricity consumption increase their renewable generation 0.5 percent annually beginning in 2015.	States responsible for 50 percent of electricity consumption increase their renewable generation 0.5 percent annually beginning in 2015.

B. LACKLUSTER, MIDDLE-OF-THE-ROAD, AND GO-GETTER SCENARIOS FOR INCREASED GENERATION FROM RENEWABLE SOURCES

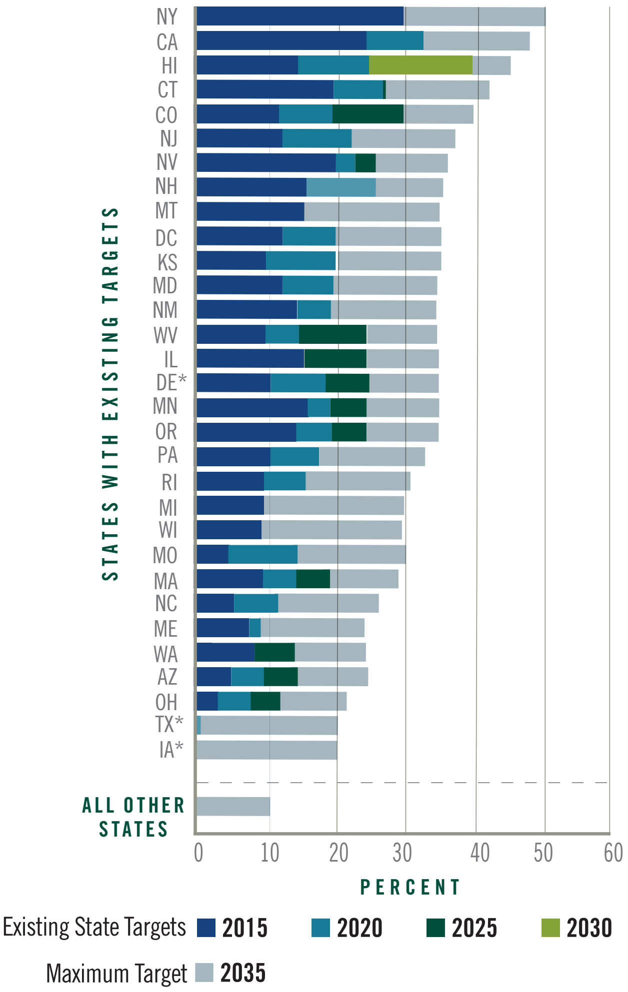
Under each scenario, we assume that some states with existing renewable standards increase these targets by 1 percent per year beginning the year after the target is reached. We choose a 1 percent annual gain because it represents the most common annual gain required by mature state programs (see Figure A-2.7).

Under each scenario, we also assume that some states without existing renewable targets increase renewable generation by 0.5 percent annually beginning in 2015. This is one-half the rate of change we model for states that already have renewable standards in place. In the lackluster scenario, we assume that this improvement occurs in states that account for 10 percent of electricity consumption in the cohort of states without existing renewable standards. In the middle-of-the-

TABLE A-2.12 **Largest Electricity Consumers, 2010**

COVERED BY A RENEWABLE TARGET			NOT COVERED BY A RENEWABLE TARGET		
State	**Demand (trillion Btu)**	**Percent of sales covered by a target**	**State**	**Demand (trillion Btu)**	**Percent of sales not covered by a target**
TX	1223	15	FL	789	17
CA	882	11	GA	480	10
OH	526	6	VA	388	8
PA	508	6	IN	362	8
IL	494	6	TN	353	8
NY	493	6	KY	319	7
NC	465	6	AL	310	7
MI	354	4	LA	290	6
WA	308	4	SC	281	6
MO	294	4	OK	197	4

FIGURE A-2.7 Existing State Renewable Targets and Scenario Assumptions



Source: Figure created using data from the Database of State Incentives for Renewables and Efficiency (DSIRE), downloaded September 2012.

Note: Solid bars represent existing renewable targets and hashed bars represent the maximum new renewable energy that could be deployed in any particular state in 2035 if they increase their renewables at the designated rate (i.e., 1 percent or 0.5 percent). As discussed above, we do not assume that each state experiences this level of incremental renewable generation, but instead assume that a fraction of the states achieve this level of incremental renewable generation. Further note that Texas and Iowa have absolute rather than percent targets. Texas' 5,880 MW by 2015 target is calculated as an approximate percentage of electricity demand for ease of display. Iowa's 105 MW target is not displayed here because the target date (2000) is earlier than what is considered here.

road and go-getter scenarios, we assume that increases to 25 percent and 50 percent, respectively. Note that the same level of benefit achieved by states without a current standard can be achieved if half the number of states pursues the same level of ambition as we assume in states that already have renewable standards (i.e., increase renewable generation by 1 percent per year). For context, see Table A-2.12, which provides a list of the top electricity consumers.

To confirm that the assumptions in our scenarios are technically achievable, we compared the maximum (undiscounted) renewables penetration for each state with its technical potential as calculated by the National Renewable Energy Laboratory (NREL). In most states, the maximum level of renewables penetration does not exceed 2 percent of the state's technical potential.

C. MODELING NOTES FOR INCREASED GENERATION FROM RENEWABLE SOURCES

AEO aggregates renewable electricity targets by North American Electric Reliability Corporation region, and does not provide individual state targets.[67] Therefore, we estimated incremental renewable generation state-by-state due to their renewable standards, using our estimated electricity demand baseline for each state (see Section II.C. of Appendix II above for details),[68] and annual RPS targets by state for the years 2005–35 from the DSIRE Renewables Database.[69]

Since our scenarios do not choose what states take action, when modeling we assumed each state took action, but discounted the incremental renewable gains by the assumed implementation level. In some states, renewable targets can be met in part through energy efficiency improvements. Due to the significant energy efficiency increases across all three of our scenarios, we assumed that those energy efficiency limits would be met, thereby reducing the level of renewable energy obtained due to programs in those states.

Most existing renewable targets, and those established in our scenarios, are tied to demand (e.g., Colorado requires that 30 percent of electricity sales will be met with renewables by 2020). Therefore, estimates of the GHG benefits from renewable programs must take into account the impacts of reduced electricity consumption from energy efficiency programs. Incremental renewable generation for each of our scenarios was calculated by comparing the total projected new renewable generation to the original renewable uptake projected under our base case scenario. The greenhouse gas benefits from the new renewable development were calculated using our electric demand module. For more information see Appendix I, Section V.

V. States Implement Policies Modeled for Federal Action

States have broad authority to regulate energy sources and emissions within their boundaries. States may therefore implement many of the same policies that we ascribe to the federal government in the federal analysis, with some exceptions. In this approach we assume that states pursue the same "lackluster," "middle-of-the-road," and "go-getter" policies that are considered in the federal scenarios. Consistent with our other state policies, we do not assume, however, that all states pursue such action. Instead, we assume that these policies are pursued by states accounting for 10, 25, and 50 percent of GHG emissions from those sources. These approaches include state action for all sectors discussed in the federal action section, except for those policies that are ill-suited for state implementation. We deemed policies that eliminate HFCs, regulate off-highway vehicles, adopt appliance and equipment efficiency standards where federal standards already exist, or regulate aviation to be ill-suited to state implementation because they are preempted by federal law. It is important to note that one implication of modeling state-level ambition off of federal ambition for these sectors is that the state scenarios provide the greatest incremental benefit when they are coupled with a less ambitious federal policy.

Endnotes

1. *Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program; Final Rule.* Federal Register, Vol. 75, No. 58, Part II, March 26, 2010.

2. *Regulation of Fuels and Fuel Additives: 2011 Renewable Fuel Standards; Final Rule.* Federal Register, Vol. 75, No. 236, Part II, December 9, 2010.

3. *Regulation of Fuels and Fuel Additives: 2012 Renewable Fuel Standards; Final Rule.* Federal Register, Vol. 77, No. 5, Part V, January 9, 2012.

4. *Annual Energy Outlook 2012.* U.S. Energy Information Administration, June 25, 2012. Accessible at: <http://www.eia.gov/forecasts/archive/aeo12/index.cfm>.

5. Thresholds for specific fuel types are as follows: 20 percent for corn ethanol, 50 percent for biomass-based diesel or advanced biofuel, and 60 percent for cellulosic biofuel.

6. *Assumptions to the AEO2012.* U.S. Energy Information Administration, June 25 2012. Accessible at: <http://www.eia.gov/forecasts/aeo/assumptions/pdf/0554(2012).pdf>.

7. To date, these states are Florida, Hawaii, Minnesota, Missouri, Oregon, New Mexico, and Washington. Massachusetts suspended its biodiesel blend mandate and implemented a voluntary program.

8. U.S. Department of Energy Alternative Fuels Data Center. Accessible at: <http://www.afdc.energy.gov>.

9. To date, these states are Alabama, Florida, Georgia, Hawaii, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Montana, New Mexico, New York, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, Rhode Island, South Dakota, Virginia, Washington, and Wisconsin. For the most recent information on state biofuels policies, see U.S. Department of Energy Alternative Fuels Data Center at <http://www.afdc.energy.gov>.

10. *Advanced Transportation Fuels Advisory Group Recommendations and Supporting Fact Sheets, Midwestern Governors Association.* For more information, see: <http://www.midwesterngovernors.org/fuels.htm>.

11. *Overview of State Biofuel Policies, Incentives, and Opportunities.* Association of State Energy Research and Technology Transfer Institutions, July 2012.

12. *Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis.* EPA (EPA-420-R-10-006), February 2010.

13. These estimates are based on 100-year global warming potential estimates as published in the IPCC Fourth Assessment Report.

14. *Low Carbon Fuel Standard 2011 Program Review Report.* Advisory Panel, December 2011. For more information, see: <http://www.arb.ca.gov/fuels/lcfs/lcfs.htm>.

15. For more information on these plans, see the following resources:
Washington: <http://www.ecy.wa.gov/climatechange/fuelstandards.htm>.
Oregon: <http://www.deq.state.or.us/aq/committees/advcomLowCarbonFuel.htm>.
Mid-Atlantic/Northeast: <http://www.nescaum.org/topics/clean-fuels-standard>.
Introducing a Low Carbon Fuel Standard in the Northeast: Technical and Policy Considerations. Northeast States Center for a Clean Air Future, July 2009.

16. California's Low Carbon Fuel Standard and similar fuel standards under consideration in other states are not included in the AEO2012 reference case.

17. State programs to promote these vehicles are still valuable. In fact, a case can be made that widespread deployment of PHEVs and EVs, in particular, is essential to meet our long-term emissions trajectory, and that states have an integral role to play in deploying the infrastructure needed to make this possible.

18. *Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis.* EPA (EPA-420-R-10-006), February 2010.

19. For more information, see: <http://www.arb.ca.gov/fuels/lcfs/lcfs.htm>. The California LCFS was ruled unconstitutional by a federal district court judge in *Rocky Mountain Farmer's Union v. Goldstene*, 719 F. Supp.2d 1170 (E. Dist. Cal. 2010), and the case is currently on appeal with the Federal Circuit Court of Appeals for the 9th Circuit. The appeal was heard on oral arguments and on deliberation by the three-judge panel when one of the judges died. Parties to the case are awaiting reassignment of the case to a new third judge. Timing of an ultimate decision is unknown but expected at the end of 2013 or early 2014.

20. *Annual Energy Outlook 2012.* U.S. Energy Information Administration, June 25, 2012. Accessible at: <http://www.eia.gov/forecasts/archive/aeo12/index.cfm>.

21. For example, see:
Growing Cooler: The Evidence on Urban Development and Climate Change. Urban Land Institute, Washington, DC, 2009.
Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions. Urban Land Institute, Washington, DC, 2009.

22. *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions.* Urban Land Institute, Washington, DC, 2009.

23. *Greenhouse Gas Reduction Act of 2009 (HB 315).* For more information, see: <http://www.mde.state.md.us/assets/document/Air/ClimateChange/GreenHouse_Gas_Reduction_Act_Bill_2009_Summary.pdf>.

24. *Maryland Climate Action Plan, Maryland Department of Transportation Draft Implementation Plan.* Maryland Department of Transportation, April 2011.

25. Sustainable Communities and Protection Act of 2008 (SB 375). For more information, see: <http://www.arb.ca.gov/cc/sb375/sb375.htm>.

26. For more details, see: <http://www.arb.ca.gov/cc/sb375/sb375.htm>.

27. *Draft Oregon Statewide Transportation Strategy.* Oregon Department of Transportation, May 2012.

28. *Sustainable Communities and Climate Protection Act of 2008 (SB 375).* Statutes of 2008. For more information, see: <http://www.arb.ca.gov/cc/sb375/sb375.htm>.

29. *Climate Action Plan Interim Report.* New York State Climate Action Council, November 2010. *Massachusetts Clean Energy and Climate Plan for 2020.* Executive Office of Energy and Environmental Affairs, December 2010.

30. We start the VMT policies one year later than the other policies we consider because of the extra time typically needed to implement local planning policies and programs.

31. *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions.* Prepared by Cambridge Systematics for the Urban Land Institute, July 2009.

32. *The 2012 State Energy Efficiency Scorecard.* American Council for an Energy-Efficiency Economy (ACEEE), Report Number E12C, October 2012.

33. As of December 31, 2010, about $400 million—52 percent of RGGI auction revenue—had been used to support energy efficiency programs in the ten states participating at the time.

34. Personal communication with Erin Boedecker, EIA, December 2012.

35. *U.S. Energy Information Administration's State Energy Data System, 2012.* Accessible at: <http://www.eia.gov/state/seds/>.

36. *The 2012 State Energy Efficiency Scorecard.* American Council for an Energy-Efficiency Economy (ACEEE), Report Number E12C, October 2012.

37. *Energy Efficiency Resource Standards: A Progress Report on State Experience.* American Council for an Energy-Efficiency Economy (ACEEE), Report Number U112, June 2011.

38. Specifically, they found that thirteen states had reached or exceeded their goals, three achieved over 90 percent of their goals, and three had reached 80 percent or less of their goals. They found, however, that several of the states that missed their goals have programs that are still ramping up, and predict that those programs will deliver greater savings in the coming years.

39. *The 2012 State Energy Efficiency Scorecard.* American Council for an Energy-Efficiency Economy (ACEEE), Report Number E12C, October 2012.

40. In Colorado, Arkansas, California, Ohio, New Mexico, Nevada, and Texas, targets apply only to investor-owned utilities (IOUs) and not to municipal utilities or cooperatives. Illinois and Pennsylvania set targets only on utilities with large numbers of customers. Arizona, Massachusetts, Rhode Island, Indiana, and Washington set targets on some combination of IOUs, municipal utilities, and cooperatives, but not on all utilities. Hawaii, Maryland, Minnesota, New York, Vermont, Iowa, Michigan, Oregon, Wisconsin, and North Carolina have targets covering all sales.

41. Estimated percent coverage in existing states obtained from *The 2012 State Energy Efficiency Scorecard*, American Council for an Energy-Efficiency Economy (ACEEE), Report Number E12C, October 2012.

42. At present, these states include Connecticut, Ohio, Texas, Massachusetts, North Carolina, Pennsylvania, Maine, Washington, Vermont, Arizona, Hawaii, and Nevada.

43. *The 2012 State Energy Efficiency Scorecard.* American Council for an Energy-Efficiency Economy (ACEEE), Report Number E12C, October 2012.

44. Personal communication with Erin Boedecker, EIA, December 2012.

45. *U.S. Energy Information Administration's State Energy Data System, 2012.* Accessible at: <http://www.eia.gov/state/seds/>.

46. *The 2012 State Energy Efficiency Scorecard.* American Council for an Energy-Efficiency Economy (ACEEE), Report Number E12C, October 2012.

47. Personal communication with Erin Boedecker, EIA, December 2012.

48. *The 2012 State Energy Efficiency Scorecard.* American Council for an Energy-Efficiency Economy (ACEEE), Report Number E12C, October 2012.

49. *Energy Efficiency Resource Standards: State and Utility Strategies for Higher Energy Savings.* ACEEE Report Number U113, June 2011.

50. *The 2012 State Energy Efficiency Scorecard.* American Council for an Energy-Efficiency Economy (ACEEE), Report Number E12C, October 2012.

51. *Assessment of Electricity Savings in the U.S. Achievable through New Appliance/Equipment Efficiency Standards and Building Efficiency Codes (2010-2025).* IEE Whitepaper, May 2011.

52. The AEO expanded standards and codes side case assumes that the AEO added three rounds of codes: a 30 percent improvement over IECC 2006 in the residential sector and a 30 percent improvement over ASHRAE 90.1-2004 in the commercial sector by 2020, then two subsequent incremental 5 percent increases in 2023 and 2026.

53. *Annual Energy Outlook 2011.* EIA, June 2011.

54. The only difference between the aggressive and moderate scenarios in the IEE paper is that the aggressive scenario adds a new code in 2024. Therefore, we assumed that the rate of change is identical in both scenarios until 2023 and the incremental difference between the two occurs in years 2024–25. We extrapolate using the sum of the incremental benefit from this code and the incremental benefit from the moderate scenario since benefits of the new code will continue to accrue through 2035.

55. *Efficiency Benefits.* Combined Heat and Power Partnership, U.S. EPA. Accessible at: <http://www.epa.gov/chp/basic/efficiency.html>.

56. *Combined Heat and Power: Markets and Challenges.* ICF International, June 2012.

57. *Combined Heat and Power: Markets and Challenges.* ICF International, June 2012.

58. Executive Order: "Accelerating Investment in Industrial Energy Efficiency." August 30, 2012. Accessible at: <http://www.whitehouse.gov/the-press-office/2012/08/30/executive-order-accelerating-investment-industrial-energy-efficiency>.

59. *Challenges Facing Combined Heat and Power Today: A State-by-State Assessment.* ACEEE Report Number IE111, September 2011.

60. ICF uses a more comprehensive data collection system compared to EIA. For example, EIA does not collect data for systems less than 1 MW in size. For medium and large sites, there may be underreporting where surveys are not sent to sites with CHP installations.

61. *Effect of a 30 Percent Tax Credit on the Economic Potential for Combined Heat and Power.* ICF International, October 2010.

62. *Effect of a 30 Percent Tax Credit on the Economic Potential for Combined Heat and Power.* ICF International, October 2010.

63. *Annual Energy Outlook 2012.* U.S. Energy Information Administration, June 25, 2012. Accessible at: <http://www.eia.gov/forecasts/archive/aeo12/index.cfm>.

64. *The State of the States: Update on the Implementation of U.S. Renewable Portfolio Standards.* Ryan Wiser and Galen Barbose, Lawrence Berkeley National Laboratory, 2011 National Summit on RPS, October 26, 2011.

65. For a summary of state incentives for renewable energy, see: <http://www.dsireusa.org/summarytables/finre.cfm>.

66. NREL defines technical potential as "the achievable energy generation of a particular technology given system performance, topographic limitations, environmental, and land-use constraints." For more details see: *U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis.* NREL Technical Report NREL/TP-6A20-51946, July 2012.

67. *Assumptions to the AEO2012.* U.S. Energy Information Administration, June 25 2012. Accessible at: <http://www.eia.gov/forecasts/aeo/assumptions/pdf/0554(2012).pdf>.

68. For those states with absolute targets rather than percent targets (Iowa, New Jersey, and Texas), we assume the absolute targets are met and add the amount of renewable generation into our electricity demand module.

69. Database of State Incentives for Renewables and Efficiency (DSIRE), RPS Database downloaded from dsireusa.org in September 2012.

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