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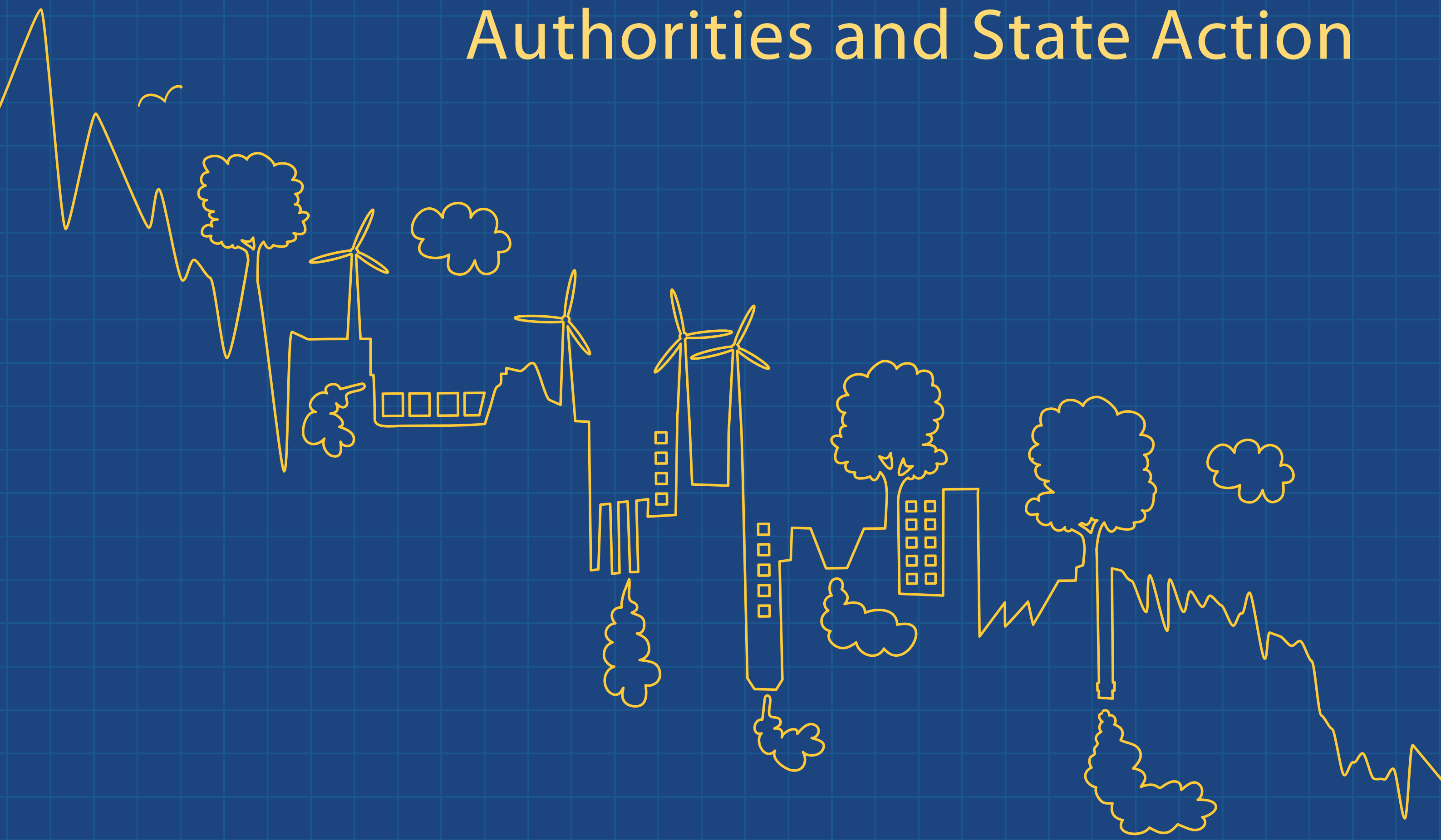
WRI REPORT

Reducing Greenhouse Gas Emissions in the United States Using Existing Federal Authorities and State Action



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I. Introduction

AS THE U.S. CONGRESS HAS STRUGGLED to pass comprehensive climate change legislation, observers in the United States and abroad have asked what greenhouse gas emissions reductions are possible under existing federal laws and through state action. Can the U.S. meet the Obama Administration's Copenhagen commitment to reduce greenhouse gas emissions in the range of 17 percent below 2005 levels by 2020 using the regulatory tools already available to federal agencies, together with announced actions at the state level? Even if congressional action is ultimately necessary to put the U.S. on a long-term low-carbon path and aid in the transition to a low-carbon economy, can federal agencies and state governments get the U.S. started down that path? To help answer these and related questions, the World Resources Institute (WRI) presents this analysis of potential reductions under existing federal authorities and announced state actions through 2030.

Set out below is a summary of the key findings of this peer-reviewed study. The aggregate range of potential federal reductions in key sectors is provided first, based on assessments from available literature on what is technically feasible, as well as the corresponding regulatory ambition required to achieve the technically feasible reductions. An explanation of how potential reductions were assessed for each sector and/or category of sources follows, including: (a) a description of the sector or category of sources affected; (b) a discussion of the regulatory policy or policies available to achieve reductions in the sector or category of sources; and (c) an explanation of how available studies were used to construct three potential reduction scenarios for each sector or category of sources.

The three potential reduction scenarios analyzed include a "Lackluster" scenario that aggregates reductions at the lower end of what is technically feasible and therefore represents low regulatory ambition; a "Middle-of-the-Road" scenario that combines reductions generally in the middle of the range considered technically feasible and corresponding to moderate regulatory ambition; and a "Go-Getter" scenario that adds up reductions that may be considered toward the higher end of what is technically feasible and corresponds to higher regulatory ambition. Readers can make their own judgment about which scenario they think is most plausible.

After assessing potential reductions through federal regulatory actions in key sectors, state-level reductions are considered. In contrast to the sector-by-sector, policy-by-policy approach used for the federal assessment, state-level reductions were quantified using economy-wide greenhouse gas reduction targets and regional cap-and-trade programs. See Box I. Similar to the federal analysis, however, reductions from state actions are reported as a range of possible reductions, with lower reductions projected if only legislated targets are implemented and states otherwise show lower ambition, and higher reductions projected if states follow through on announced goals and policies showing higher ambition. These state scenarios are also labeled "Lackluster," "Middle-of-the-Road," and "Go-Getter" to reflect the range of potential ambition and follow-through at the state level.

After the summary of key findings and more detailed discussion of the federal and state-level quantification efforts, the uncertainties underlying the emission reduction projections contained in this analysis are outlined.[1] Importantly, a detailed explication of the methods and assumptions is contained as an appendix to this paper. WRI intends to produce periodic revisions to this analysis of reductions to reflect new studies on the technical feasibility of reductions in various sectors, new actions by federal and state governments, and any identified improvements in methods.

1. The single biggest variable—the level of ambition applied by the federal administration and state governors and legislatures—is captured in the scenarios. Thus, if one assumes high ambition on the part of federal agencies, the Go-Getter Scenario will be most relevant. Conversely, if one assumes low ambition, the Lackluster Scenario will be most apt.

BOX 1. Analytical Steps to Assessing Potential Reductions at the Federal and State Levels

FEDERAL ANALYSIS

(a) Review the 2008 U.S. greenhouse gas emissions inventory;

(b) Identify those sectors and/or categories of emissions sources where existing regulatory authorities can be applied to achieve reductions;

(c) Based on available technical studies, consider the range of possible reductions in each sector and/or category of emissions sources;

(d) Model three levels of emissions reductions corresponding to different levels of regulatory ambition in each sector and/or category of sources for which reliable quantitative information is available; and

(e) Present aggregate results as three reduction scenarios based on the range technically feasible and the corresponding range of regulatory ambition: lower ("Lackluster"), moderate ("Middle-of-the-Road") and higher ("Go-Getter").

STATE-LEVEL ANALYSIS

(a) Determine which states have greenhouse gas emissions reductions targets in legislation;

(b) Determine which states have greenhouse gas emissions reduction targets in executive orders;

(c) Determine which states have announced their participation in regional initiatives to design and implement cap-and-trade programs to reduce greenhouse gas emissions;

(d) Model three levels of emissions reductions, one assuming only states with legislative targets follow through to reduce emissions; a second assuming states with legislative and executive targets follow through; and a third assuming states with targets and announced cap-and-trade initiatives follow through; and

(e) Present aggregate results as three reduction scenarios.

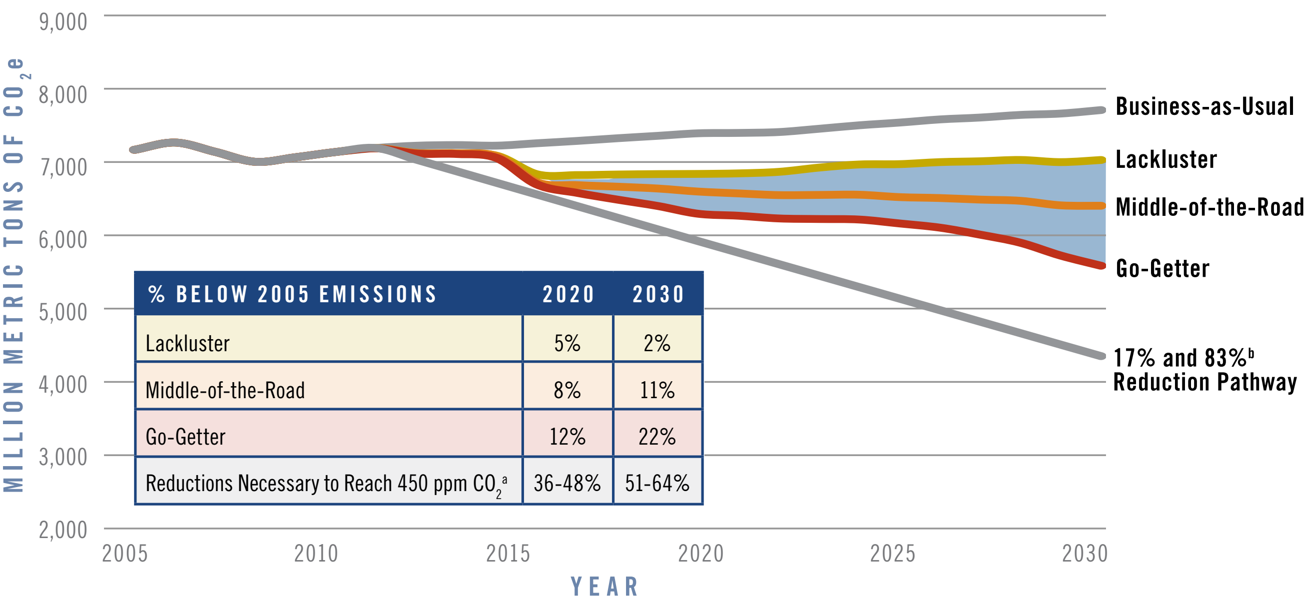
II. Summary of Key Findings

WRI'S ANALYSIS OF POTENTIAL GREENHOUSE gas emissions reductions by federal and state governments suggests a range of potential outcomes is possible. On the federal level, whether reductions are achieved at the lower end or upper end of the range shown in Figure 1 depends on the extent to which the Obama Administration and subsequent administrations use existing regulatory authority to go after reductions shown to be technically possible in the literature.[2] On the state level, whether reductions are realized at the lower or upper end of the range projected in Figure 2 depends similarly on the continued resolve by governors and legislative leaders in the 25 states counted as having taken actions. The findings set out here represent an assessment of what is possible given available inputs for some key sectors. It does not include potential emissions reductions achievable through federal policies to reduce vehicle miles traveled, management of agricultural lands and forests, new federal investments in areas such as energy efficiency, renewable energy infrastructure, or other areas that could yield reductions, nor new federal legislation of any kind. Key findings are summarized below.

- If federal agencies and states pursue the path of "go getters" and move strongly to achieve the reductions published literature suggests are technically feasible in the sectors analyzed, the U.S. could achieve significant reductions in greenhouse gas emissions, which approach but fall short of President Obama's Copenhagen pledge to reduce emissions 17 percent below 2005 levels by 2020.
- If, however, federal agencies fail to capitalize on available reduction opportunities and states fall short on their announced plans to reduce emissions, middle-of-the-road or lackluster reductions will result, falling far short of the 17 percent reduction by 2020 goal.
- Longer-term reductions post-2020 are less certain under all analyzed scenarios, primarily due to uncertainty about how quickly aging power plants will be replaced and the transportation sector can be transformed. Regulatory policies can drive technology, but without knowing what technological

2. There are of course other uncertainties and variables at play that could affect the extent of reductions. Key risks and uncertainties are outlined below and in the appendix to this report.

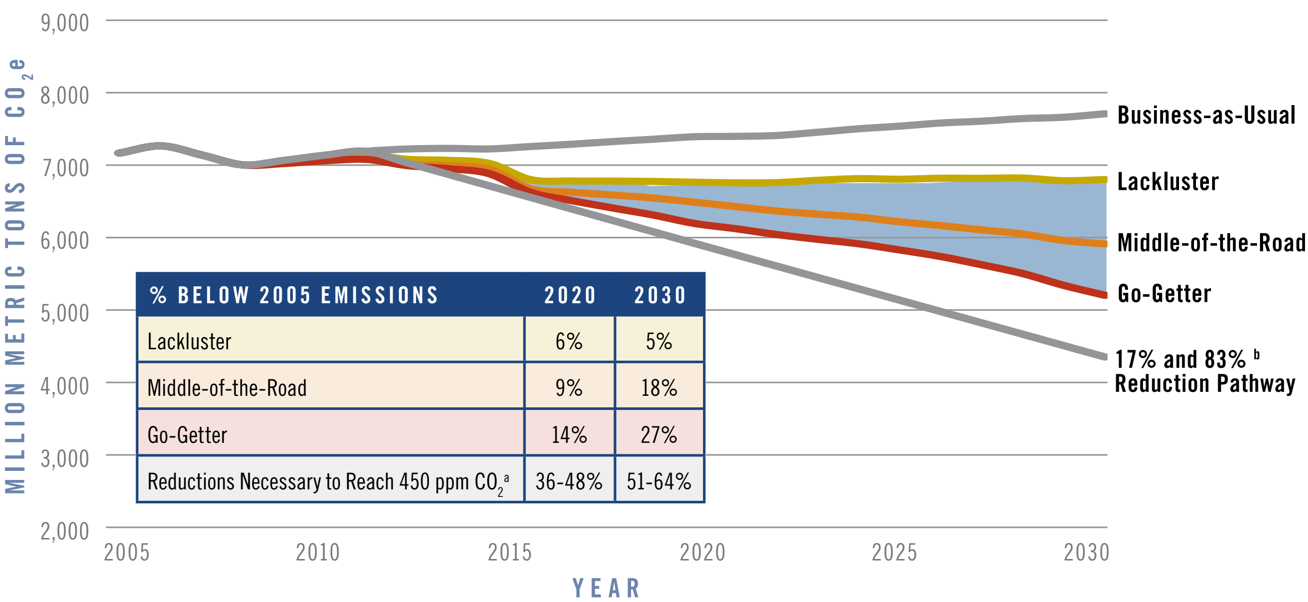
FIGURE 1. Projected U.S. Emissions under Different Federal Regulatory Scenarios



% BELOW 2005 EMISSIONS	2020	2030
Lackluster	5%	2%
Middle-of-the-Road	8%	11%
Go-Getter	12%	22%
Reductions Necessary to Reach 450 ppm CO_2[a]	36-48%	51-64%

Figure 1 provides aggregate results from the federal sector-by-sector, policy-by-policy analysis laid out more fully in subsequent sections of the report. The regulatory actions specific to each of the Lackluster, Middle-of-the-Road and Go-Getter Scenarios modeled are described in the next section of this paper and in specific detail in the assumptions and methodology section in the Appendix.

FIGURE 2. Projected U.S. Emissions under Different Federal Regulatory Scenarios and State Scenarios



% BELOW 2005 EMISSIONS	2020	2030
Lackluster	6%	5%
Middle-of-the-Road	9%	18%
Go-Getter	14%	27%
Reductions Necessary to Reach 450 ppm CO_2[a]	36-48%	51-64%

Figure 2 depicts the additional reductions achievable when three state-level scenarios are added to the federal policy scenarios.

a. The Intergovernmental Panel on Climate Change's (IPCC's) Fourth Assessment Report (2007) suggests 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 global average temperatures from increasing more than 2 degrees Celsius. This target does not necessarily represent any particular country's share.

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

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

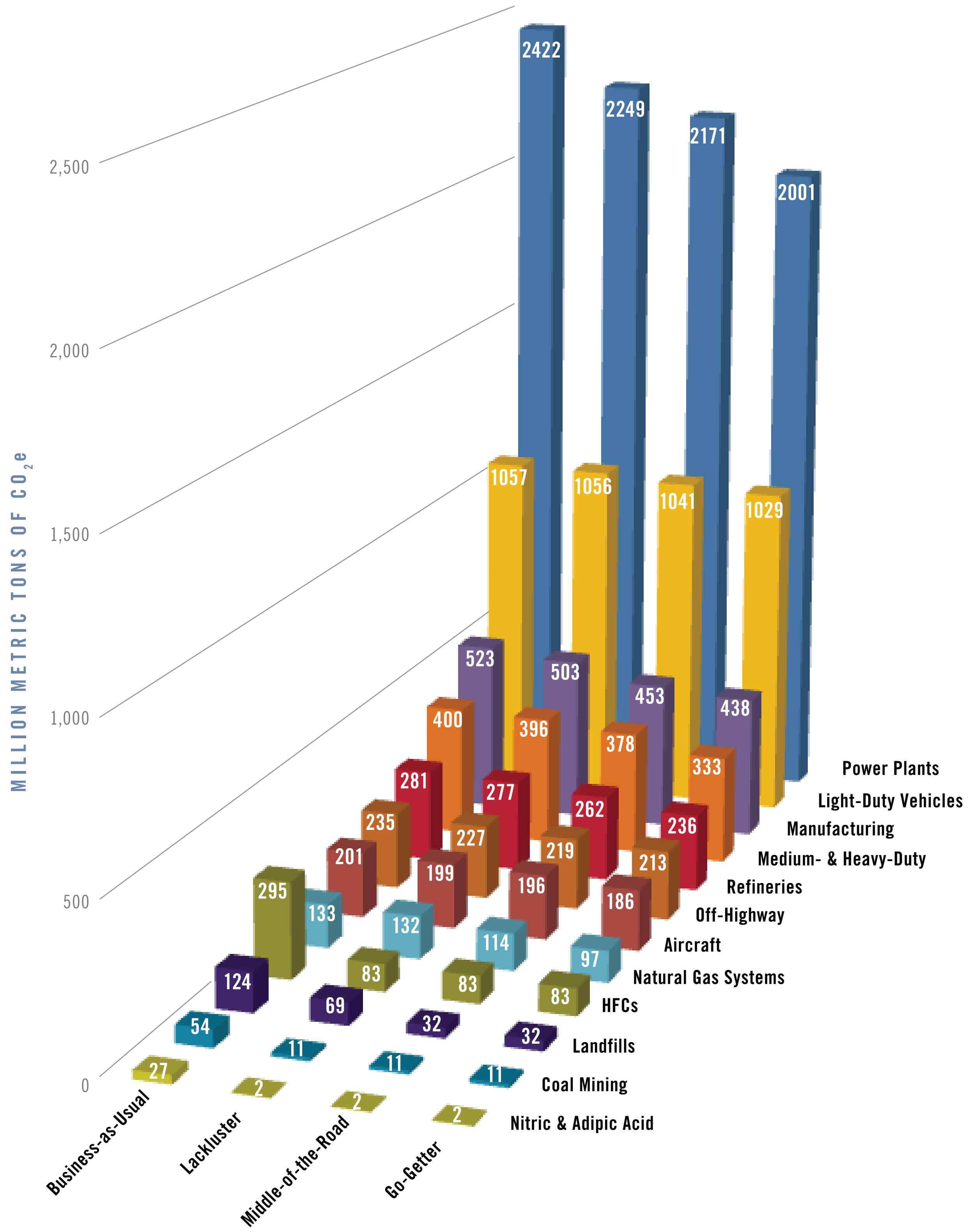


Figure 3 depicts the emissions under the three federal regulatory scenarios by sector or category of sources through 2020. The bars across the back represent the business-as-usual emissions. Emissions under the Lackluster, Middle-of-the-Road and Go-Getter Scenarios are then shown in the bars in front of the business-as-usual emissions.

FIGURE 4. Projected U.S. Emissions in 2030 by Sector under Different Federal Regulatory Scenarios

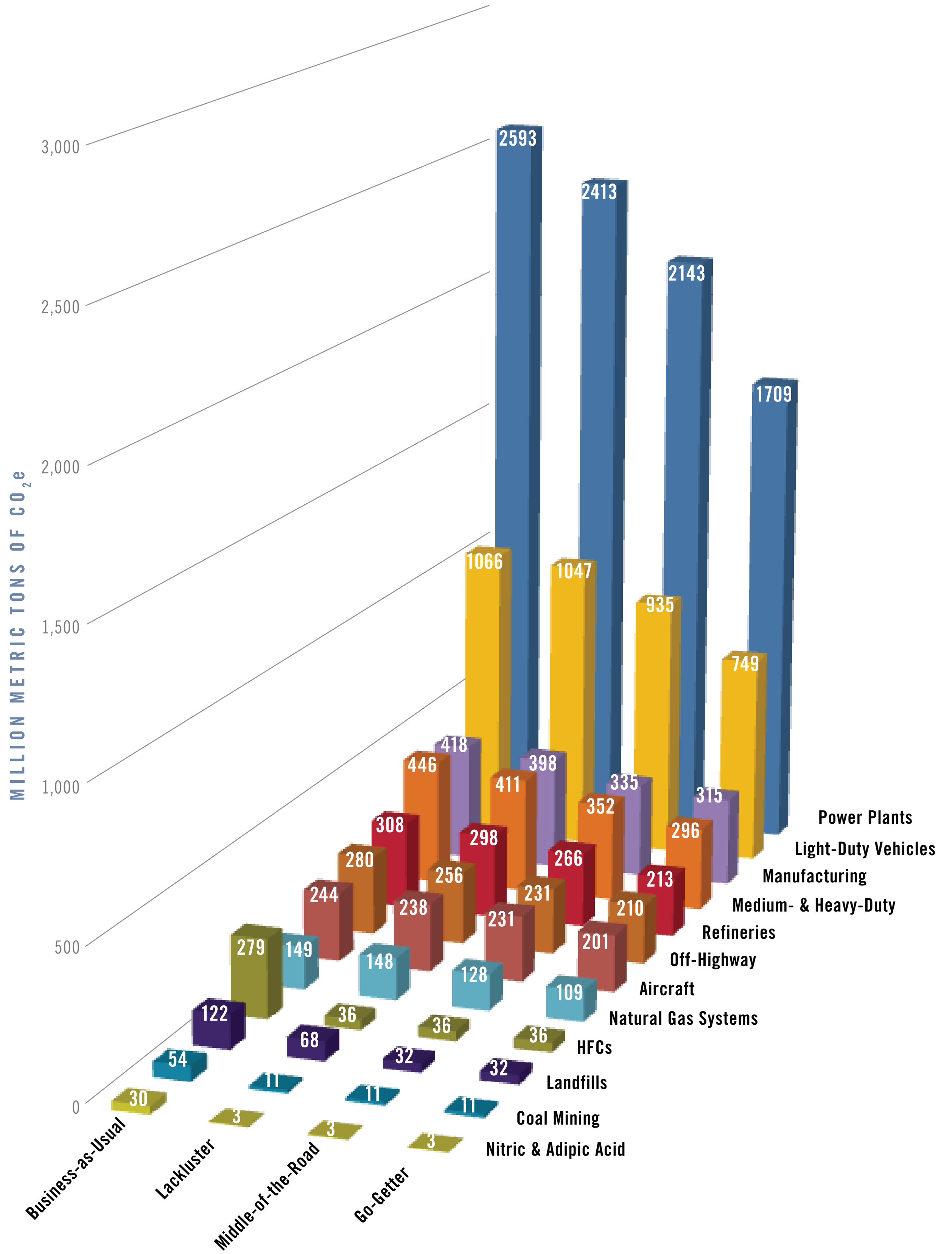


Figure 4 depicts the emissions under the three federal regulatory scenarios by sector or category of sources through 2030. The bars across the back represent the business-as-usual emissions. Emissions under the Lackluster, Middle-of-the-Road and Go-Getter Scenarios are then shown in the bars in front of the business-as-usual emissions.

advances will happen and when, it is difficult to project the tightening of regulatory standards.[3]

- All scenarios under current federal authority and announced state plans show the United States far off the pace of reductions the IPCC suggests are necessary by mid-century to prevent average global temperatures from increasing more than 2 degrees Celsius.[4]

- While the results of the analysis suggest that existing federal regulatory tools can be used effectively to reduce emissions alongside state actions, it is clear that the federal government and states will need to achieve reductions beyond those identified in even the most ambitious regulatory scenario if the United States is to meet its Copenhagen commitment. Some of these reductions might be found in regulatory policies not analyzed here, such as agricultural and forest lands management (approximately 7 percent of the U.S. inventory) or transportation planning (approximately 27 percent). Implementation of other environmental policies that encourage high-emitting sectors to modernize could also yield more reductions, such as mercury, sulfur dioxide, ozone and ash disposal regulations affecting aging coal plants.

- Among the existing federal regulatory tools most useful to achieve reductions are the mobile source and New Source Performance Standard provisions of the Clean Air Act, as well as the existing authority under Title VI of the Act to reduce hydrofluorocarbons. The vehicle fuel efficiency authority of the Department of Transportation is also important. State action that contributes reductions beyond federal regulatory policies will likewise be essential to meeting reduction goals.

- As outlined in Table 1, the analysis shows that a significant portion of the reductions can be achieved in non-energy emissions. It is expected that these

3. It is important to note that the uncertainty about future reductions relates to our ability to project into the future. It does not mean deeper reductions would not occur through existing regulatory policies, but rather that projecting those reductions is not possible given current knowledge.

4. The Intergovernmental Panel on Climate Change's (IPCC's) Fourth Assessment Report (2007) suggests 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 global average temperatures from increasing more than 2 degrees Celsius. http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm. The U.S. pledge in Copenhagen calls for reductions that put the United States at 3 percent below 1990 levels in 2020. Specifically, the U.S. pledge reads, "In the range of 17%, in conformity with anticipated U.S. energy and climate legislation, recognizing that the final target will be reported to the Secretariat in light of enacted legislation." http://unfccc.int/files/meetings/application/pdf/unitedstatescphaccord_app.1.pdf.

FIGURE 5. Projected U.S. Emissions under Different State Scenarios

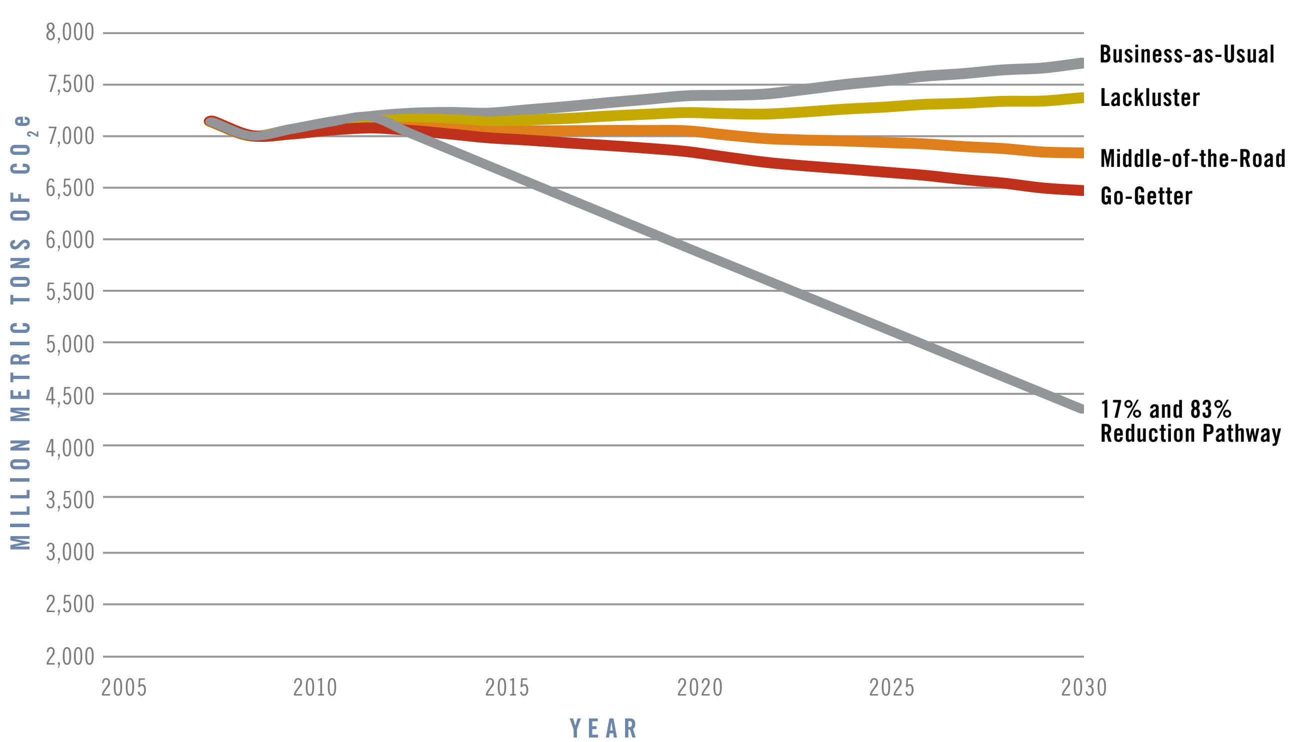


Figure 5 shows the Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for state action without considering federal actions.

non-energy reductions can be accomplished without energy price increases.

- It is likely that the U.S. Congress and states will need to step up to augment existing regulatory tools, especially if the United States is to gear up to reduce emissions by the approximately 80 to 95 percent needed by 2050 to ward off the most deleterious effects of climate change.

III. The Federal Scenarios: Will the Overall Effort be Lackluster, Middle-of-the-Road, or Go-Getter?

TO PROJECT POTENTIAL REDUCTIONS THROUGH federal action, WRI: (a) examined the 2008 U.S. greenhouse gas emissions inventory to identify key sectors or categories of sources contributing to overall emissions; (b) conducted a review of existing regulatory authorities to determine what specific actions can be used to achieve reductions; (c) reviewed available literature to decide what range of reductions are technically feasible in key sectors; (d) modeled three levels of emissions reductions in each sector or category of sources corresponding to different levels of regulatory ambition against expected business-as-usual emissions;[5] and (e) aggregated the results as three reduction scenarios based on the range of technically feasible reductions and the corresponding levels of regulatory ambition necessary to achieve the reductions.

TABLE 1. Reductions from Non-energy Emissions Sources as a Share of Total U.S. Reductions under Different Federal Regulatory Scenarios

% BELOW BASE CASE PROJECTIONS	2020	2030
Lackluster	60%	54%
Middle-of-the-Road	49%	32%
Go-Getter	37%	21%

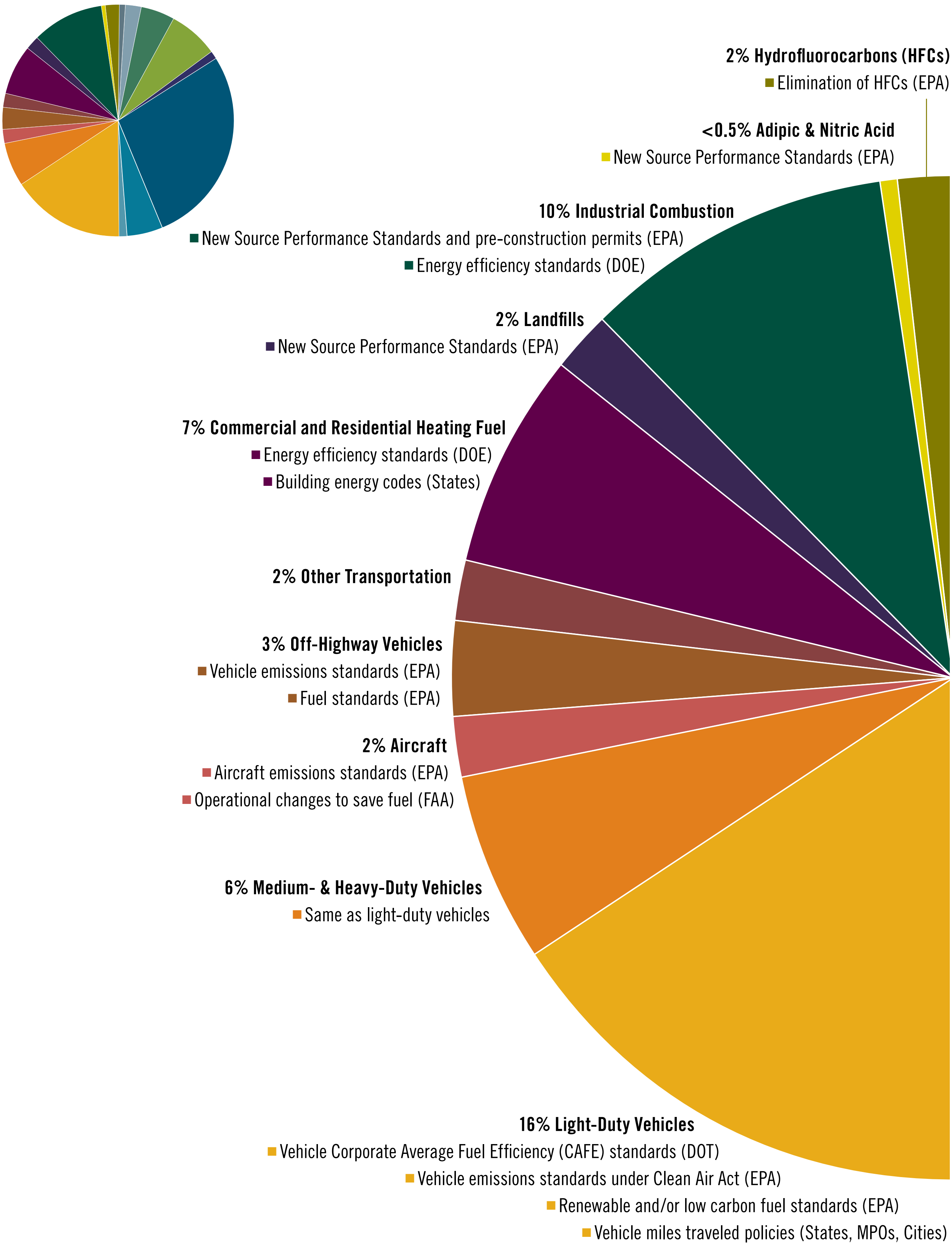
5. As described more fully in the appendix to this report, the Energy Information Agency's Annual Energy Outlook (AEO) for 2009 was used as business-as-usual for energy-related emissions, and EPA's ADAGE Model Reference Scenario, as developed for their analysis of HR 2454, the American Climate and Energy Security Act of 2009, was used for non-energy emissions.

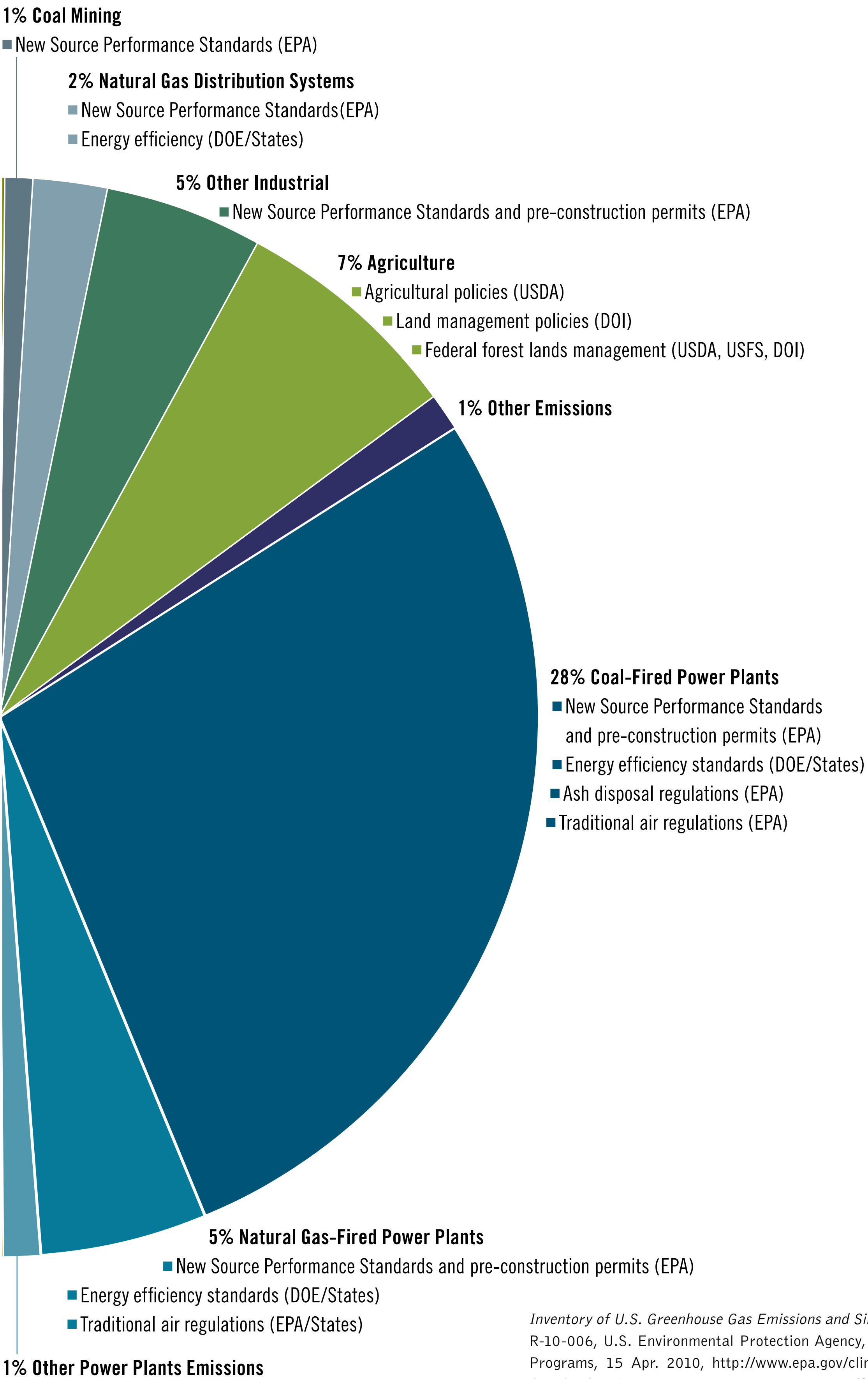
A. Emissions and Currently Available Regulatory Tools

Figure 6 depicts the 2008 U.S. greenhouse gas emissions inventory separated by key sectors and categories of sources. For each sector or source category, existing regulatory authorities are listed that can be used to achieve emissions reductions. Given the fossil-fuel origins of most U.S. greenhouse gas emissions, the existing regulatory authorities of the U.S. Department of Energy (DOE), the U.S. Department of Transportation (DOT), and the U.S. Environmental Protection Agency (EPA) are prominent among available regulatory tools in terms of their ability to drive reductions.[6] Existing energy laws provide DOE with authority to regulate the energy efficiency of appliances and commercial equipment, for example, while DOT has authority to improve the fuel efficiency of vehicles. The federal Clean Air Act vests EPA and states with substantial authority to regulate emissions that present a danger to public health and the environment. Various other federal agencies have purview over other important areas, such as the U.S. Federal Aviation Administration's (FAA) oversight of air traffic, the U.S. Department of Agriculture's programs related to agricultural lands and practices, and the U.S. Bureau of Land Management's stewardship of public lands. Specific legal authorities are provided in the more detailed explanation of the regulatory policy tools set out below.

6. For a discussion of U.S. EPA authority under the Clean Air Act, see *What to Expect from EPA: Regulation of Greenhouse Gas Emissions Under the Clean Air Act,* 40 Environmental Law Reporter 10480, Franz T. Litz and Nicholas M. Bianco, May 2010.

FIGURE 6. U.S. Emissions by Sector and Corresponding Federal Authorities (2008)

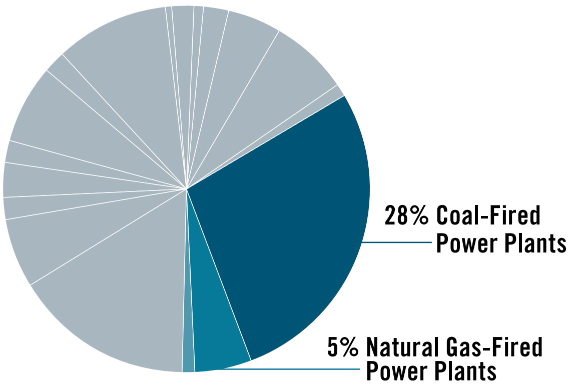




Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2008, 430-R-10-006, U.S. Environmental Protection Agency, Office of Atmospheric Programs, 15 Apr. 2010, http://www.epa.gov/climatechange/emissions/downloads10/US-GHG-Inventory-2010_Report.pdf.

B. Building the Scenarios: The Sector-by-Sector Analysis

FIGURE 7. Power Plant Emissions



As a Share of U.S. Emissions in 2008

1. POWER PLANTS.

Representing approximately 34 percent of U.S. emissions in 2008, fossil-fuel-fired power plants represent a significant emissions reduction opportunity for DOE and EPA. There are currently no federal greenhouse gas emissions reduction requirements in force for power plants.[7] Emissions from power plants, however, can be reduced using the following federal regulatory authorities:

(a) Appliance and equipment efficiency standards under Department of Energy authority.[8] Based on available studies, the three scenarios modeled assume progressively greater reductions through appliance and equipment standards, ranging from 86 terawatt-hours (TWh) of annual savings in 2030 in the Lackluster Scenario to 234 TWh annual savings in 2030 under the Go-Getter Scenario.

(b) New Source Performance Standards (NSPS) under section 111 of the federal Clean Air Act.[9] Under section 111, EPA may prescribe emissions limitations based on the "best demonstrated technology" (BDT) 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 public health and welfare.[10] To determine BDT, EPA considers technological feasibility, cost, lead-time, and energy and non-air environmental impacts. In addition, for any source category EPA regulates on the federal level, EPA must also promulgate guidelines for the states to use in developing requirements for existing sources under section 111(d). In regulating existing sources, states must also take into account the remaining useful life of the existing units. The form of regulations imposed on existing sources is not tightly prescribed in the statute, and EPA has taken the position that states could implement cap-and-trade programs to reduce emissions from existing sources, though other measures are certainly permitted.[11] Table 2 specifies the three scenarios for coal- and natural gas–fired power plants under section 111. Given the range of alternatives for existing sources, we note that cap and trade is only one example of how EPA and the states may implement section 111(d), and we expect that similar emissions reductions could be achieved using alternative regulatory mechanisms.

(c) Best Available Control Technology (BACT) requirements for major new and modified existing sources of greenhouse gas emissions under Title I, Part C of the Clean Air Act. In 2011, EPA and the states will begin applying the Prevention of Significant Deterioration (PSD) pre-construction permitting program for new sources that emit 100,000 tons or more in carbon dioxide equivalent on an annual basis, and existing sources that increase emissions more than 75,000 tons on an annual basis.[12] In the permitting process, EPA applies the BACT standard in establishing emissions rates for covered facilities. Because determinations under BACT are source-specific, it can drive reductions beyond those achieved through NSPS. It is difficult to precisely estimate these additional benefits, and therefore we do not attempt to quantify

7. Federal permitting requirements for major new and modified plants will take effect January 1, 2011, under the Prevention of Significant Deterioration pre-construction permitting program. http://www.epa.gov/nsr/documents/20100413final.pdf (as of June 26, 2010). These requirements are discussed in section III(B)(1)(c). At the state level, a number of policies are included in the Energy Information Administration's business-as-usual emissions projection, including state renewable energy standards and the Regional Greenhouse Gas Initiative (RGGI).
8. DOE appliance and equipment standards have been issued over time and are revised periodically. For a list of the standards and links to more information on each, see http://www1.eere.energy.gov/buildings/appliance_standards/.
9. 42 U.S.C. § 7411.
10. See 40 CFR Part 60 and its subparts for the existing source categories EPA has designated.
11. It should be emphasized that the same statutory considerations related to the best demonstrated technology apply to establishment of a cap-and-trade program for existing sources. Thus, in setting a reduction target under a cap-and-trade program for existing sources, EPA and the states will consider technological feasibility, cost, lead-time, and energy and non-air environmental impacts, as well as the remaining useful lives of existing units.
12. 40 CFR Parts 51, 52, 70, and 71, http://www.epa.gov/nsr/documents/20100413final.pdf (as of June 26, 2010). The final rule suggests that the tonnage threshold for triggering permitting requirements may be reduced in the future.

TABLE 2. New Source Performance Standards for Power Plants by Scneario

	LACKLUSTER	MIDDLE-OF-THE-ROAD	GO-GETTER
Existing coal-fired plants	Emissions reductions consistent with 5% improvement in efficiency	Emissions reductions consistent with 7% improvement in efficiency	Emissions improvements across all electric generators result in sector-wide reductions consistent with what is demonstrated to be cost effective through published cap-and-trade modeling reports
New coal-fired plants [a]	Emissions reductions consistent with emissions rate equivalent to natural gas [b]	Emissions reductions consistent with CCS at 90% capture rate beginning in 2020	
Existing gas-fired plants	No reductions	No reductions	
New gas-fired plants	Emissions reductions consistent with ramp up to 70% efficiency by 2030	Emissions reductions consistent with efficiency ramp up similar to Lackluster Scenario, CCS at 90% capture rate beginning in 2020	

a. It is important to note that the AEO forecast does not predict many new coal plants through 2030. Therefore, the assumed regulatory approach to new coal plants does not produce significant reductions in the analysis.

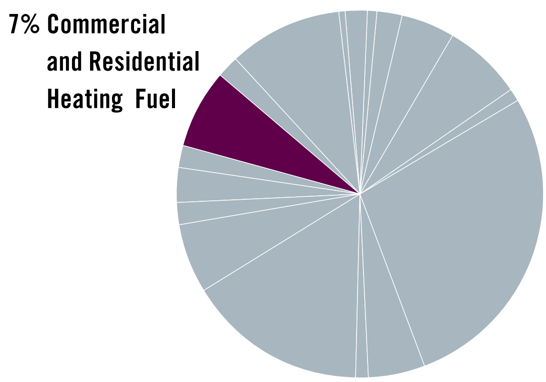
b. We note that the Clean Air Act requires performance standards be established in the form of an emissions rate. Our descriptions of particular abatement technologies or fuel choices are illustrative only.

these reductions. However, we do assume that in some instances emissions limitations are imposed on new plants sooner than NSPS requirements come into effect for a category of plants.

(d) New energy efficiency investments. The analysis does not include the emissions benefits from new federally funded energy efficiency investments in the future. The Annual Energy Outlook (AEO) emissions forecast used as the business-as-usual emissions trend in this analysis already includes the investments made by the federal government in the 2009 stimulus package. It is likely that any future similar investments could put substantial downward pressure on emissions, but given the uncertainty around federal spending in any given future year, we do not include reductions from any future investments.

(e) Pending non–greenhouse gas regulatory initiatives. Existing and pending regulatory initiatives unrelated to greenhouse gas emissions may place significant indirect downward pressure on greenhouse gas emissions. These include new coal ash disposal regulations, new fine particulate matter regulations, new sulfur dioxide and ozone regulations, and other Clean Air Act regulatory developments. The AEO2009 baseline does not reflect the increased unit turnover that may result from these pending measures or the corresponding emissions reductions, and we have not made any assumptions in this analysis about the indirect effects of regulatory programs that are not specifically greenhouse gas–focused. WRI may include this in future versions of this analysis.

FIGURE 8. Commercial & Residential Heating Emissions



As a Share of U.S. Emissions in 2008

2. RESIDENTIAL AND COMMERCIAL HEATING.

Residential and commercial heating accounted for approximately 7 percent of U.S. emissions in 2008. Emissions reductions are possible using the following federal regulatory authorities:

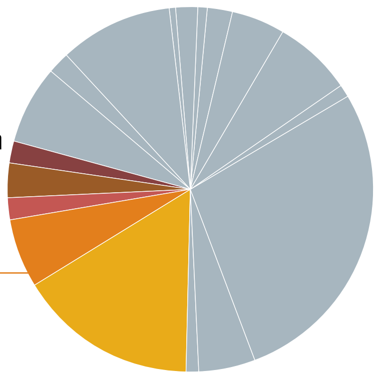
(a) Appliance and equipment efficiency standards under Department of Energy authority.[13] Based on our review of available studies, we assume for all scenarios that standards for residential and commercial appliances that combust fuel will reduce natural gas demand by 166 trillion British Thermal Units (TBtu) in 2020 and 347 TBtu in 2030, and could reduce oil demand by 2.3 TBtu in 2020 and 5.4 TBtu in 2030.

13. DOE appliance and equipment standards have been issued over time and are revised periodically. For a list of the standards and links to more information on each, see http://www1.eere.energy.gov/buildings/appliance_standards/.

(b) **New energy efficiency investments.** It should be noted that the analysis does not include the emissions benefits from new federally funded energy efficiency investments in the future. The AEO emissions forecast used as the business-as-usual emissions trend in this analysis already includes the investments made by the federal government in the 2009 stimulus package. It is likely that future similar investments could put substantial downward pressure on emissions, but given the uncertainty around federal spending in any given future year, we do not include reductions that would result from future investments.

(c) **Building code standards:** Improved building code standards will reduce emissions associated with residential and commercial heating. Existing federal programs can only encourage improvements to building codes, however, and cannot require them. Therefore, emissions reductions from improved building codes are not modeled here.

FIGURE 9. Transportation Emissions[14]



As a Share of U.S. Emissions in 2008

3. TRANSPORT VEHICLES.

Transportation emissions represented approximately 29 percent of U.S. emissions in 2008. At the federal level, regulatory policies have been most effective at reducing emissions through vehicle efficiency, vehicle emissions, and fuels requirements. The Energy Independence and Security Act of 2007, for example, raised vehicle efficiency standards for light duty vehicles to 35 mpg for model year 2020, a policy that is included in the business-as-usual emissions projection from the Energy Information Administration. The three scenarios assume additional actions to reduce emissions through federal regulatory policies, as explained below.

(a) **Corporate Average Fuel Efficiency (CAFE) standards by the U.S. Department of Transportation's National Highway Traffic Safety Administration (NHTSA).** The corporate average fuel efficiency (CAFE) regulations adopted in May 2010 will reduce greenhouse gas emissions by increasing CAFE standards for light-duty vehicles for model years 2012–2016.[15] These regulations were included in all three scenarios analyzed for light-duty vehicles, together with additional standards for the period 2017 and after, as detailed below.

(b) **Vehicle emissions standards by EPA under Title II of the Clean Air Act.** In addition to the May 2010 light-duty vehicle emissions standards adopted jointly with DOT, EPA has the ability under Title II of the Clean Air Act to revise light-duty vehicle standards and to impose medium- and heavy-duty vehicle emissions standards to achieve additional greenhouse gas emissions reductions. In considering what additional actions were possible for light-duty vehicles, available studies were reviewed.[16]

As detailed in Table 3, improvements modeled in fuel efficiency through 2030 range from 204 grams per mile (or 40 mpg) in the Lackluster Scenario to 86 grams per mile in the Go-Getter Scenario. Consistent with the EPA "Analysis of the Transportation Sector," we assume that this is achieved through a 51 mpg CAFE standard, with additional benefits from air conditioning efficiency improvements and HFC emissions reductions, as well as a 30 percent market penetration rate for electric vehicles and 17 percent market penetration for plug-in hybrid electric vehicles.

For medium- and heavy-duty vehicles, studies suggest that modest improvements in fuel efficiency, or approximately a 2.5 percent improvement per year from 2014 to 2019, are readily attainable, with

14. Table A-105 of EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2008 breaks down off-highway emissions into agricultural equipment (45.4 mmtCO2), construction & mining equipment (69.3 mmtCO2), and other sources (77.7 mmtCO2). For purposes of adjusting the EPA inventory, we assume that agricultural emissions come entirely from agricultural emissions. We also assume that construction and mining equipment come from industrial combustion emissions (the 1% of emissions depicted from coal mining are methane emissions, only). Because we cannot determine the relative contribution of each equipment type to the "other source" category, we split the emissions equally between residential, commercial, and industrial combustion emissions.

15. 75 Fed. Register 25324 (May 10, 2010).

16. Studies by the American Physical Society, Massachusetts Institute of Technology, and the EPA informed these scenarios. See discussion of assumptions and methodology in the appendix to this report.

a 0.75 percent annual rate of improvement from 2020 to 2030. Moderate improvements might be expected at double those rates, or 4.9 percent per year from 2014 to 2019 and 1.5 percent annually from 2020 to 2030. The upper ends of the potential, for all vehicles except tractor-trailers, are rates of 5.6 percent annually from 2014 to 2019 and 1 percent per year from 2020 to 2030.[17] The upper end of the potential for tractor-trailers is a doubling of fuel economy in 2017. The three scenarios are summarized in the table below.

(c) Emissions standards for off-highway mobile sources by EPA under Title II of the Clean Air Act. Off-highway sources represent just under 3 percent of total U.S. emissions and 10 percent of all vehicle emissions. For the Lackluster, Middle-of-the-Road, and Go-Getter scenarios, respectively, the analysis assumes new standards can achieve an additional 0.9 percent, 1.8 percent, and 2.4 percent annual improvement in the emissions rate for new equipment and engines from 2015 to 2030. These estimates are derived from EPA's "Analysis of the Transportation Sector."

(d) Aircraft emissions reductions. The FAA may make operational improvements in the air traffic control system that could achieve significant emissions reductions over time.[18] We draw our assumptions about operational improvements from EPA's "Analysis of the Transportation Sector" and the FAA's comments on that analysis. In its analysis, EPA suggests that sustained operational

17. Each of these scenarios corresponds to analyses published in available literature by reputable sources. For more information, see section VI of the Appendix.

18. We note that although EPA has authority to impose aircraft engine emissions standards under Title II of the Clean Air Act, the AEO business as usual emissions projectionsassume significant improvements in the emissions rate of aircraft through efficiency improvements without emissions standards. For this analysis, therefore, we did not project additional reductions through aircraft engine standards. This topic is discussed more fully in the methodology section in the Appendix.

TABLE 3. Vehicle Emissions, Efficiency Standards, & Operational Improvements

	LACKLUSTER SCENARIO	MIDDLE-OF-THE-ROAD SCENARIO	GO-GETTER SCENARIO
	May 2010 Joint EPA-DOT Standards: 35.5 mpg by model year 2016		
Light-duty vehicles	40 mpg by 2030 or 204 grams per mile; or CA + 17 states adopt 162 grams per mile (50 mpg)	50 mpg by 2030 or 162 grams per mile	86 grams per mile achieved through a 51 mpg CAFE standard, with additional benefits from A/C efficiency improvements and HFC emissions reductions, as well as a 30 percent market penetration rate for electric vehicles and 17 percent market penetration for plug-in hybrid electric vehicles
Medium- & heavy-duty vehicles	2.45 percent annual GHG emissions rate improvement each year from 2014 to 2019; +0.75 percent annually from 2020 to 2030	4.9 percent annual GHG emissions rate improvement each year from 2014 to 2019; +1.5 percent annual improvement from 2020 to 2030	5.6 percent annual GHG emissions rate improvement each year from 2014 to 2019; +1 percent annual improvement from 2020 to 2030 Tractor trailers reduce their emissions rate by 25 percent from 2014–2016, and halve it in 2017
Off-highway vehicles	0.9 percent annual improvement in the emissions rate for new equipment and engines from 2015 to 2030	1.8 percent annual improvement in the emissions rate for new equipment and engines from 2015 to 2030	2.4 percent annual improvement in the emissions rate for new equipment and engines from 2015 to 2030
Aviation emissions improvements	0.17 percent annual emissions reduction through 2030	0.4 percent annual emissions reduction through 2030	1.4 percent annual emissions reduction through 2030

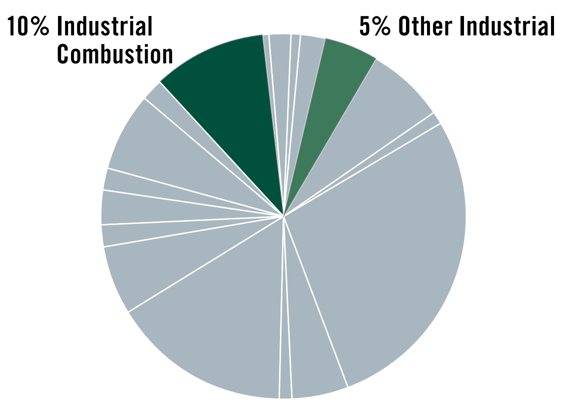
improvements reduce emissions by between 0.7 and 1.4 percent annually, so that by 2030 operational measures could produce reductions between 10 and 20 percent. EPA notes in its report, however, that the FAA considered operational improvements in the range of 0.17 to 0.4 percent per annum more appropriate. Because the FAA must implement the improvements, we modeled the upper and lower end of the FAA position for the Lackluster and Middle-of-the-Road Scenarios. For the Go-Getter Scenario, however, we assumed the FAA achieved 1.4 percent annually through 2030 as estimated by EPA. The specific reductions modeled are outlined in the transport scenario table below.

(e) Renewable fuel standard or a low carbon fuel standard. EPA has adopted a federal renewable fuel standard (RFS) as required by the Energy Independence and Security Act of 2007. The standard calls for an increase in renewable fuel supply to 36 billion gallons per year by 2022. The Energy Information Agency includes the RFS in the business-as-usual case in its 2009 Annual Energy Outlook (AEO2009), which is also used as the business-as-usual case for this study. An improved RFS or a low-carbon fuel standard that targets improvements over the current federal RFS would produce emissions reductions beyond what actually occurs from the current standards. However, the AEO2009 assumes there are no carbon dioxide emissions associated with the combustion of renewable fuel, and therefore greatly overstates the actual emissions benefits of the RFS. Review of available literature and consultation with experts in the field revealed that additional reductions beyond those included in the AEO2009 baseline emissions projections are not likely, whether through further revision of the RFS or through adoption of a low-carbon fuel standard. As a result, we have not included any emission reduction benefits of a national low-carbon fuel standard in the scenarios.

(f) Emission standards for aircraft. Title II of the Clean Air Act allows EPA to prescribe emissions standards for aircraft engines. Those standards would be implemented and enforced by the Federal Aviation Administration. These standards were not included in the scenarios for a number of reasons. First, aircraft turnover rates are very slow and turnover occurs in a highly international market where the effect of domestic US regulatory policies can be somewhat muted. Second, the AEO2009 already incorporates some improvement in commercial aircraft efficiency as a function of market forces.

(g) Emission standards for marine vessels. Marine vessels were not included in the analysis because of the difficulty in regulating vessels of international origin and a limited inventory information for the domestic fleet.[19] We note that EPA has identified a technical potential for reduction of 20 to 40 million metric tons of carbon equivalent in marine vessels, but these reductions have as yet not been coupled with any regulatory policy.[20]

FIGURE 10. **Industrial Emissions**



As a Share of U.S. Emissions in 2008

4. INDUSTRY.

Emissions from industrial facilities comprise 15 percent of the U.S. emissions inventory for 2008.

(a) New source performance standards under Clean Air Act section 111. As discussed under "Power Plants," the EPA may prescribe emissions limitations based on the "best demonstrated technology" (BDT) for new and modified existing sources within source categories it designates.[21] In addition, for greenhouse gases, where EPA adopts new source standards, it must also promulgate guidelines for the states to regulate existing sources within the same source categories

19. According to analysis by the Pew Center on Global Climate Change, international shipping accounts for 85 percent of U.S. marine emissions. "Marine Shipping Emissions Mitigation." Pew Center on Global Climate Change, Mar. 2010. http://www.pewclimate.org/technology/factsheet/MarineShipping.

20. *EPA Analysis of the Transportation Sector: Greenhouse Gas and Oil Reduction Scenarios.* U.S. Environmental Protection Agency, Mar. 2010. http://www.epa.gov/oms/climate/GHGtransportation-analysis03-18-2010.pdf.

21. 40 CFR Part 60.

TABLE 4. **New Source Performance Standards for Industry by Scenario**

	LACKLUSTER SCENARIO	MIDDLE-OF-THE-ROAD SCENARIO	GO-GETTER SCENARIO
Industrial combustion and cement kilns	10 percent improvement in emissions rate for new and existing boilers	Harness all cost-effective energy efficiency from combustion and processes for existing units	Harness all cost-effective energy efficiency from combustion and processes for existing units; all new units meet natural gas emissions rate
Refineries	1 percent one-time improvement in emissions rate	5 percent one-time improvement in emissions rate	10 percent one-time improvement in emissions rate

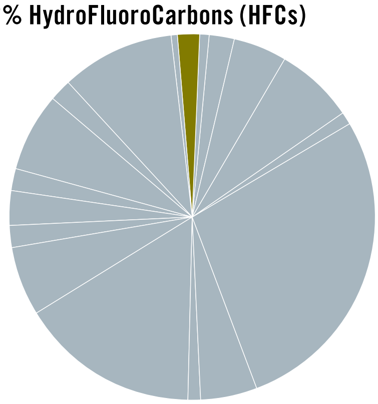
under section 111(d). States are then charged with following the prescribed guidelines, though they may implement alternative approaches that are equal to or more stringent than the federal guidelines. The form of regulations imposed on existing sources is not tightly prescribed in the statute. The NSPS regulatory policy is therefore likely to vary from source category to source category. Its application to industry subsectors is described below.

(b) Industrial combustion and process efficiency. Table 4 presents the Lackluster, Middle-of-the-Road and Go-Getter Scenarios for industrial combustion and process efficiency. The reduction percentages are taken from the analyses EPA conducted as a basis for the Advanced Notice of Proposed Rulemaking (ANPR),[22] as well as a study done for the Department of Energy by the Interlaboratory Working Group.[23] The Middle-of-the-Road and Go-Getter Scenarios call for an approach that applies an output-based emissions limitation rather than the traditional emissions limitation applied solely at the combustion source. An output-based approach would allow industrial sources to improve efficiencies at a plant to improve their emissions rates, thereby capturing reductions that would otherwise be lost under the combustion-unit-only approach.

(c) Cement kilns. The modeled policy scenarios for cement are described in Table 4 and are identical to the scenarios chosen for industrial sources. They are also based on the same technical sources.

(d) Refineries. EPA's Advanced Notice of Proposed Rulemaking cited a range of 10 to 20 percent reductions for existing refineries. However, some efficiency improvements are already built into the baseline. Therefore, as outlined in the table below, this analysis assumed one-time improvements of 1 percent in the Lackluster Scenario, 5 percent in the Middle-of-the-Road Scenario, and 10 percent in the Go-Getter Scenario.

FIGURE 11. **HFC Emissions**



5. HFCs.

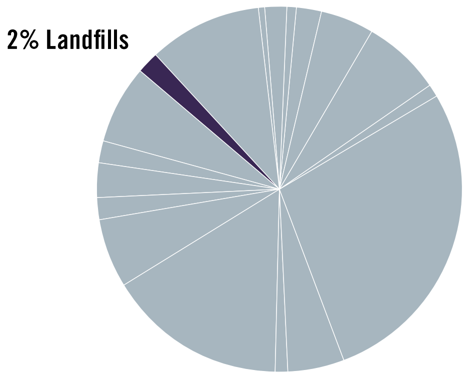
Hydrofluorocarbons (HFCs) made up just under 2 percent of the U.S. greenhouse gas inventory in 2008. If left uncontrolled, however, HFC emissions are projected to grow rapidly. EPA has existing authority to regulate HFC consumption under Title VI of the Clean Air Act and has proposed an international ramp-down schedule.[24] The scenarios modeled in this analysis are identical to that ramp-down schedule, and by 2033 would reduce emissions 85 percent below average emissions from 2004 to 2006.

22. Regulating Greenhouse Gas Emissions Under the Clean Air Act, 73 Federal Register § 147 (2008). http://www.epa.gov/climatechange/emissions/downloads/ANPRPreamble5.pdf.

23. *Scenarios for a Clean Energy Future*, Interlaboratory Working Group, ORNL/CON-476 and LBNL-44029, Nov. 2000.

24. *Analysis of HFC Production and Consumption Controls.* U.S. Environmental Protection Agency, Oct. 2009. http://www.epa.gov/ozone/downloads/HFCAnalysis.pdf.

FIGURE 12. Landfill Emissions

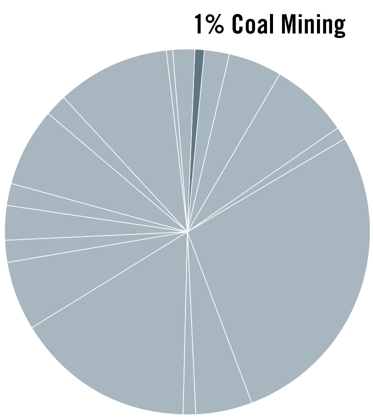


As a Share of U.S. Emissions in 2008

6. LANDFILLS.

Methane emissions from landfills represented just under 2 percent of total U.S. greenhouse gas emissions in 2008. Significant reductions from baseline emissions are possible through expanded New Source Performance Standards for landfills, implemented under section 111 of the Clean Air Act. Reduction scenarios were selected based on cost-per-ton calculations done for EPA in its analysis of federal climate change legislation. The Lackluster Scenario assumes a 44 percent decrease in emissions from the baseline, corresponding to a $5 per ton reduction cost. The Middle-of-the-Road and Go-Getter Scenarios assume a $20 and $61 per ton reduction cost, respectively, both of which result in a 74 percent reduction from baseline.

FIGURE 13. Coal Mine Emissions

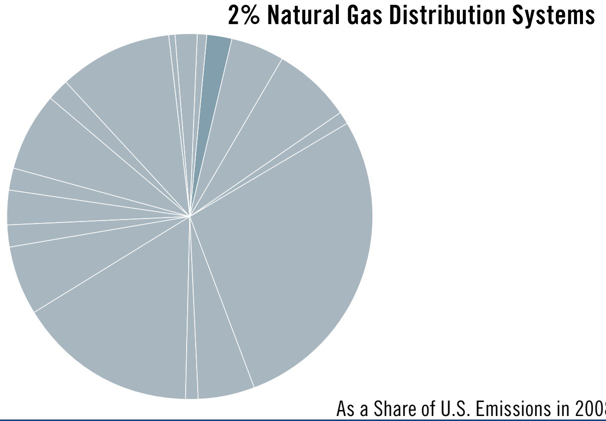


As a Share of U.S. Emissions in 2008

7. COAL MINES.

Methane emissions from coal mines represented 1 percent of total greenhouse gas emissions for the U.S. in 2008. EPA has authority to regulate coal mines as a source category under the New Source Performance Standard provisions of section 111 of the Clean Air Act. As discussed above, the EPA may prescribe emissions limitations based on the "best demonstrated technology" for new and modified existing sources within source categories it designates.[25] In addition, for greenhouse gases, where EPA regulates new sources, it must promulgate guidelines to the states to regulate existing sources within the same source category under section 111(d). States are then charged with following the prescribed guidelines, though some have taken the position that they may implement alternative requirements at the state level that are at least as stringent as the federal guidelines. The form of regulations imposed on existing sources is not tightly prescribed in the statute. For all three scenarios in this analysis, coal mines were assumed to reduce emissions by 86 percent from the baseline, consistent with EPA's analysis of federal climate change legislation and their Global Non-CO_2 Mitigation Analysis (and assuming $5, $20, and $61 cost per ton).

FIGURE 14. Emissions From Natural Gas Systems



As a Share of U.S. Emissions in 2008

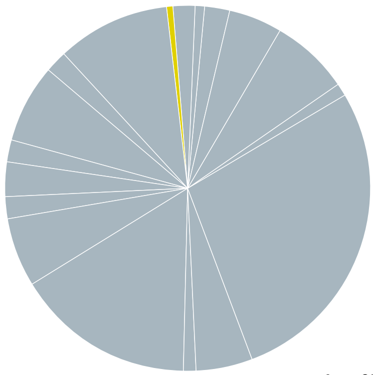
8. NATURAL GAS SYSTEMS.

Emissions from natural gas systems account for approximately 2 percent of total U.S. emissions in 2008. Similar to coal mines, EPA could regulate natural gas systems as a source category under the New Source Performance Standard provisions of section 111 of the Clean Air Act. They could require equipment changes and upgrades, changes in operational practices, and direct inspection and

25. 40 CFR Part 60.

maintenance. Achievable reductions for natural gas systems come from EPA's analysis of federal climate legislation and suggest that at $5, $20, and $61 per ton for CO_2e, emissions can be reduced by 9 percent, 14 percent, and 27 percent in 2030.

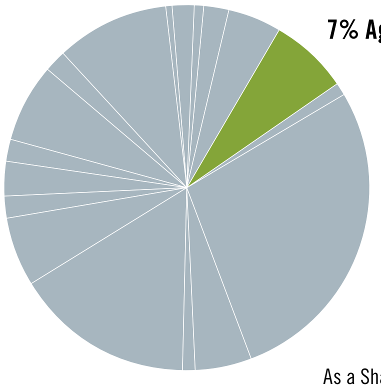
FIGURE 15. **Adipic and Nitric Acid Emissions**



9. ADIPIC AND NITRIC 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 for certain foods. The manufacture of both compounds 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.[26] N_2O emissions from the production of adipic and nitric acid manufacturing made up under one-half of 1 percent of total U.S. greenhouse gas emissions in 2008. Significant reductions from baseline emissions are possible through New Source Performance Standards for these manufacturing facilities, implemented under section 111 of the Clean Air Act. Reduction scenarios were selected based on cost per ton calculations done for EPA in its analysis of federal climate change legislation and are consistent with EPA's Global Non-CO_2 Mitigation Analysis.[27] All three scenarios in this analysis assume 96 percent and 89 percent reduction from baseline emissions for adipic and nitric acid manufacturing, respectively. These reduction levels correspond to carbon prices of $5 to $61 per ton for both types of manufacturing.

FIGURE 16. **Agriculture Emissions**



10. AGRICULTURE, FORESTRY AND LAND-USE EMISSIONS.

This category comprises about 7% of emissions in 2008. It is likely that the Forest Service (within the Department of Agriculture) could increase sequestration on federal forest lands. The Bureau of Land Management (within the Department of Interior) could potentially increase sequestration on some of the 264 million acres of public lands that they administer. The Department of Agriculture could also encourage practices that would reduce greenhouse gas or increase sequestration on farmland. Unfortunately, however, we could not identify any literature that has or would allow us to accurately quantify the magnitude of sequestration possible using existing regulatory policies without expanding program budgets. As a result, agriculture, forestry and land use emissions are not included in this analysis. Subsequent updates to this analysis may seek to address this gap.

26. *N_2O Emissions From Adipic Acid and Nitric Acid Production*, H. Mainhardt, ICF Incorporated, http://www.ipcc-nggip.iges.or.jp/public/gp/bgp/3_2_Adipic_Acid_Nitric_Acid_Production.pdf; Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, S. Solomon, et al. (eds.), Cambridge University Press, http://www.ipcc.ch/publications_and_data/ar4/wg1/en/contents.html.

27. The American Clean Energy and Security Act of 2009, H.R. 2454, 111th Cong. (2009); *Global Mitigation of Non-CO_2 Greenhouse Gases*, M. Gallaher, D. Ottinger, D. Godwin, and B. DeAngelo, Rep. no. 430-R-06-005, U.S. Environmental Protection Agency, Office of Atmospheric Programs, June 2006, http://www.epa.gov/climatechange/economics/downloads/GlobalMitigationFullReport.pdf.

IV. State Policy Scenarios

IN ADDITION TO THE FEDERAL ACTIONS analyzed by source category, this analysis seeks to quantify the reductions that might be expected under different state-level scenarios. States are pursuing a wide range of greenhouse gas mitigation policies, such as cap and trade, energy efficiency investments, renewable portfolio standards, smart-growth planning, low-carbon fuel standards, utility regulatory policy reforms, transit-oriented development, and many others. A bottom-up analysis of regulatory policies in all fifty states would require an analysis of existing legal authorities in each state, as well as the history in exercising existing state authorities. Such an extensive effort is beyond the scope of this study. Instead, state action is approached considering three top-down analytical frameworks designed to suggest the general range of state-level reductions that might be expected given the various activities carried out to date. Each scenario is described.

Lackluster Scenario: state reductions contained in state statutes. A number of states have enacted climate change legislation that calls for economy-wide reductions in greenhouse gas emissions. Those states include California, Connecticut, Hawaii, Maine, Maryland, Massachusetts, Minnesota, New Jersey, Oregon, and Washington, as depicted in Figure 17. For the Lackluster Scenario, state emissions reductions were assumed to include only the reductions called for in state legislation.

Middle-of-the-Road Scenario: state reductions called for in state statute and existing executive orders. In the absence of legislation calling for emissions reductions, governors in other states have issued executive orders establishing statewide greenhouse gas emissions reduction targets and timetables. For the Middle-of-the-Road Scenario, states with legislation or executive orders containing reduction targets are assumed to make the reductions called for in the legislation and executive orders. In general, state greenhouse gas reduction targets have been set through comprehensive greenhouse gas reduction planning that identifies policy measures that states can implement to achieve near-term targets.[28] States with legislation or executive orders are shown in Figure 18. It should be noted that while not all of the state laws and executive orders will result in the reductions assumed to occur, it is possible that additional reductions will occur in states without executive orders or laws. As such, the assumption that all executive orders are carried out is a moderate emissions reduction assumption.

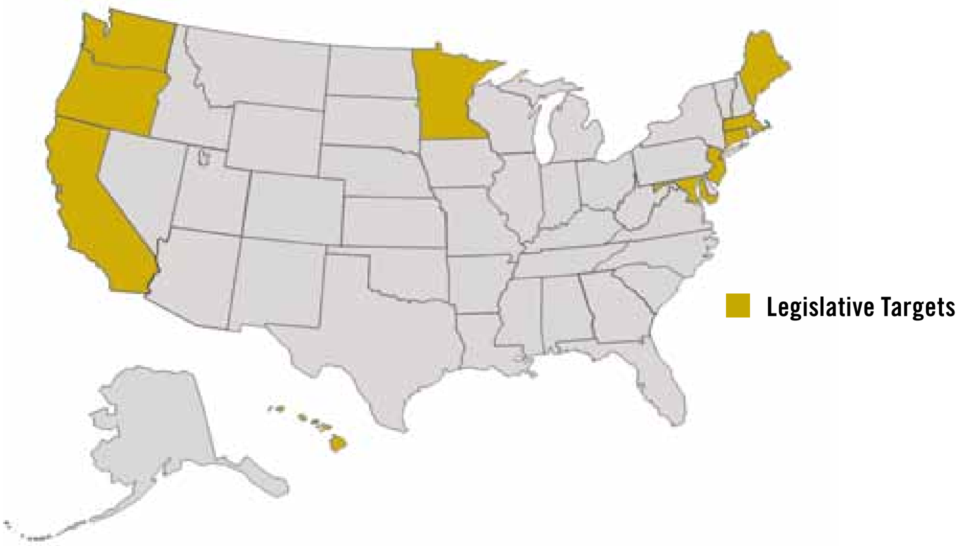
Go-Getter Scenario: state reductions from state statute, executive orders, and regional cap-and-trade programs. To project what might be expected if states and regions were to achieve higher emissions reductions, the Go-Getter Scenario assumes that state statutes, state executive orders, and regional cap-and-trade programs are all implemented to achieve their stated goals. States participating in regional cap-and-trade programs are depicted in Figure 19. While this scenario might be considered an upper bound in what might be expected from states, it is nevertheless a possibility, given that states with executive orders are likely to be progressive states on climate change issues. While some states will not follow through, other states that have previously not acted will step up and register reductions not contemplated by this analysis. Similarly, while the regional cap-and-trade programs are still to be implemented in a number of states, and it is likely some states will not follow through on their promise to cap emissions, the Go-Getter Scenario is a reasonable proxy for significant climate change action in states that represent about 40 percent of U.S. emissions.[29]

28. For a review of state climate change action plans, see the Web site for the Pew Center on Global Climate Change, http://www.pewclimate.org/states-regions.

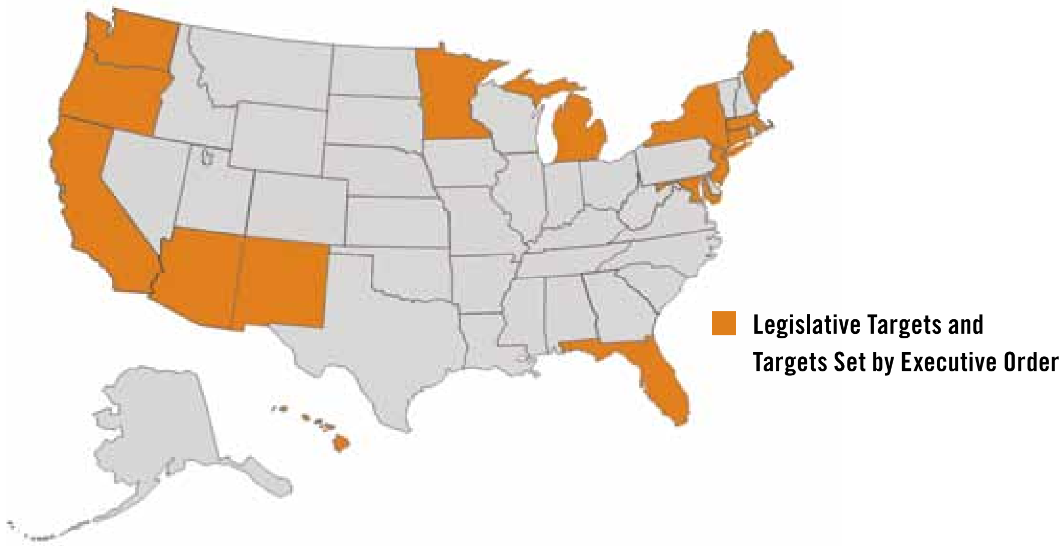
29. Note that because the Regional Greenhouse Gas Initiative (RGGI) is already operational in ten northeastern states, it is included in the business-as-usual projections.

FIGURE 17. **State Scenarios**

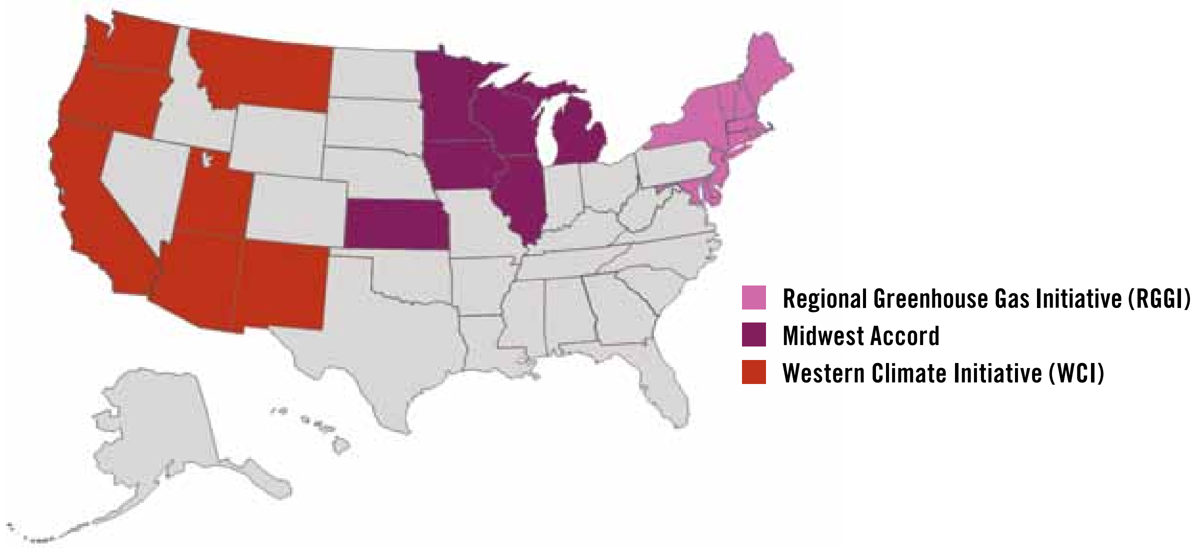
Lackluster Scenario: States with Reduction Targets Set by Legislation



Middle-of-the-Road Scenario: States with Mandatory Reduction Targets Set by Legislation or Executive Order



Go-Getter Scenario: States Part of Regional Cap-and-Trade Initiatives



BOX 2. 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 for 2009, which attempts to project energy and emissions trends into the future based a number of assumptions, including likely fuel costs, economic activity, and source turnover rates. 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.

Appendix: Methods

I. Overview

The purpose of this analysis is to estimate the range of emissions reductions achievable through federal and state climate change and energy policies. Our analysis of federal action was bottom-up, assessing the total emissions reductions achievable nationwide through an assessment of possible federal regulatory actions by sector. In comparison, our analysis of state action was top-down, relying on economy-wide reduction targets and programs in each state, without quantifying the benefits of every energy and emissions-reducing policy in each state by sector.

To assess a range of reductions achievable through federal action we first examined the 2008 national emissions inventory to determine the major sources of emissions. We then evaluated the published literature to get a sense of the level of emissions reductions achievable from these sources and evaluated the capacity of existing federal regulatory policies to drive these reductions. Due to the difficulty in predicting how federal agencies will act, we defined three scenarios meant to capture the range of potential reductions in the sector. Reflecting the literature available, 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 our scenarios. We intend to update this analysis as additional research and reports become available.

Since the state policy evaluation was top-down in nature, we developed a range of reductions by combining the various state targets set by legislation, executive order, or through participation in a regional economy-wide cap-and-trade program. A bottom-up analysis of potential reductions in each of the 50 states is beyond the scope of this study. Nevertheless, the top-down numbers provide some quantitative sense of potential in the states that have been active in addressing climate change.

To determine the cumulative greenhouse-gas-reduction benefit of state and federal action, we compared the overall percentage of reductions achieved via federal policies to each state's emissions reduction commitment. Where the state commitment was greater than the reductions achieved through federal action, we assumed states would implement additional policies to achieve the additional reductions, and thus applied the state reduction commitment to its base case emissions. Where the estimated reductions through federal action exceeded the state commitment, we assumed that states would not adopt policies that result in additional reductions.

We calculated the emissions reductions associated with each scenario using an Excel-based model that used 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. Thus, reductions in coal or natural gas demand from one set of policies did not affect deployment of those fuels in another sector. However, changes in electric demand were accounted for and fed into an electric demand module that selectively turned units on and off in a predetermined manner (see Section IV for more information).

In the pages that follow we provide more detail about our base case and modeling assumptions.

II. Base Case

Our base case, or "business-as-usual" case, was developed using the updated reference case from the U.S. Energy Information Administration's (EIA's) updated Annual Energy Outlook 2009 (AEO2009)[1] for CO_2 emissions from fossil fuel combustion. The remaining emissions were modeled using EPA's ADAGE Model Reference Scenario, as developed for their analysis of HR 2454, the American Climate and Energy Security Act of 2009.[2]

BOX A1. Modeling New Source Performance Standards under Section 111 of the Clean Air Act

Under section 111 of the Clean Air Act, EPA may prescribe emissions limitations based on the "best demonstrated technology" (BDT) for new and modified existing sources within source categories it designates. To determine BDT, EPA considers technological feasibility, cost, lead-time, and energy and non-air environmental impacts. In addition, for greenhouse gases, when EPA issues standards for new sources in a category, it must promulgate guidelines to the states to regulate existing sources within the same source categories under section 111(d). In setting requirements for existing sources, EPA and the states take into account the remaining useful life of each existing unit. States are then charged with following the prescribed guidelines, though the Act allows states to prescribe regulations that are more stringent than federal standards. The form of regulations imposed on existing sources is not tightly prescribed in the statute, and EPA has taken the position that states could implement cap-and-trade. . New Source Performance Standards (NSPS) standards must be updated every eight years to reflect technological developments.

Because no NSPS have been proposed to date that cover greenhouse gases, we made certain assumptions about the timing of the implementation of those standards for purposes of showing reductions:

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

A. AEO2009

The AEO is updated annually and is one of the leading sources of economy-wide energy emissions projections through 2030. Data outputs are disaggregated, and more detailed data tables are publicly available upon request, making this an attractive starting point. The 2030 timeline allows time to see the implications of the imposition of standards for existing units and provides enough time to see noticeable impacts from unit turnover. Longer timeframes would allow for greater unit turnover, but were not desirable due to the considerable uncertainty in predicting technological availability in future timeframes.

In 2009, the AEO reference case was updated after the passage of the American Recovery and Reinvestment Act, commonly known as the economic stimulus package, which contained significant investments in energy efficiency, among other programs.[3] This is the latest version for which detailed data tables were available when our study commenced. In addition to the American Recovery and Reinvestment Act, the updated AEO2009 captures all regulations that are "defined sufficiently to be modeled" as of November 5, 2008, and EPA's Clean Air Interstate Rule, which reduces sulfur dioxide and nitrogen oxide emissions from electric generating units. For a full discussion of assumptions, please refer to the *Assumptions to the Annual Energy Outlook 2009, With Projections to 2030*[4] and *An Updated Annual Energy Outlook 2009 Reference Case Reflecting Provisions of the American Recovery and Reinvestment Act and Recent Changes in the Economic Outlook: Reference Case Service Report.*[5]

As we update this analysis to reflect regulatory developments and new studies about the availability of new technologies, we will also update the reference scenario to include later versions of the AEO.

B. ADAGE

The AEO does not generally include non-energy and non-CO_2 emissions. EPA's ADAGE model does include those results. Because ADAGE only provides emissions data in five-year increments from 2010 through 2050, we extrapolated emissions for the intermediary years by assuming a steady, linear rate of change. EPA does not run the ADAGE model annually, but does so in response to congressional requests. Future analyses will incorporate any updated results made publicly available.

III. Power Plants

A. BASE CASE

Our modeling of the electric sector was based on the AEO2009 reference case and utilized detailed AEO2009 outputs provided by the U.S. Energy Information Agency that indicate annual capacity, generation, consumption, and emissions changes by technology type. The AEO2009 reference case includes mandatory[6] state Renewable Portfolio Standards (RPSs) and assumes that most of them will be met.[7] The reference case also includes a 3 percent increase to the added cost of capital for investment in greenhouse gas–intensive power plants without carbon capture and sequestration (CCS), which has a levelized cost similar to a fee or allowance price of $15 per ton of carbon dioxide.

Though appliance efficiency increases over time, electric demand is projected to grow from 3.9 trillion kilowatt-hours (kWh) in 2006 to 4.7 trillion kWh in 2030. Thus, even though the emissions intensity of generation is projected to decrease, total CO_2 emissions are projected to increase from 2.4 trillion metric tons in 2006 to 2.6 trillion metric tons in 2030. Base case generation and emissions breakdowns by fuel type are depicted in Figures A1 and A2, respectively.

FIGURE A1. Base Case Electricity Generation by Fuel Type

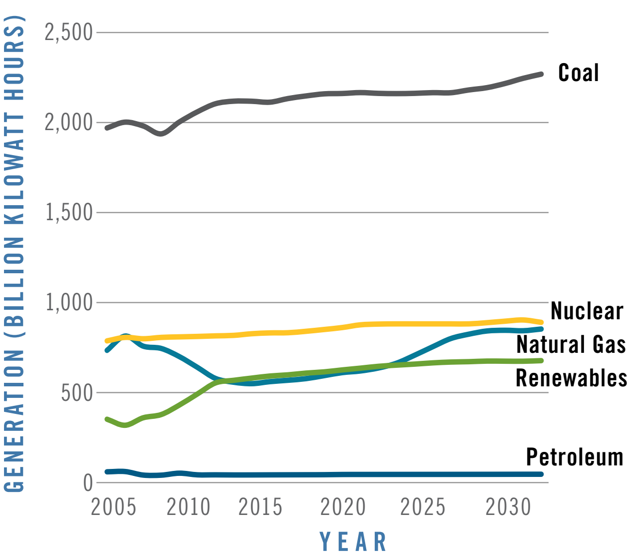
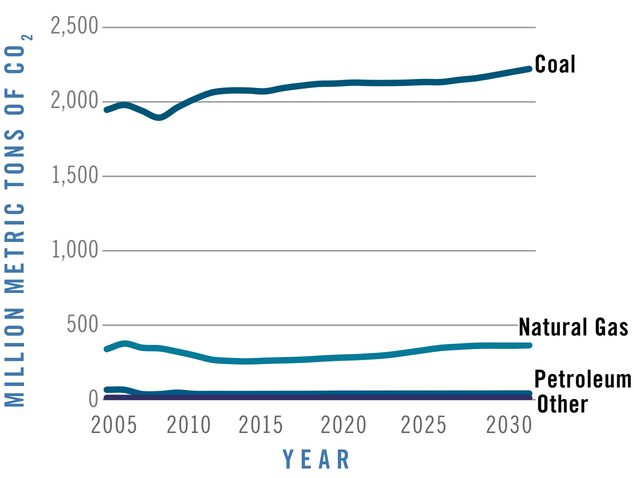


FIGURE A2. Base Case Electricity-Sector Co_2 Emissions by Fuel Type



B. LACKLUSTER, MIDDLE-OF-THE-ROAD, AND GO-GETTER SCENARIOS FOR POWER PLANTS

As with other sectors in this study, all three scenarios analyzing potential reductions from the electric power sector are based on reductions deemed feasible in the literature. Those technically feasible reductions are then paired with existing regulatory authority. In the case of fossil-fuel-fired electric generating units, we assume the primary regulatory driver for reductions will be New Source Performance Standards (NSPS) under section 111 of the Clean Air Act. In setting NSPS, EPA may prescribe 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. We assume NSPS for new units will come into effect in two years' time, but note that new source permitting requirements of the Prevention of Significant Deterioration program will operate to require new plants to meet NSPS-like requirements beginning in 2011.

For existing sources, EPA must promulgate guidelines under section 111(d) to guide states in their regulation of existing sources within any source category covered. In covering existing sources, the remaining useful life of existing units must be taken into account. The Clean Air Act does not tightly prescribe the form of regulations for existing sources. EPA and the states could implement a cap-and-trade program for existing power plants across all fuel types.[8] EPA has indicated that such an approach could be used to achieve deeper reductions than traditional NSPS approaches due to cost savings inherent in cap-and-trade.

It may be possible for EPA to use NSPS in other ways that would encourage unit turnover and emissions reductions from existing power plants. For example, EPA and the states could establish categories of permissible emissions rates based on remaining life. They could then allow operators to decide which emissions rate to meet based on their assessment of the remaining useful life of the unit. At the conclusion of the approved remaining life, units would be required to meet the NSPS for new units. Another approach would be for EPA and the states to establish emissions limits for the life of each unit. Once those limits expire, units would be required to shut down. Such an approach could permit trading of the emissions limits.

C. LACKLUSTER SCENARIO FOR ALL POWER PLANTS

For the Lackluster Scenario, we assume that EPA establishes New Source Performance Standards for new and existing natural-gas-fired and coal-fired plants. While cap-and-trade is not necessary to achieve these reductions, EPA and the states could establish an electric-sector cap-and-trade program for all existing power plants in order to help reduce the costs of compliance.

1. New Coal Plants

For new coal plants, we assume that EPA establishes an emissions standard equal to the emissions rate of a new natural-gas-fired unit. Units could achieve this emissions rate by using natural gas or co-firing with biomass, carbon capture and storage, or by utilizing waste heat. Standards could be established for new units based on the available technology through Prevention of Significant Deterioration/ Best Achievable Control Technology (PSD/BACT) any time after 2011, and NSPS beginning in 2013. We note that the AEO2009 does not predict any new unplanned coal generation that does not include CCS until after 2025, making the assumptions for new coal plants moot for this analysis except in the post-2025 timeframe. (Note, planned units are defined as those units that have broken ground, but have not yet commenced operation.)

2. New Natural Gas Plants

For new natural gas plants, we assume EPA establishes emissions standards for new units that are equal to the emissions rate achieved through increasing the efficiency of a natural gas unit to 70 percent by 2030. This target comes from the Electric Power Research Institute's (EPRI's) 2009 Prism/MERGE analysis, which 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."[9] For modeling purposes, we assume that technological advancement toward the 70 percent efficiency target commenced in 2009 and progresses through 2030 at a steady rate. Standards could be established for new units at any point based on the available technology through PSD/BACT any time after 2011, and NSPS beginning in 2016. We note that the AEO2009 does not project appreciable increases in new natural gas units until after 2020.

3. All Existing Power Plants

In the Lackluster Scenario, we assume that NSPS are established that achieve reductions consistent with a modest 5 percent improvement in efficiency at existing coal plants. The 5 percent improvement rate comes from EPA's Advanced Notice of Proposed Rulemaking (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.[10] A 5 percent improvement in heat rate would reduce greenhouse gas emissions by 5 percent at existing coal plants. Alternatively, plants could achieve a 5 percent reduction in emissions by switching in whole or in part to lower carbon fuels such as natural gas or sustainably harvested biomass, or through greater use of waste heat. As noted above, EPA could establish a cap-and-trade program to drive these reductions. This would likely reduce the total costs of regulation by increasing compliance flexibility.

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 this Lackluster Scenario. Nevertheless, these sources could be included in any cap-and-trade program to maximize emissions reduction opportunities.

To model reductions achieved through these standards, we made use of intermediary coal modeling results for the AEO2009 Updated Reference Case, which were furnished upon request from the EIA.[11] Those results indicated projected capacity, generation, consumption, and emissions by technology type for new, planned and existing units through 2030. The 5 percent improvement was applied across all existing coal-fired units. We relied on the AEO2009 for predictions of unit turnover. Thus, we estimated the emissions benefits of emissions standards for new units by applying generation originally projected from new coal units to the EIA's assumed heat rate for new natural gas units and the carbon dioxide content the EIA assumes for natural gas (tons of CO_2 per unit of energy output).

D. MIDDLE-OF-THE-ROAD SCENARIO FOR ALL POWER PLANTS

For the Middle-of-the-Road Scenario, we assume that EPA establishes New Source Performance Standards for new and existing natural-gas-fired and coal-fired power plants. While cap-and-trade is not necessary to achieve these reductions, EPA and the states could establish an electric sector cap-and-trade program for all existing power plants in order to help reduce the costs of compliance.

1. New Coal Plants

For the Middle-of-the-Road Scenario, we assume that EPA establishes emissions standards for new units beginning in 2020 that are equivalent to coal combustion with 90 percent carbon capture and storage. This is consistent with EPRI's 2009 Prism/MERGE analysis, discussed below. If EPA were to pursue this line of regulation, it would also likely set an intermediary emissions standard. Standards could be established for new units based on the available technology through PSD/BACT any time after January 1, 2011, and NSPS beginning in 2012. We note that the AEO2009 does not predict any new unplanned conventional coal generation until 2026, making assumptions for new coal units inconsequential to the analysis until the post-2025 timeframe. These reductions were modeled using the same intermediary reports and general methods that were employed in the Lackluster Scenario. In modeling generation, we used the heat rates for coal units with CCS provided in the AEO2009, which take into account the energy demands of CCS.

According to the International Energy Agency's *Technology Roadmap*, Carbon Capture and Storage, there are already five operational large-scale CCS projects worldwide, and another 100 are planned.[12] In addition, EPRI's 2009 Prism/MERGE analysis assumes that 90 percent of new coal units meet an emissions rate equivalent to coal combustion with 90 percent CCS beginning in 2020. EPRI describes the analysis 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."[13]

Additional support for an assumption on CCS deployment can be found in recently proposed federal climate legislation, which has included emissions standards for new coal units to drive deployment of CCS. Specifically, the American Clean Energy and Security Act (ACES, commonly known as Waxman-Markey) requires coal units permitted from 2009 to 2019 to emit 50 percent fewer greenhouse gases (GHGs) than they would without CCS by 2025, or earlier depending on the status of CCS technology. Meanwhile, plants permitted from 2020 onward are required to emit 65 percent fewer GHGs than they would without CCS.[14] Similar standards are included in the Clean Energy Jobs and American Power Act (CEJAPA, known as Kerry-Boxer). However, CEJAPA allows standards to be applied before 2020 if more than 10 gigawatts (GW) of commercial CCS is deployed and allows the date to be extended to 2022 if insufficient commercial deployment is found in 2017.[15] In order to help drive deployment of CCS technology, both bills allocate considerable funding to research development and deployment. Regardless of these legislative goals, the actual timing for wide-scale deployment remains uncertain.

2. New Natural Gas Plants

For new natural gas plants, we assume that EPA initially establishes emissions standards for new units equal to that achieved through the efficiency advancement curve described in the Lackluster Scenario. Beginning in 2020 we assume that EPA requires that new units to meet an emissions rate equivalent to that achievable with CCS with a 90 percent capture rate. This CCS assumption comes from the EPRI Prism/Merge Analysis.

The Electric Power Research Institute's 2009 Prism/MERGE analysis considers a target efficiency for new natural gas combined cycle units of 70 percent, and assumes that 90 percent of new natural gas units meet an emissions rate equivalent to coal combustion with 90 percent CCS beginning in 2020. As stated above, EPRI describes the 2009 Prism/MERGE analysis 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."

These reductions were modeled using the same intermediary reports and general methods that were employed in the Lackluster Scenario. In modeling the impact of such a standard, we used the heat rates for natural gas with CCS provided in the AEO2009, which take into account the energy demands of CCS.[17]

3. All Existing Power Plants

For the Middle-of-the-Road Scenario, we assume EPA establishes an NSPS for existing coal-fired units that results in a 7.1 percent reduction in GHG emissions. These reductions could come solely through efficiency improvements, from units switching to lower carbon fuels such as natural gas or biomass, or through greater use of waste heat. As noted above, EPA could establish a cap-and-trade program to drive these reductions. This would likely reduce the total costs of regulation by increasing compliance flexibility.

The 7.1 percent reduction is taken from a National Energy Technology Laboratory (NETL) analysis. 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 and result in a corresponding 10 percent decrease in GHG emissions.[18] The analysis also breaks down the coal fleet into 13 groups based on characteristics that limit efficiency and found that if each group achieved an average efficiency equal to its 90th percentile, the average fleet efficiency would increase to 35.2 percent. This corresponds with a 7.1 percent improvement in heat rate and GHG emissions rate.

As in the Lackluster Scenario, we again assume in the Middle-of-the-Road Scenario no immediate low-cost opportunities for improving the efficiency of the existing natural gas fleet, because we were unable to find reputable available studies to support a different assumption. Nevertheless, these sources could be included in any cap-and-trade program to maximize emissions reduction opportunities.

These reductions were modeled using the same intermediary reports and general methods that were employed in the Lackluster Scenario.

E. GO-GETTER SCENARIO FOR ALL POWER PLANTS

For the Go-Getter Scenario, we assume that EPA and the states will achieve reductions consistent with the out-of-stack power sector reductions achieved under the American Clean Energy and Security Act (ACES). As in the other scenarios, while cap-and-trade may not be necessary to achieve these reductions, EPA and the states could establish an electric-sector cap-and-trade program for all existing power plants to help reduce the costs of compliance.

1. New Coal Plants

For the Go-Getter Scenario, we expect EPA to issue NSPS requirements for new coal plants, but we do not make any assumption about what those standards will be. Instead, we rely on cap-and-trade modeling results to inform our assessment of reductions achievable from this sector.

2. New Natural Gas Plants

For the Go-Getter Scenario, we expect EPA to issue NSPS requirements for new natural gas plants, but we do not make any assumption about what those standards will be. Instead, we rely on cap-and-trade modeling results to inform our assessment of reductions achievable from this sector.

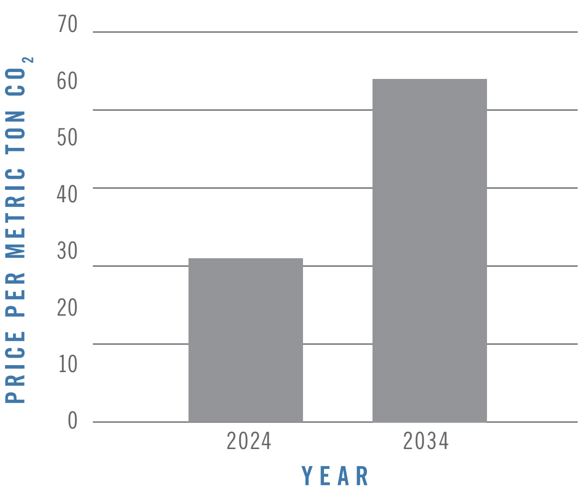
3. All Existing Power Plants

For the Go-Getter Scenario, we assume that EPA and the states seek reductions consistent with a more ambitious cap-and-trade program to drive reductions beyond those observed in the Lackluster and Middle-of-the-Road Scenarios. In determining the required reductions under the cap-and-trade program, we assume that EPA will conduct their own cap-and-trade modeling analyses to inform their determination of what is technically feasible and cost effective. Recall that under section 111 of the Clean Air Act EPA must consider technological feasibility, cost, lead-time, and energy and non-air environmental impacts. These factors are commonly built into cap-and-trade analyses completed for congressional cap-and-trade proposals.

In an effort to understand the possible emissions reduction targets that could be adopted by EPA, we examined EIA's modeling of ACES to assess the magnitude of reductions that were achieved in the electric sector at different price points. Allowance prices are equal to the marginal cost of pollution abatement. EIA modeling of the ACES base case projects allowance prices at $32 per metric ton of CO_2 in 2020 and $65 per metric ton of CO_2 in 2030.[19] These prices were found to correspond to actual on-site emissions reductions from electric generators of 8.5 percent below 2012 emissions in 2020 and 52 percent below 2012 emissions in 2030. Additional reductions could be achieved at these prices if offsets were allowed, as they could provide regulated entities with additional low-cost options for reducing emissions. However, in the ANPR EPA notes that a cap-and-trade program established under section 111(d) of the Clean Air Act would have to take place in the capped sector, and thus offsets could not be used for compliance purposes.

For the Go-Getter Scenario, we incorporate emissions reductions equivalent to the modeled reductions at electric generating facilities under ACES. While ACES commences in 2012, we assume that regulations would not be in place under section 111(d) until 2016. Therefore, we shifted back the reduction schedule under ACES to accommodate a 2016 start-date, and accounted for demand growth that occurs in the base case from 2012 to 2016 in our electricity demand module.

FIGURE A3. ACES Base Case Allowance Prices



ACES does include a Renewable Portfolio Standard (RPS). However, according to the EIA's Service Report accompanying the analysis, "The share of renewable generation far exceeds that required to comply with the combined efficiency and renewable electricity standard in all of the ACESA cases."[20] This suggests that the RPS in ACES was non-binding, and that there would be no appreciable increase in the cost of GHG abatement if it were removed from the scenario. Thus, the inclusion of the RPS in the ACES modeling does not deter use of the projected allowance prices as reasonable indicators of the cost of reductions.

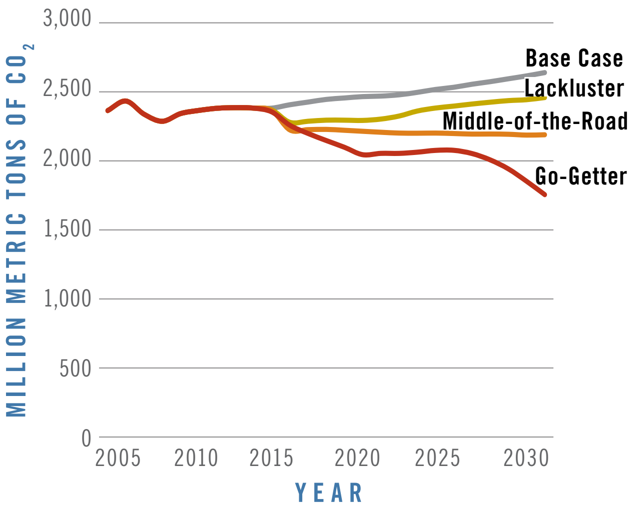
In utilizing the EIA analysis of ACES as a basis for our Go-Getter Scenario for all existing power plants, we were mindful the energy efficiency provisions of ACES reduced demand for electricity and thus reduced GHG emissions. EIA's analysis of ACES predicts that energy demand will decrease by 2.2 percent in 2020, 3 percent in 2026, and then 6.2 percent in 2030, when compared to reference case projections. Possible explanations for this decrease in demand include consumer response to higher electricity prices and the energy efficiency standards and funding for energy efficient retrofits included in ACES.

According to the EIA's *Energy Market and Economic Impacts of H.R. 2454, the American Clean Energy and Security Act of 2009*, improvements in the shell efficiency of existing commercial units increases by 1 percent relative to the reference case by 2030, and the impact of the efficiency standards is "relatively modest."[21] Unfortunately, model documentation does not provide a specific breakdown of the demand reduction attributable to efficiency standards and retrofit funding as opposed to consumer response to increased electricity prices. We note, however, that WRI's analysis of allowance allocation under HR 2454 indicates that considerable allocations were made to electricity distribution companies to benefit energy consumers through 2026, meaning the price signal normally expected in a cap-and-trade program would not reach electricity consumers during this time period.[22] After 2026, consumer allocations steadily fall to zero by 2030. This decrease in allocations for consumer benefit purposes corresponds with a jump in demand reduction from 3 percent in 2026 (which equates to 2030 in our analysis) to 6.2 percent in 2030.

If EPA were to use NSPS to implement a cap-and-trade program for electric generators, allocation of the allowances would be up to the states. We cannot predict precisely how states would use the allowance proceeds, and thus for purposes of this analysis assume that they would to some extent mirror those policies employed in ACES. Therefore, we retain the reductions in demand associated with ACES from 2012 through 2026 (our 2016 through 2030).

It is worth noting that the emissions reductions modeled in the Go-Getter Scenario are equivalent to improving the emissions rate of nearly all existing coal plants to that of natural gas units.

FIGURE A4. Reductions from Power Plants Across All Scenarios



F. UNCERTAINTIES FOR POWER PLANT SCENARIOS

The reductions assumed in the Lackluster and Middle-of-the-Road Scenarios rely on unit turnover predictions in the AEO2009. This is important because the AEO does not predict significant retirement of existing coal units through 2030. Some have suggested that new regulations for hazardous air pollutants and criteria air pollutants may accelerate the rate of retirement and with it the reductions that can be anticipated through unit turnover. The Go-Getter Scenario does assume increased unit turnover, and we believe that it remains a reasonable gauge of the emissions benefits achievable via more stringent NSPS requirements, whether or not short-term retirement is accelerated by other regulatory requirements for coal units.

We also do not assume any reduction in demand associated with increased electricity prices related to the cost of compliance. Additional reductions beyond what we model here are possible if consumers directly experience electricity price increases associated with new requirements.

IV. Appliance and Equipment Efficiency Standards (Electric)

A. MODELING APPROACH FOR APPLIANCE AND EQUIPMENT EFFICIENCY STANDARDS

The energy savings from increased appliance and equipment efficiency standards was fed into our Electric Demand Module, which also incorporates 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. Net energy savings is compared to the outputs from our Lackluster, Middle-of-the-Road and Go-Getter Scenarios for power plants. When reducing electric demand and CO_2 emissions associated with electricity generation, we first turn off new unplanned additions (i.e., new units that have not yet commenced construction) for coal and natural gas (excluding the 2 GW of coal with IGCC that is hard-wired into the model based on incentives under the American Reinvestment and Recovery Act of 2009[23] and the Energy Improvement and Extension Act of 2008).[24] Then we reduce CO_2 emissions according to the scenario-specific average emissions rate for the remaining units. 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 timeframe considered. Furthermore, while marginal units tend to be natural gas in some regions of the country (such as New England),[25] they are coal in other regions.

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.

B. BASE CASE FOR APPLIANCE AND EQUIPMENT EFFICIENCY STANDARDS (ELECTRIC)

Our base case uses the AEO2009 reference case. The AEO2009 reference case assumes that the delivered energy per household declines at an average rate of 0.6 percent. About two-thirds of this decline is due to stock turnover and the purchase of more efficient equipment. The reference case also assumes that commercial energy consumption per capita stabilizes from increases seen throughout the 1980s and 1990s.[26]

C. LACKLUSTER SCENARIO FOR APPLIANCE AND EQUIPMENT EFFICIENCY STANDARDS (ELECTRIC)

The Department of Energy may promulgate efficiency standards for consumer appliances and non-consumer equipment under existing federal law.[27] 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.[28]

We identified two major studies that quantify energy savings achievable through enhanced energy efficiency standards. Both studies compare those savings to those modeled in the AEO2009 to predict savings achievable above and beyond those already modeled in the AEO2009. These two studies served as the basis for all three of our scenarios.

In *Ka-BOOM! The Power of Appliance Standards: Opportunities for New Federal Appliance and Equipment Standards*, the American Council for an Energy-Efficiency Economy (ACEEE) and the Appliance Standards Awareness Project quantified the benefits from 23 product standards for which federal standards are due before January 1, 2013, and three additional products that the authors found had "potential savings warranting consideration for earlier-than- scheduled rulemakings." They estimate that those standards could result in 100 TWh savings in 2020, and 177 TWh savings in 2030. Energy savings were calculated as reductions compared to current units, assuming fixed demand for the appliances. The authors of *Ka-BOOM* conclude that this is the level of savings that would occur beyond AEO2009 projections because energy efficiency improvements built into the AEO2009 that they do not account for are offset by the increased product sales expected through 2030. The study does not consider the benefits of additional appliance standards due after January 2013. The standards included were found to save consumers money over the life of the product, with an average non-discounted payback period of 3.1 years. Individual product payback periods ranged from less than a year to 10.4 years.

The other study considered was the Institute for Electric Efficiency's (IEE's)[29] *Assessment of Electricity Savings in the U.S. Achievable through New Appliance/Equipment Efficiency Standards and Building Efficiency Codes (2010–2020).*[30] The study examined what IEE deemed "moderate" and "aggressive" efficiency improvement scenarios. For purposes of this analysis, we modeled the Lackluster Scenario after the electric demand reductions achieved under their moderate scenario. The IEE moderate scenario includes "appliance and equipment standards for items scheduled or overdue under DOE's rulemaking process as set forth by the Energy Policy Act of 2005 and the Energy Independence and Security Act of 2007." The IEE moderate scenario was found to result in electricity savings of 86 TWh in 2020 from the AEO2009 Reference Case. The IEE aggressive scenario assumes that "in addition to standards scheduled or backlogged under DOE (moderate scenario), standards expand to address all possible devices, with a second set of standards in later years of the forecast for some technologies." The IEE study concluded that these policies could save 234 TWh of electricity in 2020 from the AEO2009 Reference Case.

For the Lackluster Scenario, we chose the lowest range of energy efficiency improvements from the two studies, the IEE moderate scenario, which was estimated to result in 86 TWh in 2020 from the AEO2009 Reference Case. Unfortunately, 2030 results were not provided. For purposes of our analysis, we assumed that standards commence in 2015, and result in a constant increase in savings between 2015 and 2020. Because the AEO2009 reference case continues to increase appliance efficiency through 2030, we hold the reported reductions achievable in 2020 constant through 2030, instead of assuming a steady rate of change.

D. THE 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 two studies, which was found in *Ka-BOOM! The Power of Appliance Standards: Opportunities for New Federal Appliance and Equipment Standards.* This study concluded that the 26 standards considered would save 100 TWh in 2020, and 177 TWh in 2030, based on the AEO2009 Reference Case.[31] For purposes of our analysis, we assumed that standards commence in 2015, and result in a constant increase in savings between 2015 and 2020, and from 2020 to 2030.

E. THE 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 two scenarios, which was the aggressive scenario in the Institute for Electric Efficiency study. The IEE's aggressive scenario was found to result in energy savings of 234 TWh in 2020 from the AEO2009 Reference Case. For purposes of our analysis, we assumed that standards commence in 2015, and result in a constant increase in savings between 2015 and 2020. For this scenario 2030 results were not provided. Therefore, because the AEO2009 reference case continues to increase appliance efficiency through 2030, we hold the reported reductions achievable in 2020 constant through 2030, instead of assuming a steady rate of change.[32] The IEE estimates include efficiency improvements from industrial equipment standards, which we assume will be captured by our industrial Go-Getter Scenario. Therefore, we backed out the approximate 19 TWh of efficiency savings from industrial equipment standards, leaving us with 215 TWh of savings from 2020 to 2030.[33]

V. Appliance and Equipment Efficiency Standards (Heating)

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

As a general matter, the greatest opportunities for reducing direct combustion of fossil fuels in residential and commercial buildings are through the improved performance of the building envelope. We assumed there is no clear existing federal regulatory authority to require building envelope improvement. There are, however, some opportunities to increase the efficiency of appliances that use gas and oil, resulting in slight reductions in emissions.

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 fuels on the *Ka-Boom* study, discussed above.[34] The *Ka-Boom* analysis examines efficiency opportunities for the following residential appliances: clothes dryers, clothes washers, oil and gas furnaces, pool heaters, direct heaters, water heaters, as well as commercial clothes washers and commercial boilers. The *Ka-Boom* study concludes that standards for those sources could reduce gas demand by 166 TBtu in 2020 and 347 TBtu in 2030, and could reduce oil demand by 2.3 TBtu in 2020 and 5.4 TBtu in 2030. For purposes of our analysis, we assumed that standards commence in 2015, and result in a constant increase in savings between 2015 and 2020, and from 2020 to 2030. The net result of the standards is a reduction in CO_2 emissions of 9 $mmtCO_2$ in 2020 and 19 $mmtCO_2$ in 2030.

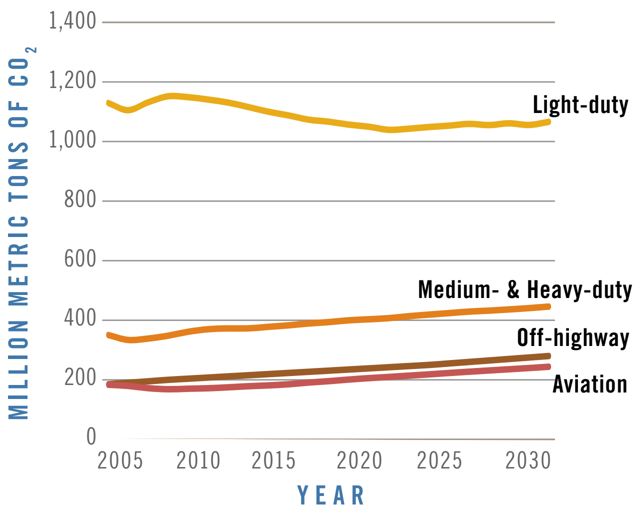
VI. Transportation

A. LIGHT-DUTY VEHICLES

1. Base Case for Light-Duty Vehicles

In the base case, the corporate average fuel economy (CAFE) for new light-duty cars and trucks increases to 35 miles per gallon (mpg) by 2020 in accordance with the Energy Independence and Security Act of 2007.[35] Vehicle miles traveled (VMT) increase from 2.7 trillion miles in 2006 to 3.8 trillion miles in 2030 due to population increases and per capita increases in miles traveled.[36] The net effect of these forces is a decrease in CO_2 emissions from 2011 to 2022 and then a gradual increase through 2030, returning back to 2016 emissions levels. The AEO2009 does not include emissions associated with the combustion of biofuels in their assessments of greenhouse gas emissions, and assumes such fuels are to be 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 A5. Base Case CO_2 Emissions from Transportation (All Sectors)



BOX A2. Modeling Light-, Medium-, and Heavy-Duty Vehicles

Greenhouse gas emissions from light-duty vehicles were projected using the latest version of Argonne National Laboratory's VISION model. The VISION model is a spreadsheet model developed by the Department of Energy to assess energy use, oil use, and carbon emissions through 2050 from on-road vehicles. The model accounts for vehicle survival and age-dependent usage characteristics to project stock, vehicle miles traveled (VMT), and energy use by technology and fuel type by year. The base case for the VISION model is based on the EIA's AEO2009 projections, which run through 2030.

The VISION model builds in VMT elasticity for cost of driving, using -0.1 cents per mile as a default (i.e., a 10 percent reduction in fuel cost per mile results in a 1 percent increase in VMT). We employed the same fuel prices used in VISION base case. This includes a predicted price for gasoline of $2.09 per 125,000 Btu (approximately 1 gallon) in 2010 and $3.72 per 125,000 Btu in 2030. Unlike the light-duty module, the medium- and heavy-duty modules assume negligible elasticity for the cost of driving, and thus do not increase VMT for medium- and heavy-duty vehicles in response to improvements in fuel economy.

Source: *Vision Model: Description of Model Used to Estimate Impact of Highway Vehicle Technologies and Fuels on Energy Use and Carbon Emissions to 2050,* by M. Singh, A. Vyas and E. Steiger, Center for Transportation Research, Argonne National Laboratory, December 2003.

2. Lackluster Scenario for Light-Duty Vehicles

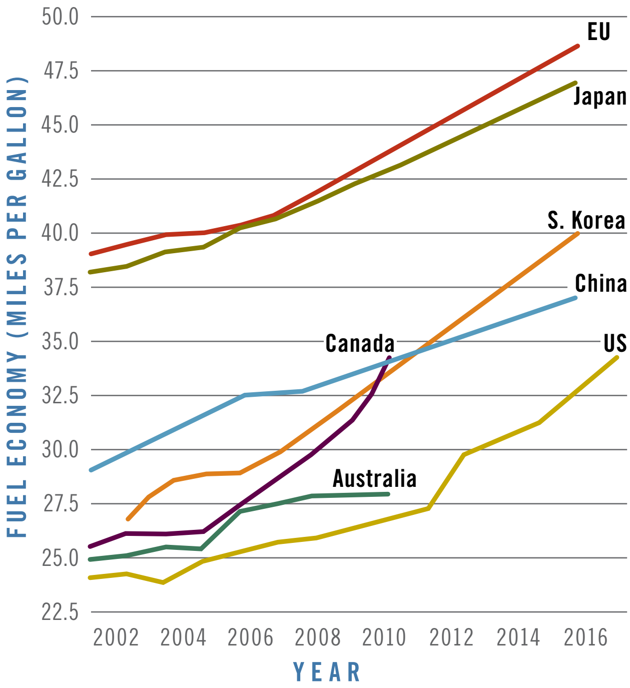
In May 2010, EPA and the Department of Transportation's National Highway Traffic Safety Administration (NHTSA) finalized a joint rulemaking under the Clean Air Act and the Energy Independence and Security Act establishing GHG emissions standards and new fuel economy rules for light-duty vehicles nationwide. The EPA standards cover CO_2 and three other vehicular emissions of greenhouse gases, including HFCs from air conditioning systems (A/C). Those regulations require that new model year 2016 vehicles 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 is actually set at 34.1 mpg, because NHTSA considers only drive train improvements and does not consider air conditioning improvements for purposes of establishing CAFE standards.[37] Because these new standards were not finalized until May 2010, they were not included in the AEO2009, our base case.

On May 21, 2010, President Barack Obama issued a memorandum on *Improving Energy Security, American Competitiveness and Job Creation, and Environmental Protection through a Transformation of our Nation's Fleet of Cars and Trucks.*[38] In that memorandum, the President directed EPA and NHTSA to begin working on a joint rulemaking with the State of California to develop automobile standards for 2017 through 2025. The memorandum indicates "the national program should seek to produce joint federal standards that are harmonized with applicable state standards, with the goal of ensuring that automobile manufacturers will be able to build a single, light-duty national fleet."

According to a study by Lynette Cheah et al. at the Massachusetts Institute of Technology, it is technically feasible to double average fuel economy to 52 mpg (52 mpg test fuel economy, equivalent to 42 mpg on-road fuel economy) by 2035, and the associated increase in vehicle costs would be recovered in the form of fuel savings within 4 to 5 years.[39] A study by the American Physical Society concluded that it was possible to increase fuel economy to 50 mpg by 2030.[40]

To give these targets an international context, consider that the EU has established a 130 g CO_2/km (48.6 mpg) target for 2015, and has proposed a 95 g CO_2/km (64.8 mpg) target for 2020. Likewise, Japan has a mandatory target of 125 g CO_2/km (47 mpg) in 2015.[41]

FIGURE A6. Comparison of Actual and Projected Corporate Average Fuel Economy for New Passenger Vehicles



Source: *Data for Fuel Economy Standards and GHG Standards Charts*, November, 2009, http://www.theicct.org/documents/ICCT_PVStd_Nov_09(Data_Sheet).xls.

In the Lackluster Scenario, we assume that EPA's vehicle emissions standards and DOT's CAFE standards increase linearly from 2017 through 2030, so that in 2030 new light-duty vehicles meet an average fuel economy of 40 mpg. This could be accomplished by establishing unified national standards. Alternatively, California and the 17 other states that adopted the California greenhouse gas emissions standards could adopt emissions standards equivalent to 50 mpg while the remaining states retain the 2016 250 g/mi standard established through the recent joint EPA and NHTSA rulemaking (and assuming no emissions leakage occurs).[42]

Emissions standards will likely be developed in a holistic manner that incorporates HFC benefits and A/C efficiency opportunities (approximately 14 g/mi and 7 g/mi, respectively).[43] Thus, the 40 mpg and 50 mpg standard would be set at 204 g/mi and 162 g/mi. Note that when modeling vehicle fuel economy we do not include the potential 14 g/mi benefits from reducing HFC emissions to prevent double counting with our HFC reduction scenarios (see Section VII). However, CAFE standards are unlikely to include HFC or A/C benefits, and thus would be set lower, likely at 39 mpg and 48 mpg.

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

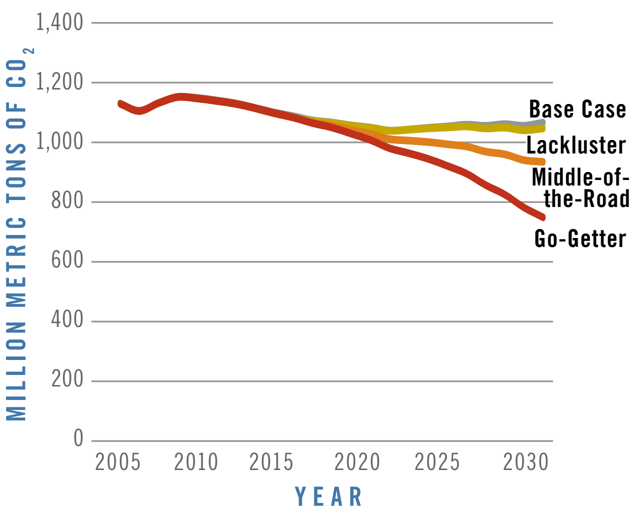
In addition to including the May 2010 vehicle emissions and efficiency standards, the Middle-of-the-Road Scenario assumes that EPA strengthens the federal vehicle emissions standards steadily so that in 2030 new vehicles must meet a corporate average emissions standard of 162 grams per mile under section 202 of the Clean Air Act. This is modeled as a 50 mpg average fuel economy for new vehicles in 2030 to prevent double counting the HFC emissions benefits. This is consistent with the American Physical Society assessment and is only slightly higher than the results expected in 2015 under European Union and Japan programs.

4. The Go-Getter Scenario for Light-Duty Vehicles

The Lackluster and Middle-of-the-Road Scenarios do not assume additional market penetration of electric vehicles and plug-in hybrid electric vehicles beyond the base case. To estimate the reductions that could be achieved if those technologies become widely deployed, in the Go-Getter Scenario we assume that electric vehicles capture 30 percent of the light-duty market in 2030, and that plug-in hybrid electric vehicles are 17 percent of the market in 2030. This is consistent with Scenario B of the *EPA Analysis of the Transportation Sector: Greenhouse Gas and Oil Reduction Scenarios*. EPA's Scenario B ramps up automobile emissions standards to 86 grams per mile by 2030. This scenario assumes that miles traveled on electricity are counted as having an emissions rate of 0 g/mi.[44] The Go-Getter Scenario also assumes that plug-in hybrid electric vehicles travel 50 percent of their miles on electricity, while electric vehicles travel exclusively on electricity. If the reductions under the Go-Getter Scenario were obtained entirely through fuel efficiency improvements, after accounting for the electricity credit, vehicles would meet an equivalent average on-road fuel economy of 63 mpg. However, EPA's scenario also includes a 14 g/mi benefit from HFCs and a 7 g/mi benefit from A/C efficiency improvements. Excluding both of these measures, as is consistent with NHTSA guidelines, the corporate average fuel economy comes out to 51 mpg.

Maximizing emissions reductions from light-duty vehicles will require EPA to establish holistic emissions standards that include A/C benefits and HFC benefits. However, for modeling purposes we do not include the HFC emissions benefits to prevent double counting AEO2009, our base case, with our HFC emissions module. Increases in electric demand were normalized with EPA's predicted electric demand increase and then fed into our energy demand module to account for increased emissions associated with increased electric demand. Marginal increases in electric demand result in additional carbon dioxide emissions, which are counted in the electric sector. For light-duty electrification, the increase in electricity demand is 190 TWh.

FIGURE A5. Tailpipe Emissions from Light-Duty Vehicles



Note: Increased emissions from electric generators associated with vehicle electrification are not included here as part of the tailpipe emissions projections, but instead are included with electric generator emissions.

5. Modeling Notes for Light-Duty Vehicle Scenarios

The VISION model calculates lifecycle emissions. Reductions in tailpipe emissions were therefore estimated based on changes in fuel consumption projected by the VISION model. On-road mpg was calculated as 80 percent of the test mpg in accordance with standard practice and VISION model design.

6. Uncertainties for Light-Duty Vehicle Scenarios

In all scenarios we relied on VISION default fuel prices, which are $2.09 per 125,000 Btu (approximately 1 gallon) in 2010, and $3.72 per 125,000 Btu in 2030. If fuel prices increase above their projections, then vehicle miles traveled (VMT) will likely decrease. Beyond fuel price changes, there are many other forces that can influence VMT. These include: heightened focus on reducing VMT growth by regional planning organizations and local land use planning boards, as well as improved public transit. These changes are not quantified in this analysis due to the current lack of a strong policy lever at the federal level. The technical potential of such approaches is quantified in the Urban Land Institute's *Moving Cooler, An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions*, prepared by Cambridge Systematics,[45] and in the EPA's *Analysis of the Transportation Sector: Greenhouse Gas and Oil Reduction Scenarios*.

In the Go-Getter Scenario, the key uncertainty is whether or not it is possible for electric vehicles and plug-in hybrid electric vehicles to obtain a 47 percent combined market penetration rate by 2030. This would require significant advancement in battery technology,[46] as well as considerable infrastructure changes. According to the International Energy Agency, battery durability and life expectancy are the two greatest technological hurdles to battery commercialization, followed by battery storage capacity and battery discharge cycles.[47] To help address these challenges, President Barack Obama's memorandum on *Improving Energy Security, American Competitiveness and Job Creation, and Environmental Protection through a Transformation of our Nation's Fleet of Cars and Trucks* requested that the Secretary of Energy provide technical assistance to cities preparing for deployment of electric vehicles.[48]

B. MEDIUM- AND HEAVY-DUTY VEHICLES

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

At this time there are neither fuel economy standards nor GHG emissions standards for medium- or heavy-duty vehicles. However, the Energy Independence and Security Act of 2007 (EISA) requires the Department of Transportation develop fuel economy standards for medium- and heavy-duty vehicles. Because standards have not yet been proposed, the VISION base case reflects AEO2009 assumptions about market-driven progression in fuel economy. The AEO2009, our base case, assumes Class 7 & 8 heavy combination trailers—the sub-set of heavy-duty vehicles used for shipping of cargo and responsible for 76 percent of heavy-duty emissions—see an increase in efficiency from 6.86 mpg in 2009 to 8.02 mpg in 2030.[49] Miles traveled by medium- and heavy-duty vehicles increase from 236 billion miles in 2008 to 347 billion miles in 2030.[50] As a result, emissions increase from 351 million metric tons CO_2 (mmtCO_2) in 2008 to 446 mmtCO_2 in 2030.

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

In President Obama's May 21 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 by as much as 25 percent.

EISA requires at least three years of "regulatory stability," whereby standards remain fixed. While this requirement would not seem to apply to GHG emissions standards under Title II of the Clean Air Act, we assume for purposes of this analysis that

FIGURE A8. Fuel Efficiency Improvements Modeled for Medium- and Heavy-Duty Vehicle Types in VISION.

Note: VISION baseline efficiency improvements differ from EPA's. In addition, our reductions start one year earlier than EPA's. Therefore, applying the EPA's listed annual efficiency improvements results in fuel economies different from those reported in the EPA *Analysis of the Transportation Sector, Greenhouse Gas and Oil Reduction Scenarios.*

both CAFE standards and GHG emissions standards are only updated once every three years and are set at the maximum level achievable in the first year of the three-year period.

In all three scenarios we assume that vehicle emissions and fuel-economy standards are established through joint rulemaking by EPA and NHTSA and are largely based on scenarios modeled in the *EPA Analysis of the Transportation Sector, Greenhouse Gas and Oil Reduction Scenarios.*[50] In that analysis, EPA provided two different scenarios, A and B, but was clear that the "illustrative example scenarios do not imply that EPA considers these to be the appropriate levels or dates for standards." However, EPA also states that "the technologies that were included in the analysis are those that are currently available or under development and are expected to pay back over the lifetime of the vehicle under AEO2009 fuel price projections."[51] Nevertheless, in an effort to ensure that our scenarios bounded the range of regulatory possibilities, we developed a Lackluster Scenario which annual improvements are equal to one-half that achieved under EPA's Scenario A.

EPA's Scenario A results in a 4.9 percent improvement each year in GHG emissions rates from 2015 through 2020, and an additional 1.5 percent each year from 2021 through 2030. We adjusted this schedule up 1 year to account for the Presidential memorandum. Thus, in 2014 we assumed a 2.45 percent improvement from predicted 2013 fuel economy in VISION, and then applied an annual 2.45 percent increase through 2019. The annual improvement fell to 0.75 percent from 2020 through 2030. These reduction targets were applied separately to each vehicle type.

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

The Middle-of-the-Road Scenario matches EPA's Scenario A for both medium-duty and heavy-duty vehicles. We adjusted this schedule up 1 year to account for the Presidential memorandum. Thus, in 2014 we assumed a 4.9 percent improvement in GHG emissions rate from predicted 2013 fuel economy in VISION, and then we applied an annual 4.9 percent improvement through 2019. The annual improvement fell to 1.5 percent each year from 2020 through 2030. These reduction targets were applied separately to each vehicle type.

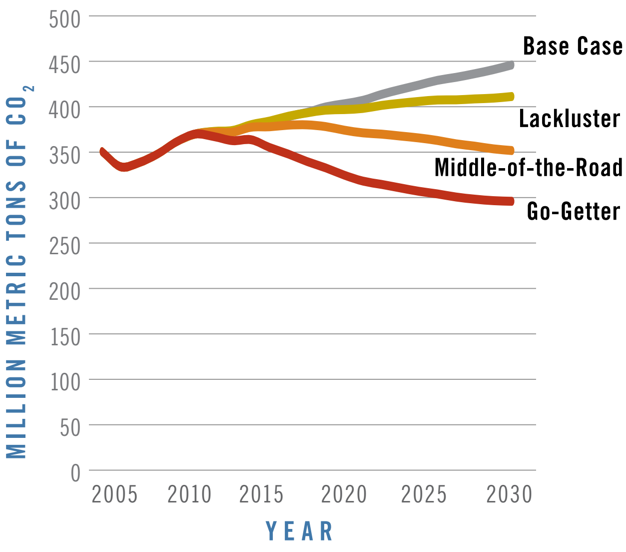
4. Go-Getter Scenario for Medium- and Heavy-Duty Vehicles

The Go-Getter Scenario for medium-duty and most heavy-duty vehicles (excluding tractor trailers) was derived from EPA's Scenario B. Again, we adjusted this schedule up 1 year. Thus, in 2014 we assumed a 5.6 percent improvement in GHG emissions rate from predicted 2013 fuel economy in VISION, and then we applied an annual 5.6 percent improvement through 2019. The annual improvement fell to an additional 1 percent each year from 2020 through 2030. These reduction targets were applied separately to each vehicle type.

We did not include the tire and trailer retrofits, which EPA included in Scenario B, because the current mechanism for achieving retrofits of this sort, the U.S. EPA SmartWay Program, is primarily voluntary in nature.[52] While California has made it mandatory, it is not clear that the federal government can or would do the same.

The Go-Getter Scenario for Class 7 & 8 combination vehicles was derived from the National Academy of Sciences *Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.*[53] That study concludes that tractor trailers can reduce fuel consumption 51 percent in the 2015–2020 timeframe. Tractor trailers account for 80 percent of VMT from Class 7 & 8 combination vehicles. Therefore, for purposes of our analysis, we assume that Class 7 & 8 combination units reduce fuel consumption by 25 percent from 2009 levels in 2014, 2015, and 2016, consistent with the Presidential memorandum. We then assume that Class 7 & 8 combination units reduce fuel consumption 51 percent from 2009 levels beginning in 2017.

FIGURE A9. CO_2 Emissions from Medium- and Heavy-Duty Vehicles



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

The VISION model calculates lifecycle emissions. Therefore, reductions in tailpipe emissions were estimated based on changes in fuel consumption projected by the VISION model. Because there are no fuel economy requirements for medium- and heavy-duty vehicles, unlike light-duty vehicles, there is no need to discount fuel economy inputs for the model, as all estimates are on-road estimates. If fuel economy or emissions estimates are biased above or below on-road estimates, then we expect that this will affect not just future standards, but also the base case estimates upon which the reduction schedule is based.

6. Uncertainties for Medium- and Heavy-Duty Vehicles

Changes in the rate of economic growth and/or shipping practices will change VMT and thus CO_2 emissions from what is modeled here. In addition, the medium- and heavy-duty vehicle fleet is very diverse. Therefore, it may be difficult to impose GHG standards across all vehicle types initially. This could lead to some amount of vehicle switching in the early stages before all relevant vehicle types can be included. Assessment of the potential impacts of vehicle switching is beyond the scope of this study.

C. OFF-HIGHWAY MOBILE SOURCES

1. Base Case for Off-Highway Mobile Sources

There is no specific off-highway category in the AEO. Instead, it is comprised of a variety of emissions sources from other sectors. 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 Scenarios* for our base case.

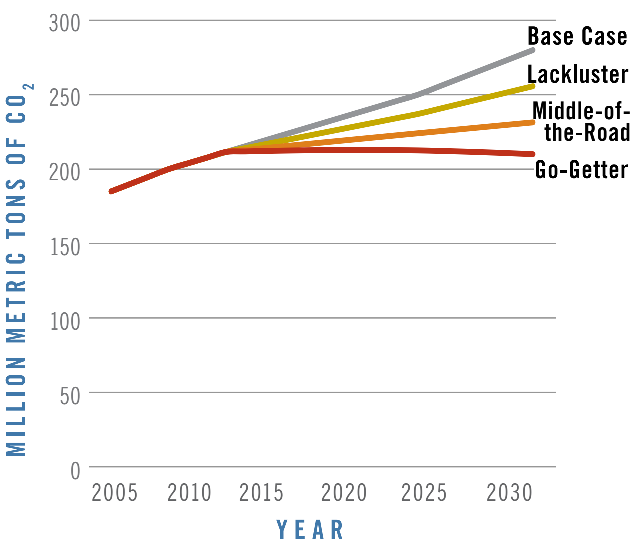
2. Lackluster, Middle-of-the-Road, and Go-Getter Scenarios for Off-Highway Sources

The *EPA Analysis of the Transportation Sector* concludes that significant reduction opportunities exist for engines and equipment used for agriculture (tractors and combines), construction (cranes and bulldozers), lawn and garden, and mining.[54] As with light-, medium-, and heavy-duty vehicles, EPA posits two greenhouse gas emissions reduction scenarios that in their technical judgment are achievable. We were unable to identify other studies to complement EPA's work, and thus based all three of our scenarios on EPA's technical study. As with medium-duty vehicles, the Lackluster Scenario was modeled at one-half the reductions achieved by EPA's Scenario A, the Middle-of-the-Road Scenario was modeled to match EPA's Scenario A, and the Go-Getter Scenario was modeled to match EPA's Scenario B. The Lackluster Scenario was made more conservative due to EPA's assessment that their "illustrative example scenarios do not imply that EPA considers these to be the appropriate levels or dates for standards."[55]

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 published reductions using the AEO2009 base case. These reductions were adjusted to remove the contribution from operational improvements. As detailed in the medium- and heavy-duty discussion above, it is not clear that EPA can mandate operational changes under existing regulatory authorities. Therefore, for our 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 2015 to 2030.

It is important to note that EPA's scenarios result in emissions reductions through increased equipment electrification. Because our scenarios include unique electric emissions rates, we estimated increased electric demand and fed that into our energy demand module to capture the resulting increases in electricity emissions. For off-highway electrification, the increase in electricity demand in 2030 is 10, 20, and 70 TWh for the Lackluster, Middle-of-the-Road, and Go-Getter Scenarios, respectively.

FIGURE A10. CO_2 Emissions from Off-Highway Mobile Sources



3. Uncertainties for Off-Highway Scenarios

Because this sector is not part of the AEO2009, and unit turnover models are not publicly available, it is not possible to verify these numbers at this time. To the extent there is uncertainty around unit turnover and growth, CO_2 emissions projections are also uncertain.

D. AVIATION

1. Base Case for Aviation

The emissions base case for aviation emissions was developed by multiplying projected energy use in Table 7 of the AEO2009, *Transportation Sector Key Indicators and Delivered Energy Consumption* by the CO_2 emissions factor for jet fuel found in Table 1.2 of the AEO2009. The AEO2009 builds in a steady improvement in energy efficiency. Nevertheless, emissions are expected to steadily increase through 2030 due to increased miles traveled.

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

We considered modeling the impact of emissions standards implemented under Title II of the Clean Air Act for aircraft and also emissions reductions achievable through operational measures implemented by the Federal Aviation Administration (FAA). For the reasons provided below, however, we did not model reductions from the aircraft emissions standards, but did model reductions from FAA operational improvements.

EPA may implement GHG emissions standards for airplanes under Title II of the Clean Air Act. The FAA enforces airplane emissions standards. In addition to enforcing EPA standards, the FAA can also drive reductions of their own through operational improvements in the way that air travel is managed in the United States. Through its Next Generation Air Transport Systems (NextGen), the FAA takes a five-pronged approach to address environmental issues: scientific advances, operational improvements, new technologies, renewable fuels, and policy initiatives such as the environmental management system (EMS). FAA's NextGen Implementation Plan contains firm commitments to environmental improvements and specific dates for attaining those goals.[56]

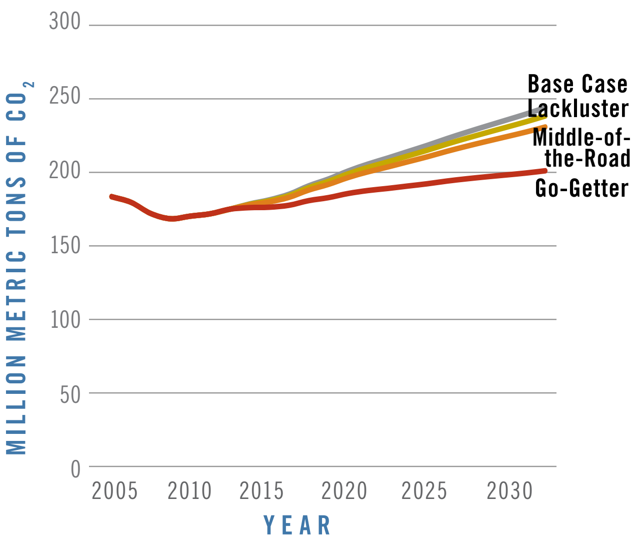
The AEO2009 builds in airplane efficiency improvements, assuming that aircraft will be 7 percent more efficient beginning in 2014, 10 percent beginning in 2015, 11 percent in 2020, and 15 percent in 2025.[57] In the EPA Analysis of the Transportation Sector, EPA suggests that by 2030 it may be possible to see engine improvements around 20 percent, and airframe weight and drag reductions between 5 and 20 percent. EPA's estimates are comparable to those provided by the European Advisory Council for Aeronautics Research in its *Strategic Research Agenda Working Paper,* which suggests reductions of 15–20 percent from fuel efficient engines and systems, and 20–25 percent from airframe improvements.[58] The *International Air Transport Association Technology Roadmap Report*, suggests that in the 2020 to 2030 timeframe reductions might be possible in the range of 25–50 percent.[59]

However, when examining EPA's analysis, we found that most of the emissions reductions can be attributed to operational measures. This is likely due to the lengthy turnover time for aircraft.[60] Given EPA's results, our inability to obtain a readily available off-the-shelf model that calculates the benefits of aircraft turnover, and concern about our ability to model any leakage due to the international nature of aircraft fleets, we chose not to model the GHG emissions reductions that would result from airplane emissions standards.[61]

The analysis does include projected emissions reductions achieved through improved operational measures implemented by the FAA. We draw our assumptions about operational improvements from *EPA Analysis of the Transportation Sector*. In its Scenario A, EPA assumes that sustained operational improvements reduce emissions by an additional 0.7 percent each year, so that in 2030 there is a 10 percent reduction from operational measures. In Scenario B, annual improvements are an additional 1.4 percent each year, so that in 2030 there is a 20 percent reduction from the base case. However, in their report EPA noted that the FAA thought that operational improvements should have been limited to an additional 0.17 percent per year in Scenario A, and 0.4 percent for Scenario B.

Because the FAA must implement the improvements, we modeled the FAA position in our Lackluster and Middle-of-the-Road Scenarios. For the Lackluster Scenario, we assume the FAA's low-range operational improvement (0.17 percent annually). For the Middle-of-the-Road Scenario, we assume the FAA's high-range operational improvement (0.4 percent annually). In the Go-Getter Scenario, we modeled EPA's high-range operational improvement (1.4 percent annually).

FIGURE A11. CO_2 Emissions from Aircraft



3. Uncertainties 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. It is also worth noting that there is no guarantee that the level of efficiency improvements (and thus emissions reductions) built into the AEO2009 will occur without regulations. Emissions standards on aircraft may theefore be necessary to capture efficiency improvements assumed by the AEO2009.

VII. Non-Energy Emissions

A. BASE CASE FOR NON-ENERGY EMISSIONS

Our base case projections of non-energy CO_2 emissions and other non-CO_2 gases 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).[62] ADAGE is a dynamic computable general equilibrium model run by RTI International.[63] ADAGE projects emissions in 5-year intervals from 2010 to 2050. To estimate emissions between those intervals, we applied a linear rate of change between intervals. Emissions for 2006 through 2009 were estimated by applying the same rate of change observed from 2010 to 2015. The ADAGE base case does not present the same level of detail as does the AEO base case. Therefore, in the sections that follow we simply describe the reported output for each of the base case emissions projections.

B. LACKLUSTER, MIDDLE-OF-THE-ROAD, AND GO-GETTER SCENARIOS FOR NON-ENERGY EMISSIONS

For most sectors in this category (i.e., landfills, natural gas systems, coal mining, and manufacture of nitric and adipic acid), we based our assessment of emissions reductions achievable on the marginal abatement cost curves that EPA used in their assessment of ACES. These curves were derived from EPA's *Global Mitigation of Non-CO_2 Greenhouse Gases*.[65] Marginal abatement cost curves are useful because in setting performance standards for these source categories, EPA and the states will set prescribed emissions rates for both new and existing units after considering the cost of abatement. EPA's marginal abatement curves provide cost information per ton of emissions reduced, and have been used by EPA with ADAGE emissions forecasts.

In order to get a sense of the range of reductions achievable, we based our Lackluster Scenario on the reductions achievable at a cost of $5 per ton of CO_2e. Our Middle-of-the-Road Scenario was based on the reductions achievable at a cost of $20 per ton of CO_2e. Our Go-Getter Scenario was based on the reductions achievable at a cost of $61 per ton of CO_2e.

The selected costs cover the range of prices being considered at the federal and state level in cap-and-trade program design.[65] More importantly, they also cover the range of prices to be considered in the Interagency Working Group on the Social Cost of Carbon's *Technical Support Document: Social Cost of Carbon Regulatory Impact Analysis Under Executive Order 12866*, released in February 2010.[66] 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. The abatement cost curves EPA used for their analysis of ACES did not go above $61. Therefore, it was not possible to assume a higher price range for the Go-Getter Scenario, or one that is more in line with the upper estimates put forth by the Interagency Working Group.

C. UNCERTAINTIES FOR NON-ENERGY EMISSIONS

There are inherent limitations to assessing abatement achievable through emissions standards using marginal abatement cost curves, which may lead to the realization of different levels of emissions reductions. Nevertheless, we believe that EPA's marginal abatement cost curves represent the best available data at this time.

D. LANDFILLS

1. Base Case for Landfills

The ADAGE Model aggregates all residential methane emissions into one category. Therefore, we relied on the documentation for EPA's abatement cost curves, which provided estimates for 2010 (125.4 mmtCO_2e) and 2020 emissions (123.5 mmtCO_2e). We assumed that emissions would change in a linear manner between 2010 and 2020, and that the same rate of change would hold constant through 2030, so that in 2030 emissions would be 121.6 mmtCO_2e.

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

For landfills, all three scenarios assume that EPA and the states establish New Source Performance Standards for new and existing units in a manner that results in sector-wide abatement of methane emissions consistent with the cost-effective reductions identified in EPA's marginal abatement cost curves (as set out in EPA's analysis of ACES). Abatement at landfills is accomplished through methane capture and destruction. For simplicity, we assumed that relatively few new units would come online between 2010 and 2015, and thus do not model any reductions until 2016, the earliest expected date that performance standards could be in place for existing landfills. Table A1 shows the level of GHG emissions reductions achieved under the three scenarios, and the corresponding cost per ton from the EPA analysis.

3. Uncertainties for Landfills

In this section, we model the impact of NSPS on new and existing landfills. EPA's marginal abatement cost curves do not differentiate between new and

TABLE A1. Methane Emissions from Landfills

	CARBON PRICE ($/TON$CO_2$e)	2016–2030 REDUCTION (PERCENT)	EMISSIONS (MMTCO_2e)		
			2010	2020	2030
Base Case	—	—	125	123	122
Lackluster	5	44	—	68	68
Middle-of-the-Road	20	74	—	32	32
Go-Getter	61	74	—	32	32

existing units, and the curves that we employed here do not show any changes in abatement over time (from 2010 to 2020). 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 differently than is predicted by ADAGE, then base case emissions will change accordingly. Under the Lackluster and Middle-of-the-Road Scenarios, abatement is 74 percent, suggesting that the primary driver of future emissions will be the NSPS and not changes in the amount or type of waste sent to landfills.

E. COAL MINES

1. Base Case for Coal Mines

For the base case we relied on EPA's ADAGE model, which predicts that methane emissions will decrease from 60 mmtCO_2e in 2010 to 54 mmtCO_2e in 2030.

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

All coal mine methane scenarios assume that EPA and states establish New Source Performance Standards for new and existing coal mines in a manner that results in sector-wide abatement of methane emissions consistent with the reductions identified as cost-effective in EPA marginal abatement cost curves. Reductions at coal mines can be achieved through degasification and pipeline injection or oxidation of ventilation air methane, for example. For simplicity, we assumed that relatively few new units would come online between 2010 and 2015, and thus do not model any reductions until 2016, the earliest that performance standards could be in effect for existing coal mines. Table A2 shows the level of GHG emissions reductions achieved under the three scenarios, as well the corresponding costs per ton.

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 2006, abandoned coal mines account for approximately 8 percent of coal mine methane emissions.[67, 68] Abandoned mines pose significant challenges to enforcement of standards. Therefore, we assume that only the 92 percent of coal mine methane that comes from active mines is abated in response to NSPS. This is consistent with EPA's *Global Mitigation of Non-CO_2 Greenhouse Gases*, which derives the abatement curves based on reductions of methane emissions from active mines only.

3. Uncertainties for Coal Mine Scenarios

In this section, we model the impact of NSPS on new and existing coal mines. EPA's marginal abatement cost curves do not differentiate between new and existing mines, and the curves that we employed here do not show any changes in abatement over time (from 2010 to 2020). This means that the rate that new mines come into production should not affect the abatement rate. However, if production increases or decreases differently than is predicted by ADAGE, then base case emissions will change accordingly. Under all scenarios modeled methane was abated 86 percent, suggesting that the primary driver of future emissions will be the NSPS themselves and what percentage of mines are subject to them. There is uncertainty about what percentage of mines will be abandoned in future years. If that percentage falls below 8 percent, then emissions from this sector will decline beyond what is modeled here.

TABLE A2. Coal Mine Methane Emissions

	CARBON PRICE ($/TON$CO_2$e)	2016–2030 REDUCTION (PERCENT)	EMISSIONS (MMTCO_2e)		
			2010	2020	2030
Base Case	—	—	60	54	54
Lackluster	5	86	—	11	11
Middle-of-the-Road	20	86	—	11	11
Go-Getter	61	86	—	11	11

TABLE A3. Methane Emissions from Natural Gas Systems

	CARBON PRICE ($/TONCO$_2$e)	2016–2030 REDUCTION (PERCENT)	EMISSIONS (MMTCO$_2$e)		
			2010	2020	2030
Base Case	—	—	112	133	149
Lackluster	5	9	—	132	148
Middle-of-the-Road	20	14	—	114	128
Go-Getter	61	27	—	97	109

F. NATURAL GAS SYSTEMS

1. Base Case for Natural Gas Systems

For the base case we relied on EPA's ADAGE model, which predicts that methane emissions will increase from 112 mmtCO$_2$e in 2010 to 149 mmtCO$_2$e in 2030.

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

All scenarios assume that EPA and the states establish New Source Performance Standards for new and existing natural gas systems in a manner that results in sector-wide abatement of methane emissions consistent with the marginal abatement cost curves found in EPA's analysis of ACES. Realizing that this level of reductions would likely require some equipment changes and upgrades, changes in operational practices, and direct inspection and maintenance, we did not model any reductions until 2016, the earliest date we expect performance standards for existing distribution facilities could be in place. The adjacent table shows the level of GHG emissions reductions achieved under the three scenarios and the corresponding cost per ton.

3. Uncertainties for Natural Gas Systems

In this section, we model the impact of NSPS on new and existing natural gas systems. EPA's marginal abatement cost curves do not differentiate between new and existing natural gas systems, and the curves that we employed here do not show any changes in abatement over time (from 2010 to 2020). This means that the rate that new units replace old units may not significantly affect the abatement rate. If production increases or decreases differently than is predicted by ADAGE, then base case emissions will change accordingly. Because the abatement rate for this sector is modest under all three scenarios, changes in production by natural gas systems can have a noticeable impact on sector-wide emissions.

G. NITRIC AND ADIPIC ACID MANUFACTURERS

1. Base Case for Nitric and Adipic Acid Manufacturers

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 for 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.[69]

The ADAGE projections do not provide line-item emissions estimates for N_2O emissions from nitric

TABLE A4. N_2O Emissions from Adipic Acid Manufacturers

	CARBON PRICE ($/TONCO$_2$e)	2016–2030 REDUCTION (PERCENT)	EMISSIONS (MMTCO$_2$e)		
			2010	2020	2030
Base Case	—	—	8	10	11
Lackluster	5	96	—	0.4	0.4
Middle-of-the-Road	20	96	—	0.4	0.4
Go-Getter	61	96	—	0.4	0.4

TABLE A5. N_2O Emissions from Nitric Acid Manufacturers

	CARBON PRICE ($/TON$CO_2$e)	2016–2030 REDUCTION (PERCENT)	EMISSIONS ($MMTCO_2$e)		
			2010	2020	2030
Base Case	—	—	16	17	19
Lackluster	5	89	—	2	2
Middle-of-the-Road	20	89	—	2	2
Go-Getter	61	89	—	2	2

and adipic acid manufacturers. Therefore, we developed base case emissions projections based on the 2010 and 2020 projections provided in the marginal abatement cost curve documentation for the ACES analysis. To formulate 2030 projections, we calculated the rate of change between 2010 and 2020, and applied the rate to all years from 2006 through 2030. Using this approach, we estimate that emissions of N_2O from nitric acid manufacture will increase from 8 mmtCO_2e in 2010 to 11 mmtCO_2e in 2030, while emissions from adipic acid manufacture will increase from 16 mmtCO_2e in 2010 to 19 mmtCO_2e in 2030.

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

All three scenarios assume that EPA and the states establish New Source Performance Standards for new and existing units in a manner that results in sector-wide abatement of N_2O emissions consistent with the marginal abatement cost curves found in EPA's analysis of ACES. 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.[70]

For simplicity, we assumed that relatively few new units would come online between 2010 and 2015, and thus do not model any reductions until 2016, the earliest expected date that performance standards could be in place for existing manufacturing facilities. Tables A4 and A5 show the level of GHG emissions reductions achieved for each type of facility under all scenarios together with the corresponding per metric ton cost for reductions.

3. Uncertainties for Nitric and Adipic Acid Manufacturers Scenarios

In this section, we model the impact of NSPS on new and existing units. EPA's marginal abatement cost curves do not differentiate between new and existing units, and the curves that we employed here do not show any changes in abatement over time (from 2010 to 2020). This means that the rate that new units replace old units should not affect the abatement rate. However, if production increases or decreases differently than is predicted by ADAGE, then base case emissions will change accordingly. Under all scenarios modeled N_2O was abated 96 percent from adipic acid manufacturers and 89 percent from nitric acid manufacturers. This suggests that the primary driver of future emissions will be the NSPS themselves and not changes in production.

H. HYDROFLUOROCARBONS (HFCs)

1. Base Case for Hydrofluorocarbons

Our base-case projections of non-energy CO_2 emissions and other non-CO_2 gases come from EPA's ADAGE Reference Scenario.[71] As stated previously, ADAGE projects emissions in 5-year intervals from 2010 to 2050. To estimate emissions between those intervals, we applied a linear rate of change between intervals. Emissions for 2006 to 2009 were estimated by applying the same rate of change observed from 2010 to 2015. Emissions for 2005 (119.3 mmtCO_2e) were obtained from EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2008*.[72] According to ADAGE projections, HFC emissions will increase from 169 mmtCO_2e in 2010 to 279 mmtCO_2e in 2030. Emissions of HFCs have been increasing due to the phase out 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.[73]

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

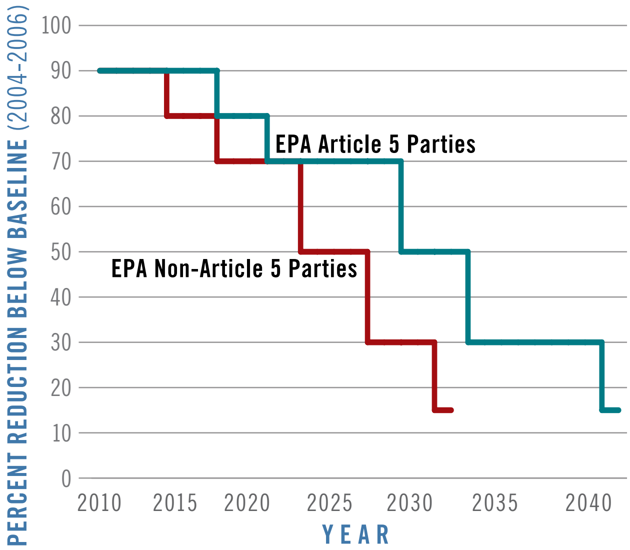
On April 30, 2010, EPA filed a joint proposal with Canada and Mexico to amend the Montreal Protocol. That proposal calls for a ramp-down of emissions of high global warming potential (GWP) HFCs, so that in 2033 the U.S. and other non–Article 5 Parties' production and consumption of HFCs on a GWP-weighted basis are 15 percent of base case emissions. The base case is defined as average production and consumption from 2004–2006. The proposal puts forth a separate, slightly less aggressive reduction schedule for developing countries listed under Article 5 of the Montreal Protocol. EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2008* does not contain 2004 emissions. Because the emissions inventory shows a clear upward trend in emissions for the available data points in 2000 (103.2 mmtCO_2e), 2005 (119.3 mmtCO_2e), 2006 (121.8 mmtCO_2e), and 2007 (127.4 mmtCO_2e), we applied EPA's emissions reductions schedule to reported 2005 emissions only.

EPA's authority for regulating emissions of ozone-depleting substances comes from Title VI of the Clean Air Act. The phase-down of HFCs could be implemented through its Significant New Alternatives Policy (SNAP) program. The SNAP program implements section 612 of the 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.[74] In its report, *Analysis of HFC Production and Consumption Controls*,[75] EPA notes that the most promising options for reducing HFC consumption through the SNAP program include:

- "Substituting HFCs with low- or no-GWP substances in a variety of appliances (where safety and performance requirements can be met);
- Implementing new technologies that use significantly lower amounts of HFCs; and
- Various process and handling options 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. Because the reduction schedule proposed by EPA achieves relatively large reductions from the base case, and because they have signaled a strong intention to pursue this long-term path, we assume that EPA enforces the reduction schedule for non–Article 5 Parties for all three scenarios in this analysis.[76]

FIGURE A12. **GWP-weighted HFC Reductions for Article 5 and non–Article 5 Countries** (percent of HCFCs and HFCs production and consumption compared to average emissions from 2004 to 2006)



3. Uncertainties for Hydrofluorocarbons

Baseline uncertainties will impact the observed reductions, but should not impact actual emissions, which are based on a reduction from historical emissions. Because the reduction schedule is based on consumption (production plus imports), there is uncertainty regarding the actual emissions in any given year.

VIII. Industry

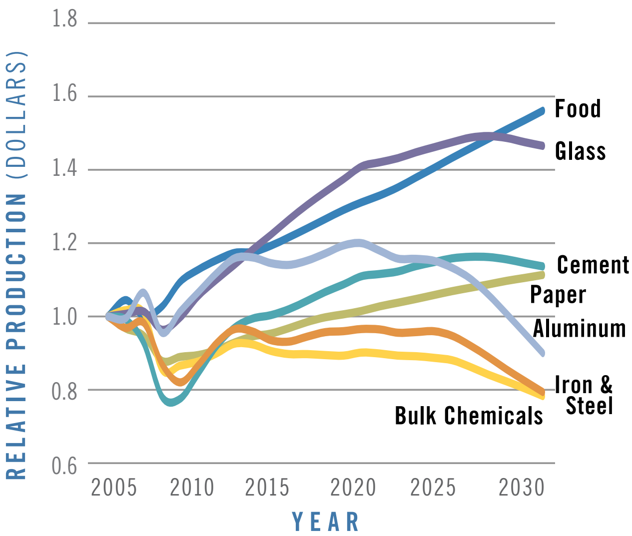
A. MANUFACTURING

1. Base Case for Manufacturing

Baseline emissions for energy-related CO_2 emissions come from the EIA's AEO2009. We relied on tables 35–44 for the Middle-of-the-Road and Go-Getter Scenarios, and the spreadsheet "indusa,"[77] for the Lackluster Scenario. "Indusa" is a more detailed model output provided by EIA upon request.

Under the AEO2009 Reference Scenario, industrial production projections are varied. Food, paper, glass, and cement manufacture all have upward trends in production, so that 2030 production exceeds production in 2006. Meanwhile, the AEO projects reduced production of aluminum, bulk chemical, and iron and steel production in 2030, as compared to 2006.

FIGURE A13. Relative Changes in Production from 2006 for Major Manufacturing Sectors, Expressed in Dollar Value of Shipments

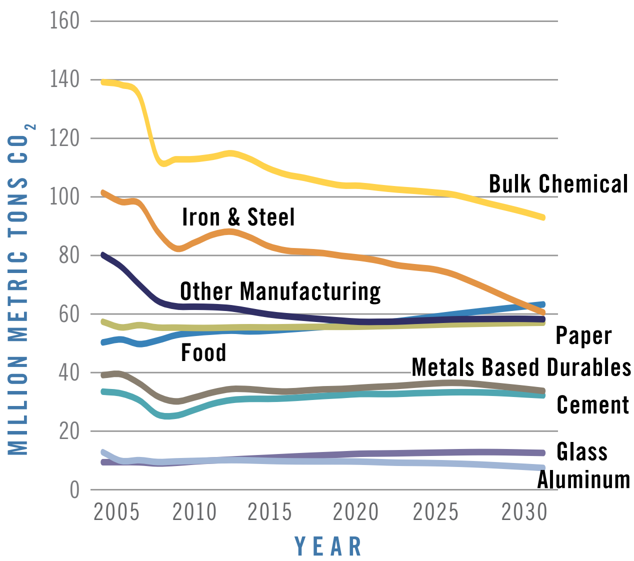


Note: "Metals based durables" and "other manufacturing" are not included here because they include a number of sub-sectors. While those sectors can be summed for purposes of depicting CO_2 emissions, it is inappropriate to sum their output (expressed as dollar value of shipments).

The AEO builds considerable energy efficiency gains in overall process efficiency into the base case.[78] Boiler efficiency, however, remains relatively constant over time. The AEO2009 is built using the National Energy Modeling System (NEMS). NEMS assumes that gas burners have heat rates of 1.25 (80 percent efficiency) and oil burners have heat rates of 1.22 (82 percent efficiency), in accordance with the Energy Policy Act of 1992. Cogeneration units experience a steady increase in their efficiency through 2030.

Overall emissions from the manufacturing sector fall from 523 mmtCO_2e in 2006 to 418 mmtCO_2e in 2030. This is largely driven by reductions in the bulk chemical and iron and steel industries. More detailed sector breakdowns are depicted in Figure A14.

FIGURE A14. Carbon Dioxide Emissions from Fossil Fuel Combustion at Manufacturing Facilities



Note: Metals based durables include: fabricated metal products, machinery, computers, transportation equipment, and electrical equipment. Other manufacturing includes: wood products, plastics, and the balance of manufacturing.

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 can be obtained by replacing an existing boiler with a CHP unit.[79]

For the Lackluster Scenario, we assume that EPA and the states establish New Source Performance Standards for new and existing units. 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 business-as-usual projections. This was modeled as a 10 percent reduction in fuel use across all units and fuel types in the manufacturing sector, which includes: food, paper, bulk chemical, glass, cement, iron and steel, aluminum, metals based durables, and other manufacturing.[81] A comparable level of emissions reductions could be achieved through a variety of combinations of new unit and existing unit standards. Since in the early years few new units are expected, for simplicity we model these reductions starting in 2016 to account for the 6-year time lag for developing NSPS for existing units.

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

According to NEMS support documentation for the AEO2009, industrial boilers only consume 29 percent of manufacturing heat and power energy consumption, excluding byproduct fuels.[81] Therefore, in the Middle-of-the-Road Scenario, we assume that EPA devises performance standards that account for the entire industrial facility, not just the emissions sources. Instead of merely capturing boiler efficiency opportunities, a 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 NSPS than EPA has implemented in the past, but such an approach is under discussion in the Climate Change Working Group of the Clean Air Act Advisory Committee.[82] It could be accomplished by incorporating output-based emissions rates in new NSPS standards for industry categories under section 111 of the Clean Air Act and/or through a cap-and-trade program for industry that rewards improvements in emissions per unit of output.

In order to gauge the additional reductions achievable through process efficiency improvements beyond those included in the AEO2009, we relied on the Department of Energy (DOE) commissioned study, *Scenarios for a Clean Energy Future* (CEF). The CEF study examines the effect of a suite of voluntary policies on reducing industrial emissions below what was otherwise predicted in the AEO2009. In the CEF, two different policy implementation scenarios are analyzed: a moderate and advanced scenario. The CEF advanced scenario includes 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 $17 per ton of carbon dioxide.[83] This price could be realized through the establishment of a cap-and-trade program for existing sources under section 111(d) of the Clean Air Act, or integrated into the development of sector-appropriate emissions rates that are output-based.

While the CEF study was completed in November 2000 (and based on the AEO 1999), in *Real Prospects for Energy Efficiency in the United States*, 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." For our Middle-of-the-Road Scenario, we applied the CEF reduction estimates for 2010 and 2020 to years 2020 and 2030, to provide the sector with time to turn over stock and adopt improved efficiency measures at existing facilities. We assumed that reductions commenced in 2016 due to the time lag for establishing standards on existing units through section 111(d), and that they increase linearly until 2020. We also assume a linear rate of change between the emissions reductions modeled in 2020 and 2030. For this scenario, we did not need to independently calculate unit turnover as it is already built into the CEF reduction scenario. However, it is should be noted that the CEF assumed a slightly higher unit retirement rate than is incorporated into the AEO2009.

The CEF's consideration 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 our model. Since this study was published, there have been other analyses that 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 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 may be some inconsistencies. Still, for purposes of these studies, state of the art/best practice is generally defined as the lowest energy consuming option in current practice. The definition of practical minimum varies somewhat between the energy required "assuming application of reasonable technologies such as heat recovery, batch preheating, etc."[84] and the "energy required for a typical plant after deployment of new process technologies developed through applied research and development."[85]

Table A6 compares the bandwidth energy reductions to those obtained under the Middle-of-the-Road and Go-Getter Scenarios. For instance, our analysis

TABLE A6. Energy and CO_2 Intensity Improvements in the Manufacturing Sector

	ENERGY SAVINGS					MODELED CO_2 INTENSITY IMPROVEMENT 2030 VS. 2010 (TONS CO_2 FROM COMBUSTION/VALUE OF SHIPMENT)			
	WITH BEST PRACTICE (Bandwidth)	WITH PRACTICAL MINIMUM (Bandwidth)	AEO2009 2030 vs. 2010	CEF 2030 v BAU 2030	CEF+BAU 2030 v 2010	Base Case	Lackluster (10% efficiency gain all boilers)	Middle-of-the-Road (CEF)	Go-Getter (CEF + natrual gas emissions rate for new units)
Food Products	NA	NA	12%	17%	29%	16%	21%	35%	39%
Paper	26%	39%	9%	6%	14%	18%	24%	43%	48%
Bulk Chemical	18%	71%	12%	18%	26%	9%	15%	23%	25%
Glass	35%	52%	6%	18%	18%	7%	8%	14%	15%
Cement	NA	NA	12%	20%	23%	13%	13%	28%	40%
Iron & Steel	3%	31%	21%	15%	30%	24%	26%	30%	36%
Aluminum	NA	NA	14%	18%	32%	13%	14%	21%	24%

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.[86]

finds that glass and paper manufacturers reduce their energy consumption by about one-half the level that would be achieved if they all employed the best practices identified in their respective bandwidth studies. Meanwhile, we predict that the bulk chemical sector reduces energy intensity more than current best practices, but significantly less than the bandwidth's practical minimum. Our projected energy reductions obtained from iron and steel are nearly as great as the bandwidth's practical minimum (which is not expected to be technically feasible without additional R&D), raising questions about the comparability between the bandwidth study findings for the iron and steel industry and our conclusions based on 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.[87] Furthermore, an American Iron and Steel Institute study, *Saving One Barrel of Oil per Ton,*[88] sets an industry-wide goal of reducing energy-use per ton of steel production by 39 percent in 2025. Due to this lack of consensus in the available literature, we did not adjust the iron and steel numbers from those found in the CEF.

4. Go-Getter Scenario for Manufacturing

In the Go-Getter Scenario, we again assume that EPA captures efficiencies in the entire industrial process by establishing equipment efficiency standards, sector-wide benchmark standards, or a cap-and-trade program for industry. However, we also assume that EPA establishes emissions standards for all new combustion sources (not just boilers) through New Source Performance Standards, and that those standards achieve reductions consistent with burning natural gas. This could be accomplished through co-firing of biomass, fuel switching, carbon capture and sequestration, or built into a CO_2 cap reduction schedule. We applied the CEF emissions reduction improvements in the same manner as the Middle-of-the-Road Scenario.

The AEO2009 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. Since this scenario is based on the CEF study, we employed the retirement rates found in the CEF, which are higher than those used in the AEO2009. The AEO does not build discrete industrial units, but instead considers increases and decreases in total supply to correspond to the building and shutting down of discrete (and very small) units. Thus, new units were built to account for incremental increases in production, and to account for the annual incremental retirement of units. Our modeling of new unit development is somewhat simplified and can lead to the over-deployment 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 our turnover was based. Our model did not build out new units if it projected that sector production would result in surplus supply within seven years of new unit construction. Seven years was chosen as it parallels the AEO2009 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

We calculated the base case emissions for energy-related CO_2 emissions using EIA's AEO2009 in a manner identical to that used for the rest of the industrial sector. See section VIII.A.1 for more information.

In the Middle-of-the-Road and Go-Getter Scenarios, we also reduced emissions of non-energy CO_2 emissions, or process emissions from the calcination of limestone. In our analysis, we relied on ADAGE for our 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. Because our Middle-of-the-Road and Go-Getter Scenarios reduce process emissions for cement, we developed our own projections. We determined the percentage of industrial process CO_2 emissions attributable to cement production in 2008 using EPA's 2010 *Inventory of Greenhouse Gas Emissions and Sinks*[89] and multiplied this by the AEO's 2008 projections. We then multiplied 2008 emissions by the percent change in cement output for all subsequent years, as obtained from Table 39 of the EIA's AEO2009, *Cement Industry Energy Consumption*. Using this approach, we estimate that process emissions will increase from 31 mmtCO_2 in 2010 to 45 mmtCO_2 in 2030. This methodology is viable because the AEO2009 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), the AEO2009 does not include this requirement because the proportion of mineral component is not specified in the legislation or subsequent regulations.[90]

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. 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, the AEO2009 assumes that no new wet kilns are built and that all new cement plants are dry kilns,[91] making this comparison less relevant for purposes of our analysis. Therefore, for the Lackluster Scenario, we assume that EPA and the states establish New Source Performance Standards 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.

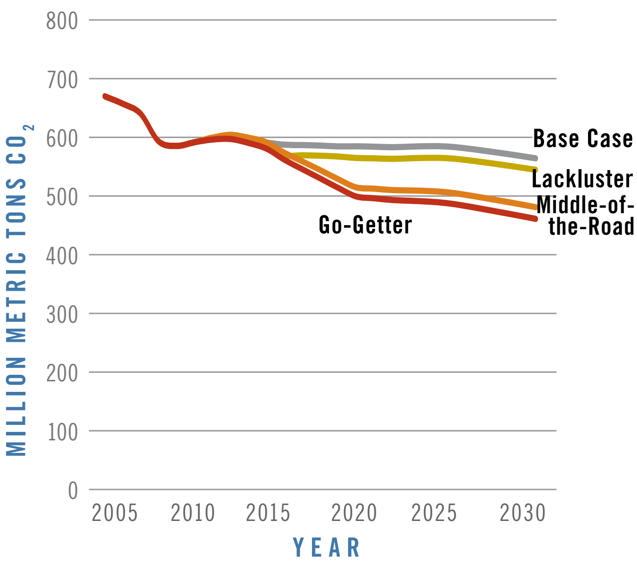
3. Middle-of-the-Road and Go-Getter Scenarios for Cement Kilns

According to the AEO2009, boilers are projected to only account for about 4 percent of total energy consumption at cement plants in 2010. 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 both combustion and process emissions. This could be accomplished through output-based emissions rate standards, or through the establishment of a cap-and-trade program. 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 a carbon dioxide cap ramp-down schedule.

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 is that for the cement sector we also included reductions in process emissions through greater use of blended cements. Applying CEF reduction percentages leads to reductions in CO_2 process emissions of 4 percent in 2020 and 13 percent in 2030. CO_2 emissions reductions are detailed in Figure A15.

FIGURE A15. Cumulative Manufacturing CO_2 Emissions from Fossil Fuel Combustion and Process Emissions Under All Scenarios



C. UNCERTAINTIES FOR MANUFACTURING AND CEMENT KILNS

There is considerable uncertainty in industrial unit turnover. Greater turnover could lead to more significant reductions depending on the actual standards set. Lower turnover would lead to fewer reductions.

There is also considerable uncertainty about the long-term production forecast for each manufacturing sub-sector. Increased production beyond what is modeled in the AEO2009 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 NSPS. 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 our analysis provides a sense of the range of reductions achievable through federal authority given the assessments currently available.

D. PETROLEUM REFINERIES

1. Base Case for Petroleum Refineries

Base case emissions came from Table 34 of the AEO2009 *Refining Industry Energy Consumption*, and predict that CO_2 emissions from combustion will increase from 256 mmtCO_2 in 2010 to 308 mmtCO_2 in 2030. Reductions in the refinery sector come from demand reductions and refinery efficiency improvements. As a simplifying assumption when calculating the refinery emissions reductions from decreased refinery product demand, we treated all refinery outputs as though their production required the same relative energy input, and thus 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 U.S.-based refineries. Our base case assumptions for the projected relative contribution of each refinery product for years 2006–2030 comes from Table 11 of the AEO2009, *Liquid Fuels Supply and Disposition*, and was expressed in million barrels per day.[92] The relative reduction in each refinery product was based on transportation scenario outputs and the relative contribution from each transportation sector in 2008, as reported in EPA's 2010 *Inventory of Greenhouse Gas Emissions and Sinks*.[93]

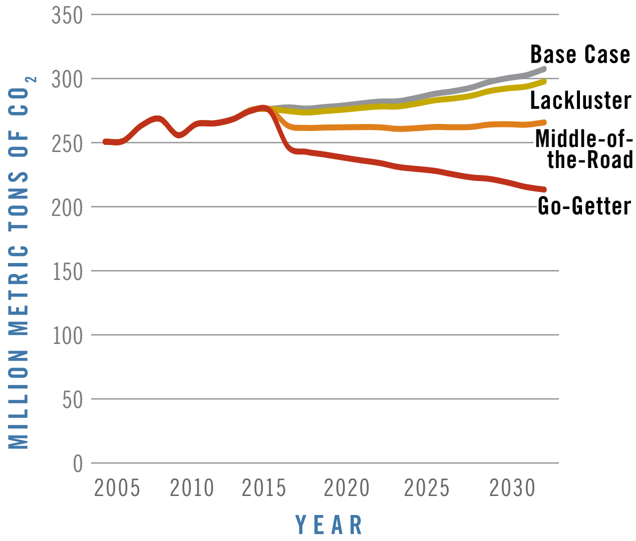
2. The Lackluster, Middle-of-the-Road and Go-Getter Scenarios for Petroleum Refineries

In all scenarios, we assume that emissions from refineries are reduced from (1) demand reductions caused by emissions standards for vehicles and industry; (2) demand reductions from energy efficiency standards for home appliances; and (3) New Source Performance Standards for new and existing units. In the Advanced Notice of Proposed Rulemaking, EPA concludes that competitive 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.[94] 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 more than 35 percent energy savings are achievable within these five major processes using existing "best practices and state-of-the-art technologies under real world conditions," and that "plant-wide refinery energy savings potential is usually found to be around 30 percent."[95]

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. The specific efficiency improvements built into the refinery module of the AEO2009 are confidential, making it impossible to examine the specific efficiency improvements built into its projections. However, according to Table 34, *Refining Industry Energy Consumption*, the total energy consumption per unit of refinery input remains relatively constant from 2010 through 2030. This suggests that it may be challenging to get additional efficiency improvements beyond what is already included in the AEO2009.

Given the lack of access to the data underlying the AEO2009 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 our reduction scenarios are based on the lower range of estimates provided by EPA in the ANPR. For the Go-Getter Scenario, we assumed EPA and the states would require existing units to reduce emissions 10 percent below future projected levels beginning in 2016 through New Source Performance Standards. This is equal to the lower range for existing units provided by EPA. Maintaining this level of reduction through 2030 would likely require a periodic updating of the standard. For the Middle-of-the-Road Scenario, we assumed that EPA and the states 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 and the states would establish standards for new and existing units, we only modeled reductions for existing sources. This is because the AEO2009 does not predict significant deployment of new refineries after 2011,[96] and any new development is expected to be largely offset by reductions in demand caused by our transportation scenarios.

FIGURE A16. Carbon Dioxide Emissions from Refineries Under All Scenarios



3. Uncertainties for Refineries Scenarios

The impact of heavier-crude slates is uncertain. It is also not entirely clear what efficiency improvements have been built into the AEO2009 base case for refineries. Little unit turnover is projected and this could change, making our emissions reductions projections too low. Under the scenarios we considered, the primary source of emissions reductions in 2030 was reductions in demand, and not NSPS for refineries. Thus, actual refinery emissions will vary based on actual fuel economy standards, fuel content standards, and changes in vehicle miles traveled.

IX. State Scenarios

A. MODELING APPROACH FOR STATE SCENARIOS

In contrast to the bottom-up approach utilized to project emissions from various sectors under federal regulatory scenarios, for state actions we employed a top-down approach. Analysis of existing regulatory authorities in each of the 50 states was beyond the scope of this effort. Instead, we examined announced actions, which have been made by 25 states. These announced actions were put into three categories:

(1) state legislation with mandatory or advisory emissions reductions targets; (2) executive orders issued by governors in the states calling for economy-wide emissions reductions; and (3) state announcements of intent to participate in one of two economy-wide regional cap-and-trade programs. We constructed our Lackluster, Middle-of-the-Road, and Go-Getter Scenarios around each of these three categories of announced actions.

The top-down approach has some important limitations as compared to the bottom-up approach employed for federal actions. First, advisory targets in legislation and executive orders do not have the force of mandatory law. In fact, we note that in many states additional legislative action will be required before the emissions targets can be achieved. Second, because legislative action may be required in addition to gubernatorial resolve, upcoming elections are likely to shift the political landscape in many of the 25 states assumed to take action, creating additional uncertainty around potential reductions through state action.

Despite the uncertainties inherent in the top-down approach to calculating potential reductions through state action, the three state scenarios shed some light on the overall potential of announced state actions. Because it may be necessary for states to continue to contribute as partners alongside the federal government in the drive to reduce emissions, it is helpful to understand that when a number of states act to reduce emissions, significant reductions can occur.

B. BASE CASE FOR STATE SCENARIOS

We constructed a "business-as-usual" case for the state scenarios using multiple data sources, because we found no single source that reported annual estimates of total GHG emissions[97] for each U.S. state and the District of Columbia over the entire period of analysis (1990–2030). We developed our own base case for the years 1990, 2000, 2001, and 2005–2030 using the following four data sources:

- The EIA's *Annual Energy Outlook (AEO) 2009 – Updated Reference Case*, which captures all state and federal regulations that are "defined sufficiently to be modeled" as of November 5, 2008;[98]
- EPA's ADAGE Reference Case scenario from June 2009 – *The United States Environmental Protection Agency's Analysis of H.R. 2454 in the 111th Congress, the American Clean Energy and Security Act of 2009*;[99]
- The EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2008*;[100] and
- WRI's Climate Analysis Indicators Tool (CAIT-US, v.4.0).[101]

The specifics regarding how each source was used (including related calculations) to produce estimates of total GHG emissions by state for 1990, 2000, 2001, and 2005–2030 are described below.

1. CO_2 Emissions from Energy in the States

Carbon dioxide emissions associated with fossil fuel combustion came from EIA's AEO2009, which contains projections from 2006 through 2030 for nine, non-overlapping geographic regions[102] (as well as by economic sector).[103]

2 Non-energy CO_2 and Non-CO_2 Emissions

The ADAGE Reference Case scenario contains emissions projections by greenhouse gas and by fuel/sector from 2010 through 2050 at 5-year intervals. All estimates of non-energy-related CO_2 and non-CO_2 emissions—methane (CH_4), nitrous oxide (N_2O), and "F-gas" (HFC, PFC, SF_6) emissions—for each year of available data (2010, 2015, etc., through 2030) were compiled directly from the EPA's *Analysis of the American Clean Energy and Security Act of 2009*.[104]

Estimates of emissions in intervening years (i.e., between reported totals; for example, 2011–2014) were linearly interpolated. Estimates of annual emissions prior to the start year of the ADAGE Reference Case (2010) but necessary to appropriately "match" with estimates of annual CO_2 emissions as noted above (i.e., 2006–2009) were linearly extrapolated. For example, the estimate for 2009 is the difference between totals for 2011 and 2010. Values for 2006–2008 were calculated using a similar method.

Once a 2006–2030 time series was established for all non-energy CO_2/non-CO_2 emissions and sources, U.S. totals were summed for each year. To allocate the calculated annual U.S. totals of non-energy CO_2 and non-CO_2 emissions on a regional basis (in order to "match" to the CO_2 emissions data from EIA), estimates of non-energy CO_2/non-CO_2 emissions for each of the nine regions for 2006–2030 were calculated by multiplying the national total for each year by the percentage of non-energy CO_2/non-CO_2 emissions attributable to each region. The regional percentage (contribution) was calculated as the multi-year (2005–2007) average based on estimates from

WRI's CAIT-US (v.4.0). While it is likely that regional contributions of non-energy CO_2 and non-CO_2 emissions will change over time, for the purposes of this study these estimates were held constant from 2006–2030.

3. Base Case by Region

Estimates of total GHG emissions for each of the nine regions and the United States from 2006–2030 were then calculated by summing the annual estimates of regional CO_2 from energy emissions and regional non-energy CO_2 and non-CO_2 emissions (i.e., the results described in the previous two sections).

4. Base Case by State

To provide estimates of annual GHG emissions for each U.S. state and the District of Columbia, three approaches were employed, depending on the reference case year:

(1) For the years 1990, 2000, 2001, and 2005, state totals are estimated by first calculating the percentage of national GHG emissions contributed by each state based on the CAIT-US data set and then multiplying that percentage by the annual total GHG emissions for each year, as reported in the EPA National GHG Inventory.[106] This minor adjustment is made to compensate for the small difference in national GHG estimates between the CAIT-US data set and the EPA National Inventory. It enables a more appropriate comparison of state GHG emissions with the estimates based on the AEO2009 and ADAGE reference scenarios, as well as the composite reference case scenario approach described in the preceding sections.

(2) For 2006—the first year for which an annual GHG estimate based on the AEO2009 and ADAGE projections is available—the same calculation is applied as described in approach 1, except that calculated state percentages are multiplied by the 2006 total U.S. emissions estimate from the region-based reference case (see preceding section) to produce state totals.

(3) Individual state projections from 2007–2030 were then calculated by taking the annual growth rate for the corresponding region in the region-based reference case and multiplying by the previous year's estimate. For example, the total for Alabama for 2007 is calculated by taking the calculated percentage growth from 2006 to 2007 in the East South Central region of the region-based reference case and multiplying by the 2006 estimated value (as calculated in approach 2). This process is then applied to all years through 2030.

C. LACKLUSTER, MIDDLE-OF-THE-ROAD, AND GO-GETTER SCENARIOS FOR STATES

To date, state economy-wide GHG reduction targets have been put forth through three distinct mechanisms: enacted legislation, governor-issued executive orders, and state participation in a regional cap-and-trade program. These measures were combined to create three scenarios as follows:

- Lackluster: legislation only;
- Middle-of-the-Road: legislation plus executive orders; and
- Go-Getter: legislation, executive orders, and participation in a regional cap-and-trade program.[106]

Existing state climate targets were identified using the National Association of Clean Air Agencies' State Greenhouse Gas Actions database[107] and the Pew Center on Global Climate Change's State Action Map.[108] Data for policies relevant to this analysis (i.e., enacted legislation, executive orders, and regional cap-and-trade program participation) were categorized according to "policy type." A complete listing of the state targets modeled in this study is available in Table A7.

A few exceptions were made to the general protocol for modeling state policies, particularly regarding the inclusion of states participating in regional cap-and-trade programs, and are reflected in Table A7:

- **Western Climate Initiative (WCI) partners.** Most states that participate in the WCI have adopted legislation or executive orders formalizing their commitments under the cap-and-trade program. In these instances (AZ, CA, NM, OR, and WA), the legislation or executive order is modeled in the Lackluster or Middle-of-the-Road Scenario, respectively. In states that have not formalized their participation in the WCI through some other policy means (MT and UT), the GHG reduction goals of the state under the WCI are modeled in the Go-Getter Scenario only.

- **Regional Greenhouse Gas Initiative (RGGI) states.** The impact of the RGGI on total GHG emissions is already included in the AEO2009.[109] Because the impacts of RGGI are expected to be modest, we do not adjust state reduction targets established through legislation or executive order to account for reductions already anticipated under RGGI.

TABLE A7. State emissions reduction targets

STATE	ENACTED LEGISLATION	EXECUTIVE ORDERS	REGIONAL CAP-AND-TRADE PROGRAM	NOTES
Arizona		2000 levels by 2020, 50% below 2000 levels by 2040		
California	1990 levels by 2020	2000 levels by 2010, 1990 levels by 2020, 80% below 1990 levels by 2050		For modeling of California's EO, 2008-2009 estimates were linearly interpolated between 2007 and 2010
Connecticut	10% below 1990 levels by 2020, 80% below 2001 levels by 2050			
Florida		2000 levels by 2017, 1990 levels by 2025, 80% below 1990 levels by 2050		
Hawaii	1990 levels by 2020			
Illinois			Midwestern Accord[a]	
Iowa			Midwestern Accord[a]	
Kansas			Midwestern Accord[a]	
Maine	1990 levels by 2010, 10% below 1990 levels by 2020, 75-80% below 2003 levels in the long-term			For 2008-2009 estimates, a linear interpolation was applied between 2007 and 2010. A target of 75% below 1990 levels was applied to 2050
Maryland	25% below 2006 levels by 2020			
Massachusetts	10-25% below 1990 levels by 2020, 80% below 1990 levels by 2050			A target of 10% below 1990 levels was applied to 2020
Michigan		20% below 2005 levels by 2025, 80% below 2005 levels by 2050	Midwestern Accord[a]	
Minnesota	15% below 2005 levels by 2015, 30% below 2005 levels by 2025 and 80% below 2005 levels by 2050		Midwestern Accord[a]	
Montana			Montana's WCI target is 1990 levels by 2020	
New Jersey	1990 levels by 2020, 80% below 2006 levels by 2050			
New Mexico		2000 levels by 2012, 10% below 2000 levels by 2020, 75% below 2000 levels by 2050		
New York		80% below 1990 levels by 2050		

STATE	ENACTED LEGISLATION	EXECUTIVE ORDERS	REGIONAL CAP-AND-TRADE PROGRAM	NOTES
Oregon	No growth by 2010, 10% below 1990 levels by 2020, 75% below 1990 levels by 2050			"No growth" in 2010 was modeled as equivalent to 2009 estimated emissions
Utah			Utah's WCI target is 2005 levels by 2020	
Washington	1990 levels by 2020, 25% below 1990 levels by 2035, 50% below 1990 levels by 2050			
Wisconsin			Midwestern Accord[a]	

a. State is a participant in the Midwestern Greenhouse Gas Reduction Accord, which sets a program-wide reduction goal for each state of 20 percent below 2005 levels by 2020 and 80 percent below 2005 levels by 2050.

Note: U.S. states not listed in Table A7 do not currently have formalized GHG emission reduction targets in any of the three forms of policies examined here (and are therefore not applicable to this analysis). However, other state climate-related policies may exist.

To estimate the GHG emission reductions achieved from each state policy type listed in Table A7, the targets and timetables for relevant states were applied to the state reference cases (described above) by assuming that each state will meet the reduction goals established by legislation, executive order, or via a cap-and-trade program. For example, to model a state GHG emissions reduction goal of "10 percent below 1990 levels by 2020," the 2020 value in the state reference case would be recalculated as 10 percent of the 1990 state reference case value, and emissions totals for preceding years were then estimated by linearly interpolating between 2010 (the designated "start" year for this analysis) and the "target" year (in this example, 2020).

For state policies that include a single target year, interpolations were always made between the target year and 2010 (unless otherwise noted in Table A7). When states set intermediate goals, but not long-term goals (e.g., a 2020 target but no 2050 target), we assumed that GHG emissions would be held constant after the intermediate goals are reached. For policies that include more than one target year (e.g., a 2020 goal and a 2050 goal), a linear interpolation between target years was made in addition to the interpolation between the first target year and 2010.

Once targets for each state were applied to the state reference case, an annual total U.S. GHG emissions trajectory for each policy type from 2010–2030 was calculated as the sum of all state trajectories (states with GHG emissions targets and those that remained on a reference case trajectory).

D. UNCERTAINTIES FOR STATE SCENARIOS

The uncertainties inherent in the top-down approach to modeling state reductions are greater in magnitude than those sketched out above for the bottom-up federal measures. This is due to the fact that top-down legislation, executive orders, and gubernatorial announcements to participate in a mandatory cap-and-trade program depend on continued political resolve to obtain the necessary state legislative authority prior to enactment of rules. This resolve, in turn, is subject to change when new governors arrive in state capitals and the composition of state legislatures change. We have not undertaken an analysis of which state policies will require additional legislative action.

E. COMPARING STATE AND FEDERAL REDUCTIONS

To determine the reductions achievable through a combination of state and federal policies, we compared the reductions achieved through state policies to the reductions achieved through federal policies. We compared the Lackluster state scenario to the Lackluster federal scenario, the Middle-of-the-Road state scenario to the Middle-of-the-Road federal scenario, and the Go-Getter state scenario to the Go-Getter federal scenario. In each scenario, we applied to each state whichever emissions reduction scenario resulted in the greatest percentage of emissions reductions.

Appendix Endnotes

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