





**ISSUE BRIEF 3**

**ASSESSING THE COSTS OF  
REGULATORY PROPOSALS FOR  
REDUCING U.S. GREENHOUSE  
GAS EMISSIONS**

JOSEPH E. ALDY

## ASSESSING THE COSTS OF REGULATORY PROPOSALS FOR REDUCING U.S. GREENHOUSE GAS EMISSIONS

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### SUMMARY

Reducing greenhouse gas (GHG) emissions requires costly changes in behavior for firms and individuals. Various ways exist to measure these costs, but most economic analyses focus on changes in gross domestic product (GDP), prices, employment, and sometimes disaggregated impacts on particular sectors. Two recent studies by the Energy Information Administration (EIA) and the Massachusetts Institute of Technology (MIT) provide insights into the range of costs associated with recent proposals for limiting U.S. GHG emissions over the next several decades.<sup>1</sup> This issue brief further emphasizes impacts in 2015 both because nearer-term modeling results are more reliable, and hence more informative, and because this timeframe is most relevant for the current policy debate.

- A single measure of program stringency—average annual emissions allowed over the 2010–2030 timeframe—is used to facilitate comparisons across different regulatory scenarios. The studies reviewed here consider regulatory proposals that would limit average annual GHG emissions over the 20-year modeling period to actual emissions in the years 1992 and 1996 and forecast emissions for the years 2007, 2008, and 2015. To estimate costs for achieving these emissions limits, all of the studies assume a perfectly efficient, economy-wide cap-and-trade program.

<sup>1</sup> Specifically, we discuss results for the period 2010–2030, because this timeframe matches the available data from EIA and because of the inherent difficulty and uncertainty associated with modeling economic impacts over longer time horizons. This is in contrast to Issue Brief #2, where use of an extended (2010–2050) timeframe is appropriate in discussing longer-term environmental outcomes.

- The carbon dioxide (CO<sub>2</sub>)-equivalent price associated with GHG allowances increases over time in all analyses. In 2015, carbon prices are estimated at \$10 per metric ton CO<sub>2</sub> for the least stringent target and \$50 per metric ton for the most stringent target. By 2030, the least stringent target yields a carbon price of \$15 per metric ton, and the most stringent target \$100 per metric ton.<sup>2</sup>
- Energy prices increase along with CO<sub>2</sub> prices. Electricity prices increase 6–32 percent in 2015 relative to projected business-as-usual electricity prices for that year.
- The near-term GDP and employment impacts of the regulatory scenarios analyzed are modest. Modeled energy price increases are estimated to reduce overall economic output in 2015 by three-tenths to seven-tenths of 1 percent below the business-as-usual GDP forecast. Under the 2007 and 2015 average annual emissions cases, manufacturing employment is estimated to be 0.6–1.0 percent less than the business-as-usual employment forecast. This occurs against a backdrop of 2.9 percent annual growth in GDP and a baseline annual rate of decline in manufacturing employment of one-half of 1 percent over the same period.

The modeling analyses reviewed here show that the United States will bear costs in mitigating GHG emissions, but that these aggregate costs will be small in the context of overall trends. It is worth noting, however,

<sup>2</sup> All price and GDP data in this issue brief are presented in year 2005 dollars.

that all of these analyses assume a regulatory approach that produces cost-effective, economy-wide emissions abatement. Failure to promote least-cost abatement across all emissions sources could increase the costs of a domestic emissions mitigation policy.

## Introduction

Moving the United States off its current GHG emissions trajectory will require policies to change the behavior of firms and individuals. Changing behavior—such as inducing greater investment in and consumption of more energy-efficient and lower-carbon goods and services—imposes costs as firms and individuals take actions and make investments they would not otherwise undertake. A well-designed climate change policy achieves its goal by changing behavior and lowering GHG emissions in a manner that minimizes the disruption to the economy and the costs borne by firms and consumers. This issue brief examines the cost of domestic policies for reducing CO<sub>2</sub> and other GHG emissions based on existing analyses by EIA and MIT that attempt to model the economic impacts of various national emissions-mitigation scenarios.<sup>3</sup>

To provide a basis for understanding and comparing results across different analyses, we begin by reviewing common measures of cost and their key determinants. We then examine recent modeling results for different levels of emissions caps that roughly correspond to the range of targets contained in current legislative proposals. The issue brief concludes with a short discussion intended to put these cost estimates in context and comment on important cost-related issues that lie beyond the scope of existing models.

## Measures of Cost

Various measures of cost may prove informative in the design and implementation of a domestic climate change policy. This section briefly describes the most commonly used cost measures: change in the prices of energy- and emissions-intensive goods, change in economic output (GDP), and change in employment. The section concludes with a brief comment on the sectoral and demographic distribution of costs.

### Energy-Price Changes

A cap-and-trade program or tax on GHG emissions will increase the cost of electricity, gasoline, and other fuels consumers buy, as well as the cost of emissions-intensive goods. It does not matter whether emissions allowances in a cap-and-trade program are auctioned or freely given away; energy prices will increase.<sup>4</sup> These price increases can be translated to costs to households in considering likely impacts on household budgets. Energy price increases are likely to be of particular interest to those concerned about the effects of a climate change policy on the competitiveness of U.S. industry.

### GDP Changes

By changing the behavior of individuals and firms and by inducing them to reallocate their resources, a domestic regulatory regime for limiting GHG emissions will cause economic output to grow more slowly than it would without the policy. These impacts, quantified as GDP, are typically measured relative to a no-policy, business-as-usual forecast. Thus, the costs of GHG regulation generally do not produce absolute reductions in output (GDP) from current levels—rather, they result in lower output than would be expected in the future, absent regulation.

### Employment Changes

Higher prices for energy- and emissions-intensive goods can reduce the rate of employment growth through several channels. First, slower growth in the economy will slow the rate of job creation. Second, an increase in energy prices effectively increases the costs of virtually all goods, and this reduces the buying power of workers' wages. Effectively lower real wages could reduce the incentive for some individuals to work.

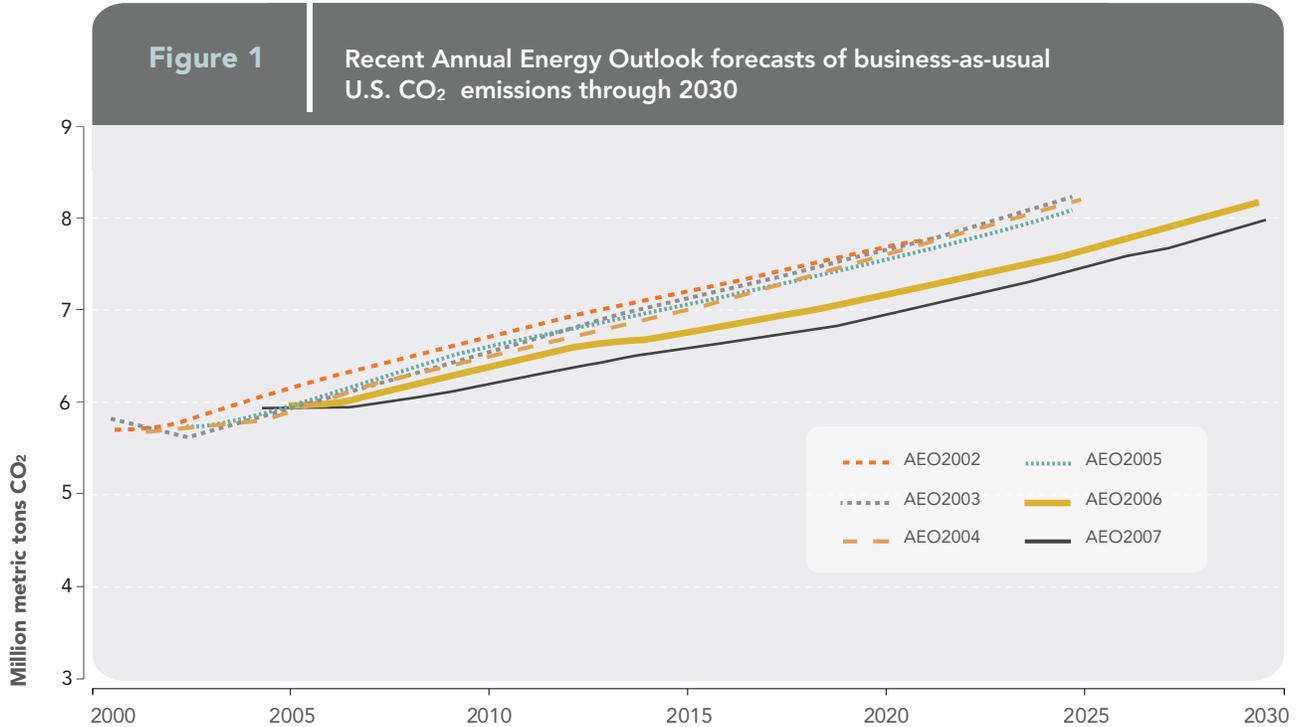
### Distribution of Costs

Climate policies could yield fairly modest changes in aggregate economic output or employment but impose substantial costs on specific industries or demographic groups. For example, output in emissions-intensive industries could decline much more than the average for U.S. industry as a whole, and low-income households could be more adversely affected by higher energy prices than typical households.<sup>5</sup>

<sup>3</sup> We focus on the EIA and MIT results as these have been the only analyses to consider a range of emissions-reductions targets consistent with recent U.S. policy proposals. Other studies, discussed in Issue Brief #2, have modeled scenarios that assume U.S. participation in a cost-effective global effort to stabilize atmospheric GHG concentrations at various levels.

<sup>4</sup> Electricity price increases may vary with the share of allowances auctioned versus freely allocated in states that have not deregulated their electricity markets and still require public utility commissions to set retail electricity rates.

<sup>5</sup> Industry-specific impacts are discussed in more detail in Issue Brief #7, which addresses competitiveness concerns.



## Key Determinants of Cost in Domestic Regulatory Programs

The cost of any effort to constrain GHG emissions in the U.S. economy will be a function of several factors, including the stringency of the policy relative to the business-as-usual emissions path, what opportunities exist for energy efficiency and fuel switching, which emissions sources are covered, whether emissions offsets are allowed under the policy, and how revenues from a carbon regulatory regime are used.

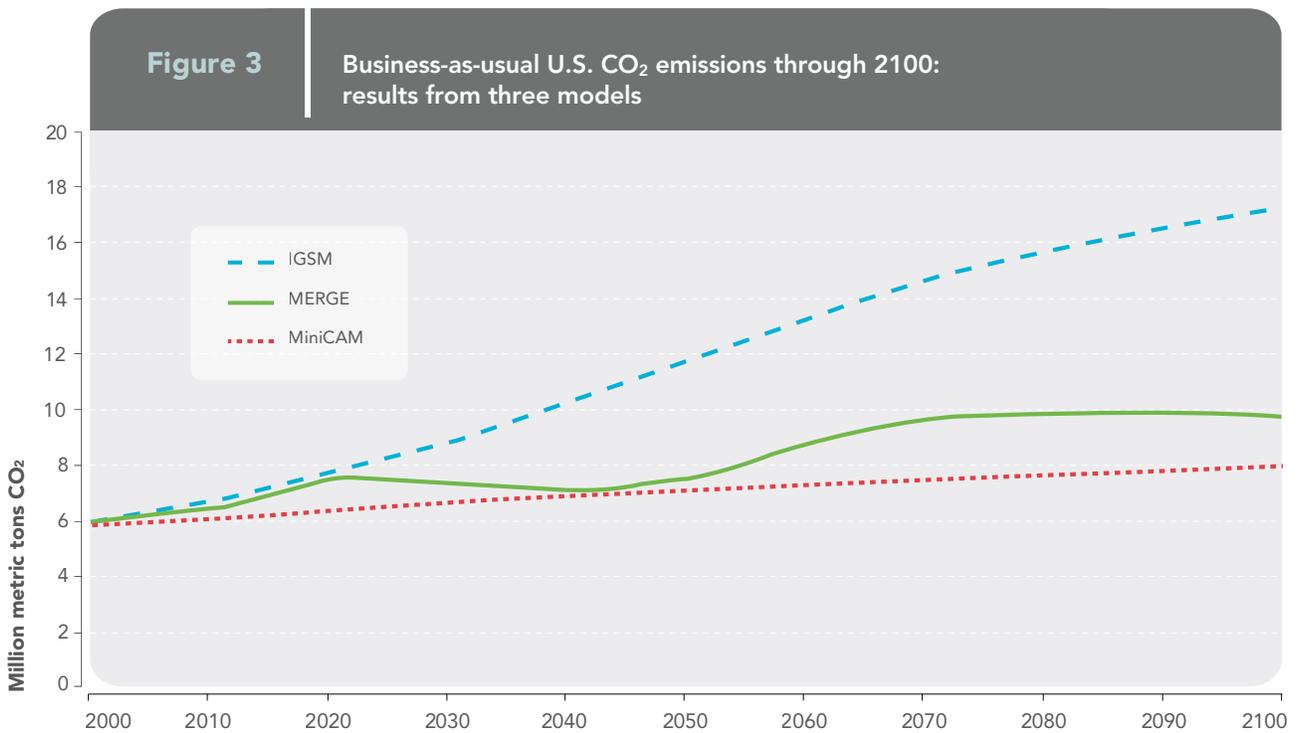
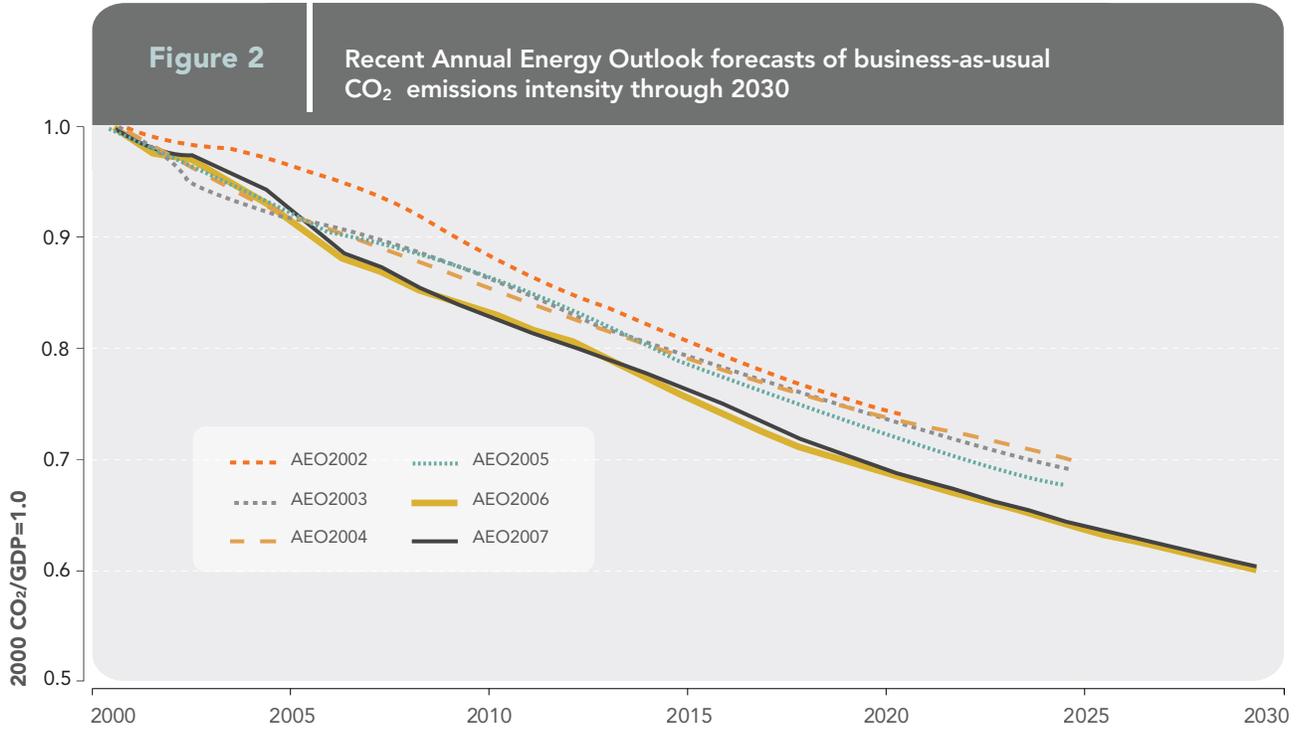
Abating GHG emissions imposes costs on society because individual consumption and firm investments must be changed to produce a shift away from the business-as-usual emissions path. Evaluating the cost of any GHG-reduction policy requires an explicit comparison between business-as-usual emissions and expected emissions under the new policy. Emissions forecasts, in turn, are driven by a variety of factors, including the rate of economic growth, population growth, and the effect of higher prices on the energy intensity of economic output and the carbon intensity of energy consumption.

EIA produces forecasts of business-as-usual CO<sub>2</sub> emissions as a part of its Annual Energy Outlook (AEO) report. Due primarily to a recent increase in energy prices, EIA's 2006 and 2007 AEO

reports have estimated lower business-as-usual emissions for the next 20-plus years than forecasts published earlier this decade (Figure 1). Specifically, EIA's current forecast for U.S. CO<sub>2</sub> emissions in 2010 shows a 7 percent increase over year 2000 emissions; by 2020, forecast emissions are 20 percent above year 2000 levels. These forecasts reflect an assumption that the emissions intensity of the economy—defined as the ratio of CO<sub>2</sub> emissions to GDP (see Figure 2)—will continue to decline. Specifically, the emissions intensity of the U.S. economy is forecast to decline 17.6 percent between 2000 and 2010 and 31 percent between 2000 and 2020, with an annual rate of change of 1.7 percent over the 2000–2030 timeframe. These more recent business-as-usual forecasts suggest that the estimated costs of achieving a given quantitative emissions cap or intensity-based target could be lower now than under the pre-2006 forecasts.

To complement the EIA forecasts, the U.S. Climate Change Science Program recently commissioned three models to estimate business-as-usual CO<sub>2</sub> emissions for the United States through 2100. Figure 3 presents results obtained from Pacific Northwest National Laboratory's MiniCAM model, Manne and Richel's MERGE model, and MIT's IGSM model (which includes the EPPA model reviewed below).<sup>6</sup>

<sup>6</sup> For more information about these models, refer to: <http://www.pnl.gov/gtsp/research/minicam.stm> (MiniCAM); <http://www.stanford.edu/group/MERGE/> (MERGE); and <http://web.mit.edu/globalchange/www/if.html> (IGSM).



The cost of moving from business as usual to a new, lower emissions path depends on the rate and magnitude of the required change. EIA studies of the economic impacts of implementing the Kyoto Protocol, for example, found high costs because, under some scenarios, the Protocol would have required dramatic emissions reductions over a relatively short period of time—such as reducing U.S. emissions 7 percent below 1990 levels by 2010. Policies that aim to take advantage of the natural timing of consumer and firm decisions—particularly those that allow dramatic emissions reductions to be delayed until the capital stock adjusts and new technologies are developed—can reduce the costs of achieving a particular long-term goal.

In general, the easier it is to switch to low- and zero-carbon energy sources, the lower the costs of mitigating CO<sub>2</sub> emissions. For example, a key driver of abatement costs in the electricity sector will be the cost of natural gas relative to coal. This is because switching from coal to natural gas—which generates 40 percent lower CO<sub>2</sub> emissions per unit of primary energy supplied than coal—is an important near-term mitigation strategy *if* additional natural gas is available at a reasonable price. Over time, the cost of abatement will also reflect the potential for nuclear and renewable sources of power to substitute for all fossil fuels in electricity generation, as well as the potential for carbon capture and storage technology to be incorporated in fossil-fuel generation plants. The scope for investment in energy-efficiency improvements also influences the estimated cost of mitigating emissions.

Program coverage is another important factor in determining costs. Most models assume that all sources in a given region are equivalently covered by an emissions trading program and produce cost estimates consistent with an economy-wide program. In reality, many policies, especially those focused only on large emitters, will exclude some fraction of mitigation opportunities. Sector-specific approaches have also been proposed—for example, emissions from electricity generation could be regulated separately from transportation sector emissions. The estimated costs of a fragmented and/or non-price policy<sup>7</sup> would be higher than model estimates of an integrated, economy-wide trading program because a fragmented and/or non-price policy generally precludes or limits the ability to substitute cheaper abatement options for more expensive forms of mitigation wherever those options exist.<sup>8</sup>

The inclusion of alternative compliance mechanisms will also influence program costs. For example, many policies propose using offsets—emission-reduction credits generated by sources not covered under an overall emissions cap—either domestically or internationally. Projects that reduce emissions from uncovered sources would be allowed to generate emissions abatement credits that could be used by covered sources to satisfy their obligations under either a cap-and-trade or tax regime. Allowing offsets typically lowers the estimated cost of achieving a particular emissions target for covered sources, but the availability, quality, and transaction costs associated with offsets are highly uncertain.<sup>9</sup> In many cases, modeling analyses of programs with offsets make alternative ad hoc assumptions to examine the sensitivity of cost estimates to various possibilities. In the discussion that follows, we focus on direct U.S. GHG emissions without considering the impact of offset provisions for either domestic biological sequestration or international projects.

A final issue in analyzing regulatory cost concerns the use of revenues from an emissions tax or from the sale of emission allowances under a cap-and-trade policy. Some program designs can generate revenues that would allow the government to offset existing taxes. For example, if the government implemented an emissions tax to stimulate private-sector emissions abatement, then revenues from the tax could allow taxes on labor or capital to be reduced in a revenue-neutral manner.<sup>10</sup> In some models, these changes can have aggregate consequences by increasing the overall efficiency of the tax system; that is, reducing taxes on labor or capital will increase the supply of those factors, raising GDP. Most economic modeling analyses show that such revenue recycling can reduce some, but not eliminate all, of the costs of an emissions tax or cap-and-trade program. In the discussion that follows, we ignore revenue-recycling effects.

## Overview of Major Domestic Regulatory Proposals

In the 109<sup>th</sup> Congress, a dozen bills were drafted that would impose mandatory climate-change regulations on part or most of the U.S. economy. As of the summer recess of the 110<sup>th</sup> Congress, in August 2007, more than a half-dozen cap-and-trade proposals had been introduced in the Senate, and several more in the House. Several bills have also proposed a tax on GHG emissions. It is beyond the scope of this issue brief to provide a detailed review of each of these proposals,

7 We use the term “non-price policy” to refer generically to traditional forms of regulation such as performance standards, technology mandates, etc. For further discussion of different regulatory approaches, see Issue Brief #5.

8 The cost implications of different policy-design decisions—such as program coverage and scope, flexibility, reliance on price signal vs. traditional regulation, etc.—are discussed in Issue Briefs #4, #5, and #10.

9 See Issue Brief #15 on offsets.

10 See further discussion in Issue Brief #5 (on different regulatory strategies) and Issue Brief #6 (on allocation).

## Abating GHG emissions imposes costs on society because individual consumption and firm investments must be changed to produce a shift away from the business-as-usual emissions path.

but this section will highlight a few key elements common to several of them.<sup>11</sup>

In the Senate, specific legislative cap-and-trade proposals have been introduced by Senators Bingaman and Specter, Boxer and Sanders, Feinstein and Carper, Kerry and Snowe, Lieberman and McCain, and Alexander (co-sponsored with Lieberman); on the House side, Congressmen Udall and Petri and Waxman have sponsored bills. All proposals except for the Feinstein-Carper and Alexander-Lieberman bills, which focus on the electricity sector, address all six important types of GHGs<sup>12</sup> across all or a large part of the U.S. economy. Congressmen Stark and Larson have each proposed bills to establish an economy-wide tax on the carbon content of fossil fuels.

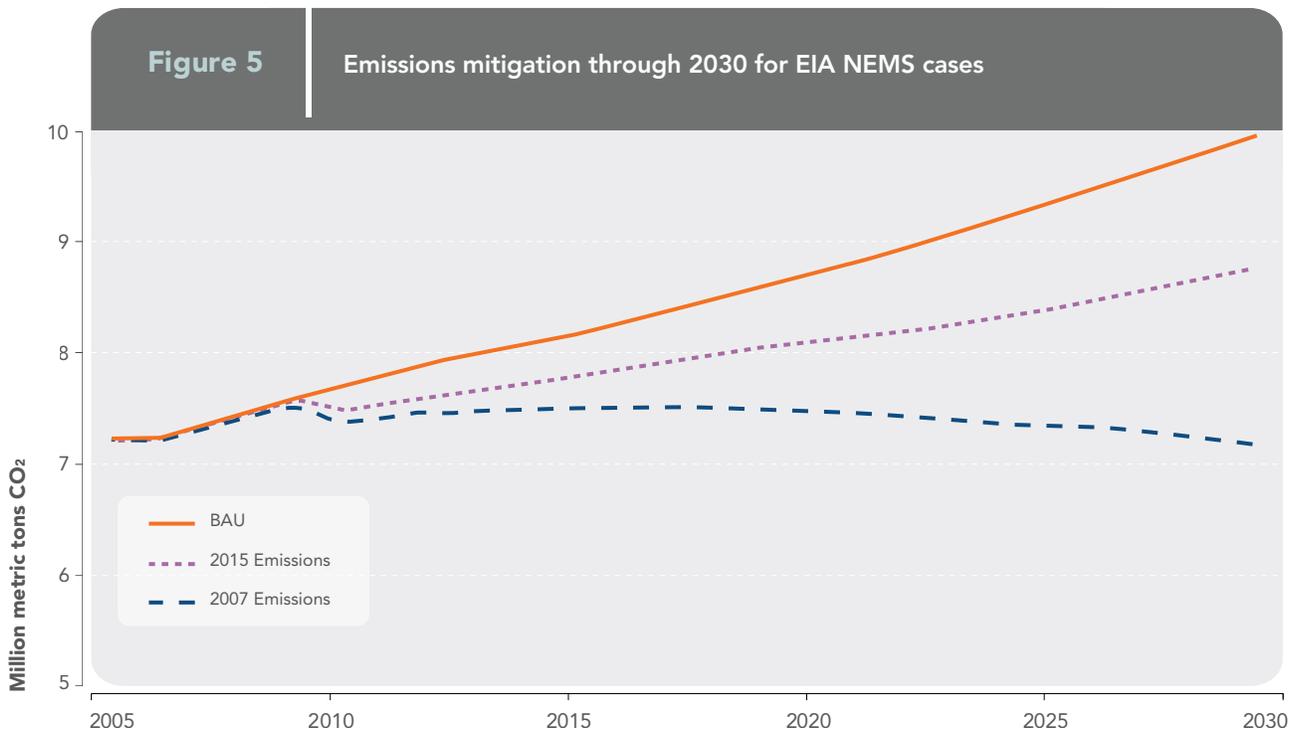
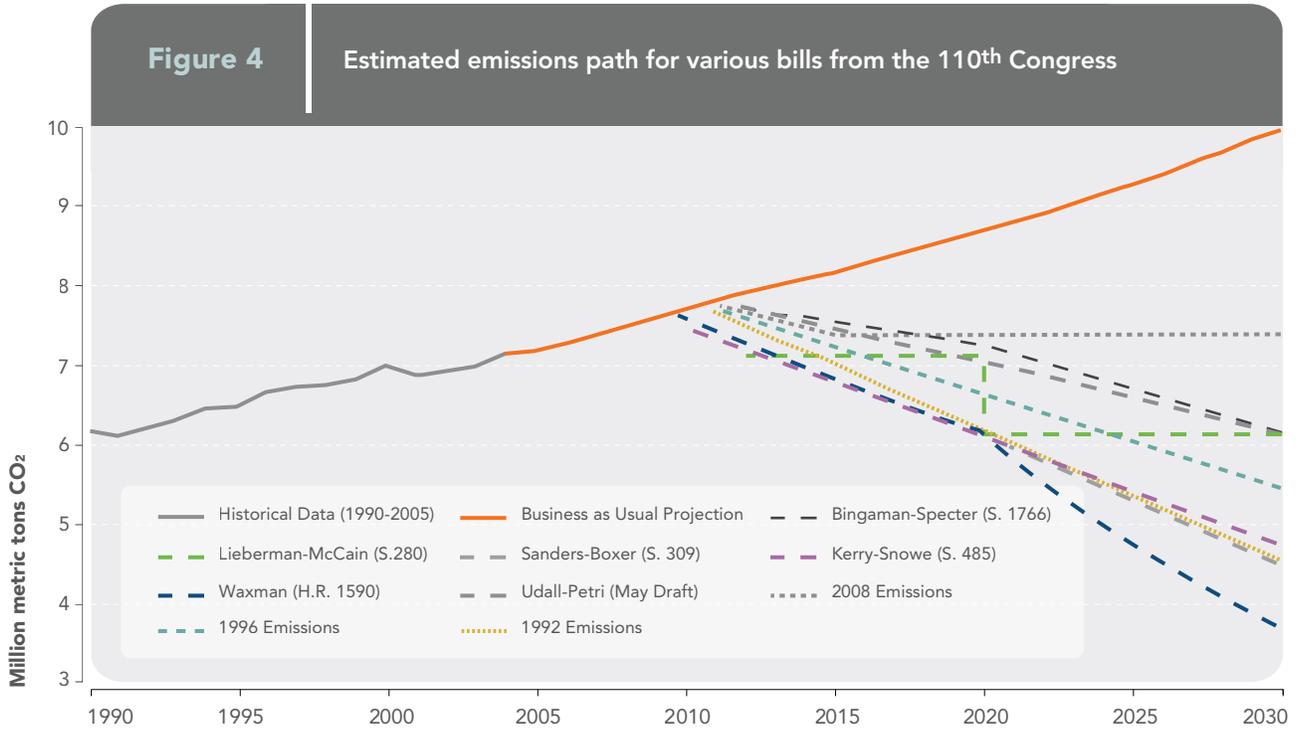
Current cap-and-trade proposals would institute emissions targets starting between 2011 and 2020, and run out through at least 2050. Some bills propose emissions targets in the form of a cap that declines by a fixed percentage every year; others would establish new targets every 10 years. Earlier versions of the Bingaman-Specter bill set emissions targets based on a declining carbon-intensity objective; by contrast, the current version of the bill calls for reducing emissions to 2006 levels by 2020 and 1990 levels by 2040. The Sanders-

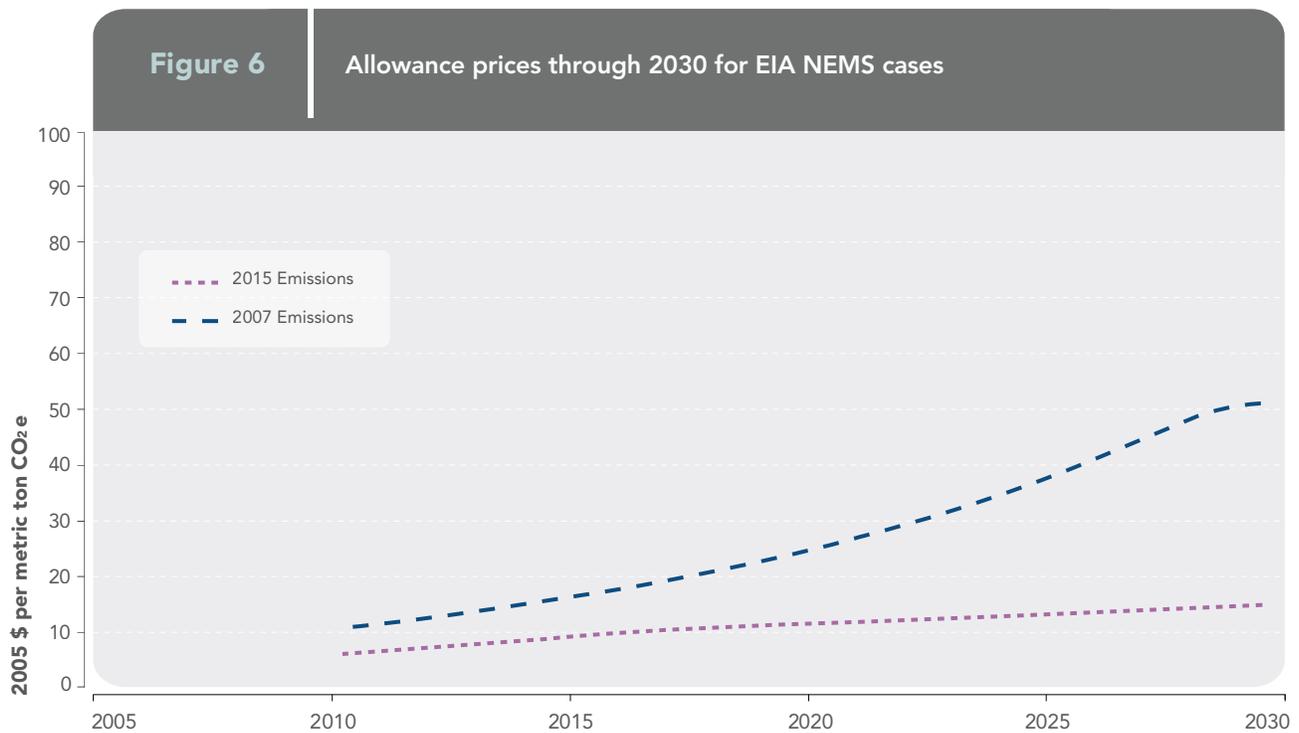
Boxer proposal sets a long-term goal of stabilizing the atmospheric concentration of CO<sub>2</sub> at 450 parts per million. The Bingaman-Specter and Udall-Petri proposals include a “safety valve” mechanism designed to provide cost certainty and limit the potential for adverse economic impacts. Both bills would provide regulated firms the opportunity to purchase an unlimited number of additional allowances at a predetermined price; this price would rise each year at a known rate to provide a steadily stronger incentive for emissions abatement over time. The starting price of the safety valve in recent proposals that contain this feature has ranged from about \$7 to \$12 per metric ton of CO<sub>2</sub>, and the proposed rate of increase in this price for future years has been set at 5 percent per year. The current Bingaman-Specter legislation specifies that this annual increase is in addition to inflation—that is, the safety valve price rises 5 percent per year in real rather than nominal terms.

Current legislative proposals also vary in how they account for offsets, especially from agricultural and forestry activities, and in terms of the rules they propose for banking and borrowing emissions allowances. The different emissions trajectories implied by these proposals through 2030 are presented in Figure 4. Actual U.S. emissions under these targets in any given year will depend on the extent that various cost-containment measures—such as banking and borrowing, offsets, or a safety valve—are employed by regulated firms. In addition, emissions will depend on which sources are included and excluded from the policy (the targets in the figure all assume economy-wide coverage). The Lieberman-McCain legislation proposes a step-like emissions path in which targets are lowered once every ten years, while other proposals employ emissions targets that change annually. The dashed lines in the figure refer to emissions scenarios modeled by the MIT Joint Program on the Science and Policy of Climate Change (“Assessment of U.S. Cap-and-Trade Proposals,” April 2007, Report no. 146). These dashed lines provide a basis for comparing modeling results to policy proposals currently under consideration. The MIT 2008 emissions scenario lies above the Bingaman-Specter and Udall-Petri emissions paths; the MIT 1996 emissions scenario achieves a 2030 emissions target similar to that proposed by McCain-Lieberman; and the most ambitious MIT scenario, in which annual average emissions for 2010–2030 are equal to 1992 emissions, is similar to the Kerry-Snowe and Sanders-Boxer emissions paths.

<sup>11</sup> Additional bills by Senators Lieberman and Warner, and by Congressman Dingell, were under discussion as this issue brief went to press. Updated information on current Congressional proposals is available at: [www.rff.org/climatechangelegislation](http://www.rff.org/climatechangelegislation).

<sup>12</sup> The relevant types of greenhouse gases covered by these proposals include carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride.





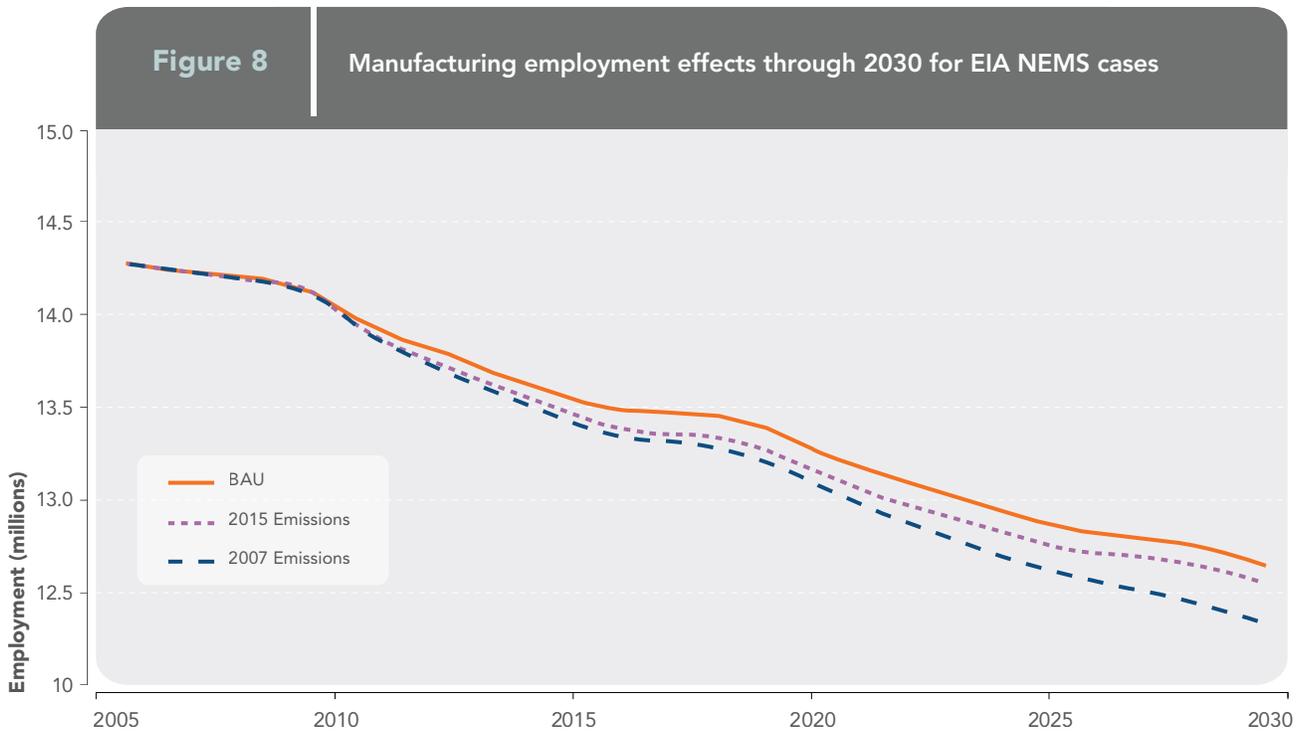
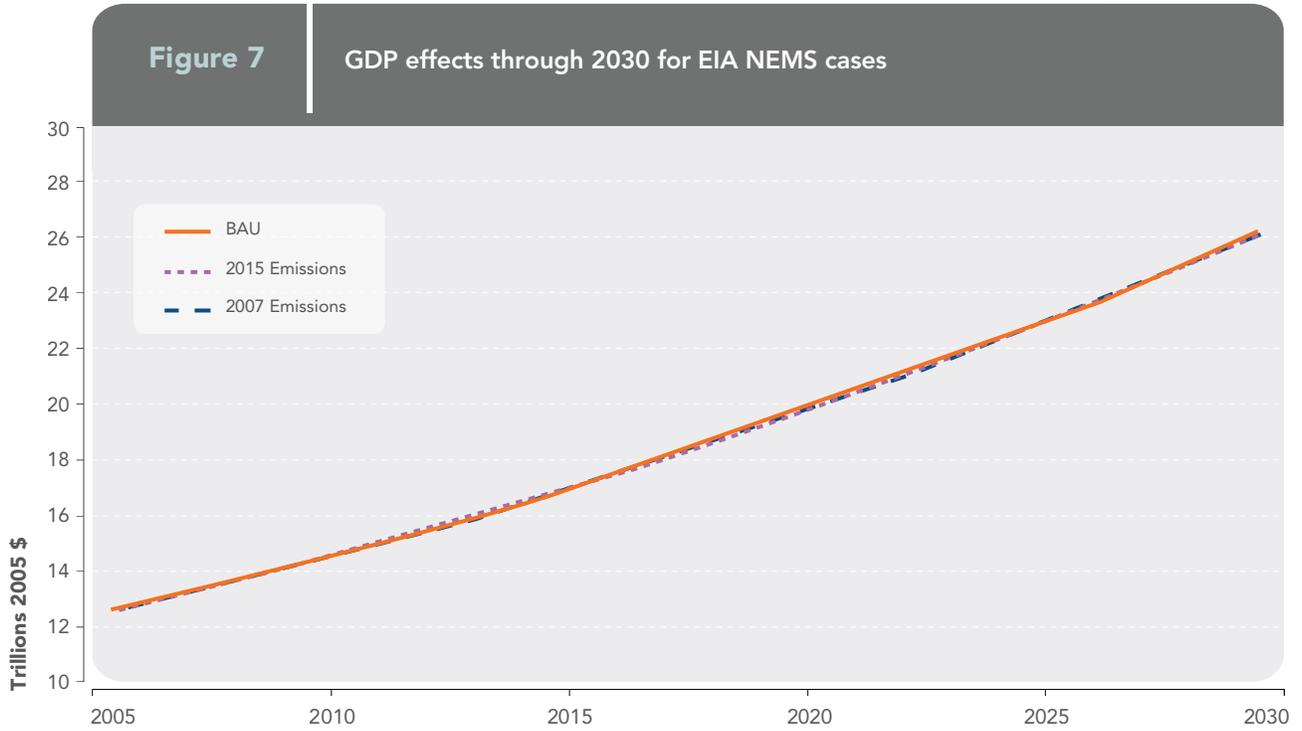
## Results from Several Recent Economic Modeling Analyses

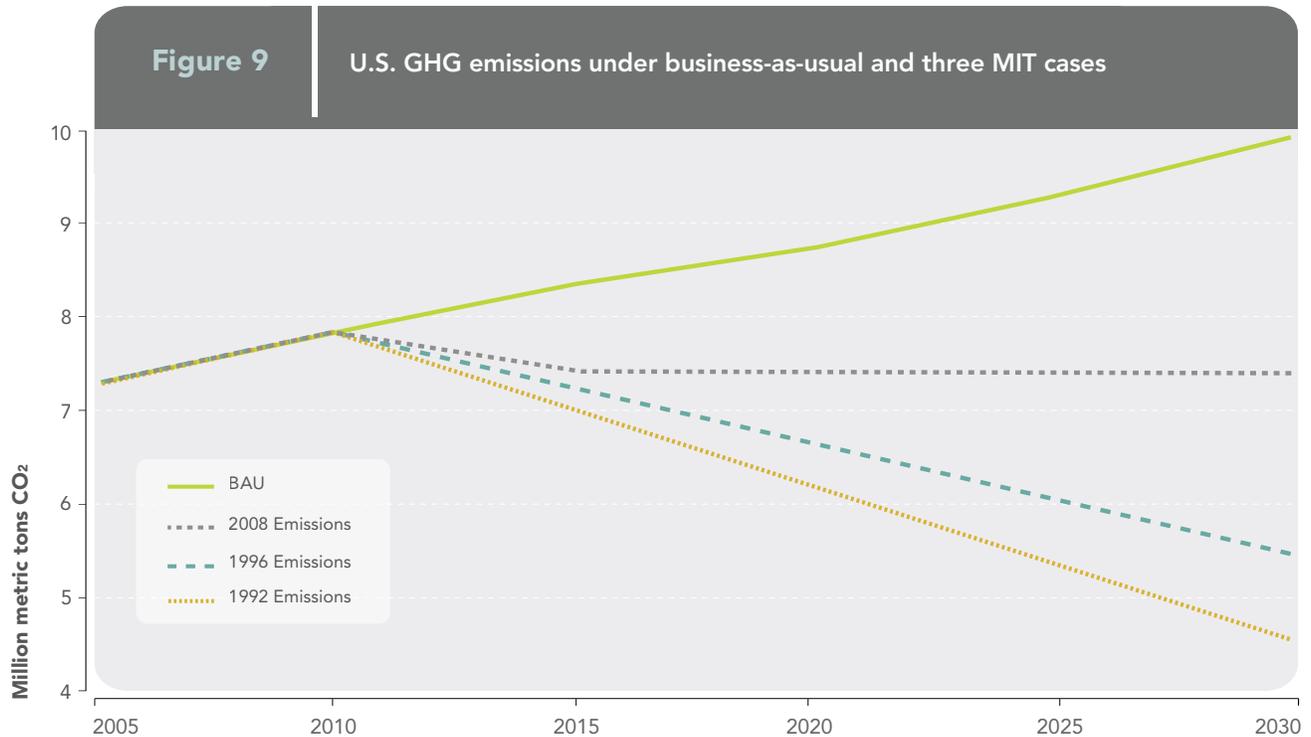
Numerous models have been developed to assess the economic impacts of cap-and-trade programs and emissions taxes. The EIA National Energy Modeling System (NEMS) model represents the U.S. energy system and economy in one-year periods and is better oriented to assess short-term economic impacts. NEMS is typically run for 20–25 years into the future. We also present results from the MIT EPPA model, which runs in five-year periods, accounts for all types of GHG emissions, and is better designed to evaluate the longer-term effects of policies. Recent MIT analyses of three “representative” policy scenarios (the dashed lines in Figure 4) run through 2050.

EIA has used the NEMS model to evaluate mitigation policies assuming different GHG cap levels and safety-valve prices (“Energy Market Impacts of Alternative Greenhouse Gas Intensity Reduction Goals,” March 2006, SR/OIAF/ 2006-01). The resulting cost estimates show the effect of imposing

carbon prices<sup>13</sup> that result in average annual GHG emissions equal to year 2015 and 2007 forecast emissions over the 2010–2030 time period. The 2015 emissions scenario is based on EIA’s modeling of emissions targets that reflect an annual reduction in the emissions intensity of the overall economy (metric tons per dollar of GDP output) of 2.6 percent per year between 2010 and 2019 and 3.0 percent per year thereafter, coupled with a safety valve price that starts at a little less than \$9 per metric ton of CO<sub>2</sub> in 2010 (measured in 2005 dollars). The 2007 emissions scenario reflects more ambitious emissions targets—corresponding to a 3.0 percent annual reduction in emissions intensity between 2010 and 2019 and a 4.0 percent per year reduction between 2020 and 2030—and a safety valve price starting at more than \$30 per metric ton of CO<sub>2</sub> in 2010. Figure 5 shows the emissions pathways for the business-as-usual, 2015 emissions, and 2007 emissions scenarios. The first policy scenario slows emissions growth, while the second begins by slowing growth and then yields a decline in absolute emissions below current levels.

<sup>13</sup> Throughout this issue brief, we use the terms “carbon price” or “price per metric ton of CO<sub>2</sub>,” to refer to the allowance price that would apply to all GHGs included in the policy based on a conversion to CO<sub>2</sub>-equivalent emissions.





Emissions reductions relative to the business-as-usual reference case are driven by the implementation of a cap-and-trade program coupled with a safety valve price that increases over time. Figure 6 shows allowance prices (in dollars per metric ton of CO<sub>2</sub>) over the 2010–2030 period for these two cases. By 2015, allowance prices range from \$9 to \$16 per metric ton, and increase to \$14–\$50 per metric ton in 2030. The faster growth in allowance prices in the 2007 emissions case reflects the much more substantial deviation from business-as-usual emissions achieved under this scenario over time.

Figure 7 shows that macro-economic impacts—in terms of change in forecast GDP—are very small at the CO<sub>2</sub> emissions and price levels modeled in the EIA NEMS scenarios. Specifically, the estimated reduction in overall GDP in these two cap-and-trade cases is between one-fifth and three-fifths of 1 percent below the business-as-usual forecast for 2030. This reduction is small compared to underlying economic trends which, according to NEMS, project an approximate doubling of economic output from 2005 to 2030—as a result the lines in Figure 7 are barely distinguishable. Modeled impacts on aggregate, economy-wide employment are similarly small: in the 2007 emissions case, total non-farm employment in 2030 is reduced by 700,000 jobs compared to

the business-as-usual case, but this impact is minimal relative to a forecast increase of nearly 40 million jobs between 2005 and 2030.

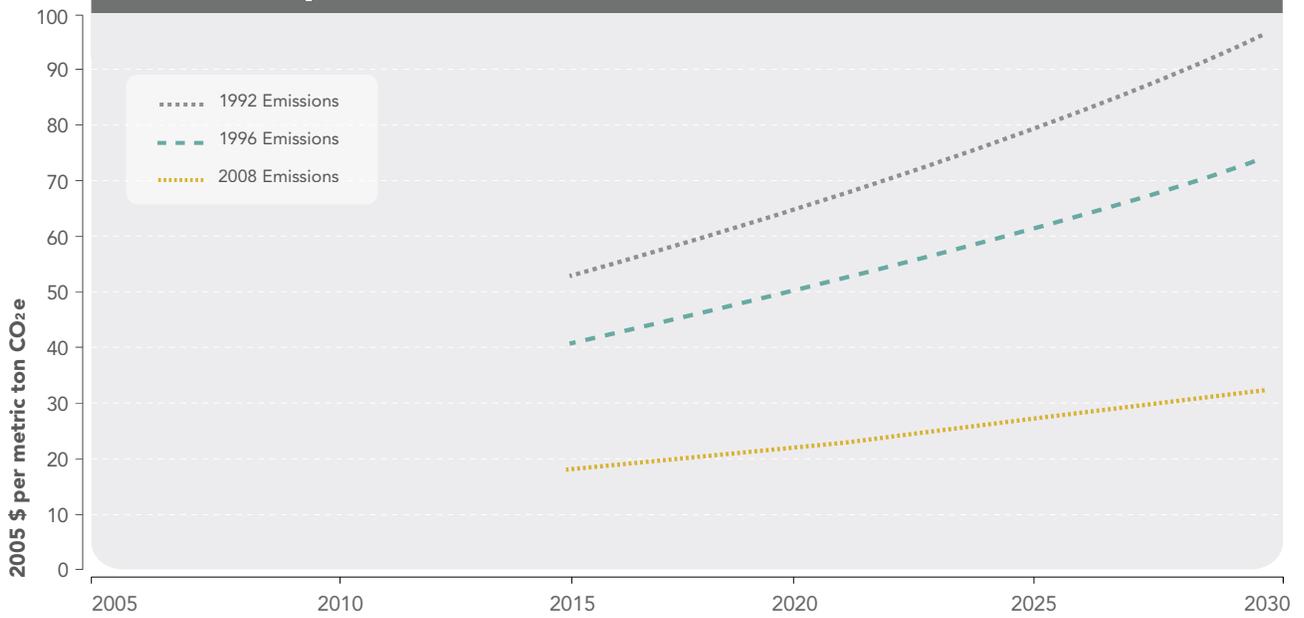
Estimated impacts on aggregate GDP and employment, however, can mask sector-level changes in consumption and production that are more significant. In other words, the policies being analyzed can produce shifts within the economy that are not immediately visible in overall national-level results. The cap-and-trade programs actually spur an additional \$10–\$20 billion of investment in 2030 compared to the business-as-usual case, and consumption losses equal the decline in GDP. Nearly half of estimated job losses by 2030 as a result of GHG regulation occur in the manufacturing sector; thus, as shown in Figure 8, impacts on manufacturing employment specifically are more significant than impacts on overall non-farm employment.

### MIT EPPA Model

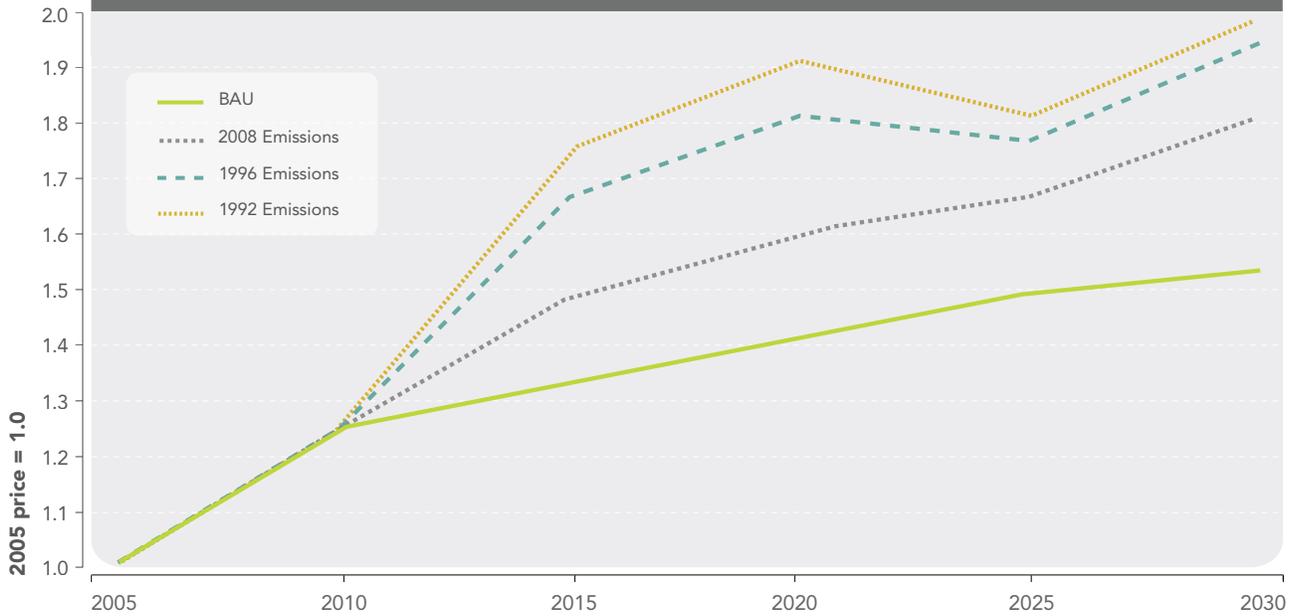
The MIT modeling group recently evaluated three emissions scenarios represented by the dashed lines in Figures 4 and 9.<sup>14</sup> The top line represents average annual GHG emissions equal to 2008 emissions over the 2010–2030 time period. We refer

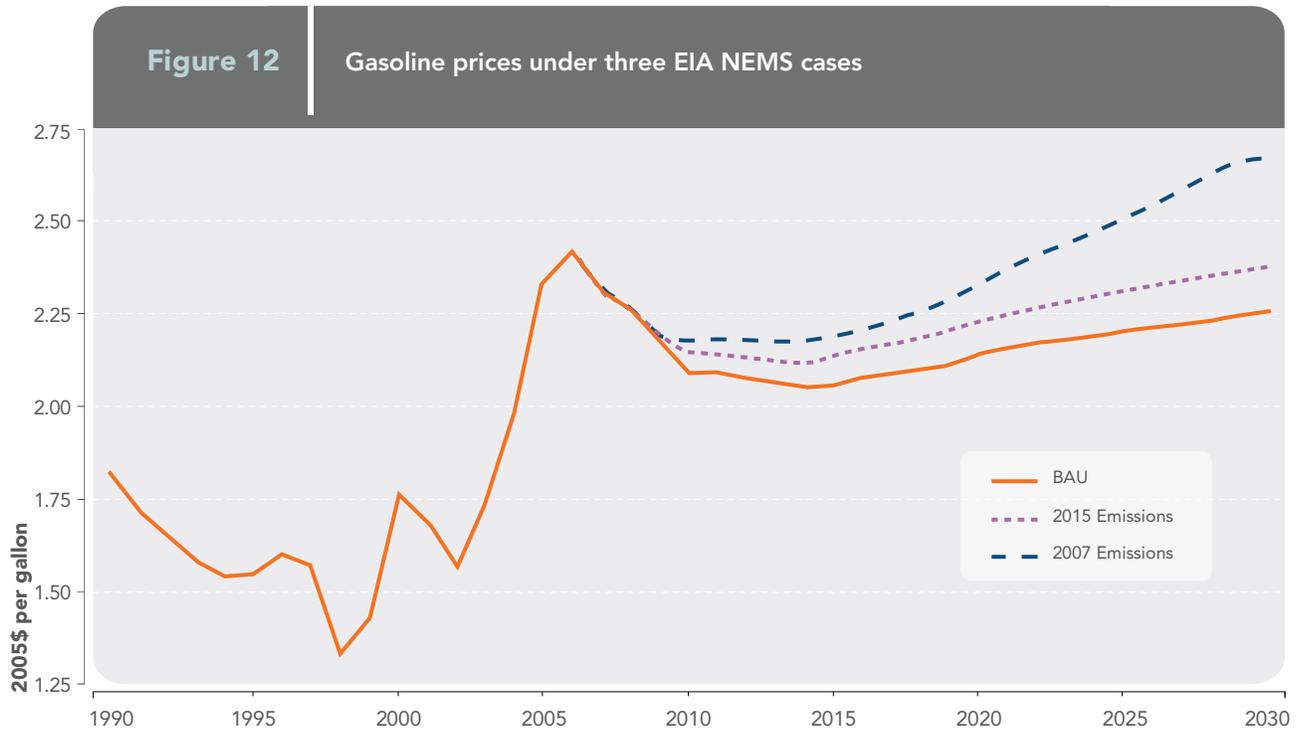
<sup>14</sup> To facilitate comparisons with the EIA results, we have relabeled the MIT cases which are denoted by cumulative emissions in billion metric tons (bmt) allowed over the 2012–2050 time period. The 2008 emissions case corresponds to MIT's 287 bmt case, the 1996 emissions case corresponds to MIT's 203 bmt case, and the 1992 emissions case corresponds to MIT's 167 bmt case.

**Figure 10** U.S. allowance prices under three MIT cases



**Figure 11** Forecast U.S. electricity prices for three MIT cases compared to business as usual





to the second dashed line as the 1996 emissions scenario; this emissions path is similar in stringency to the Lieberman-McCain proposal. The third dashed line, representing the 1992 emissions scenario, is similar to the most ambitious proposals put forward to date in Congress, such as the Sanders-Boxer, Kerry-Snowe, and Waxman bills. These emission targets yield the economy-wide allowance prices presented in Figure 10.

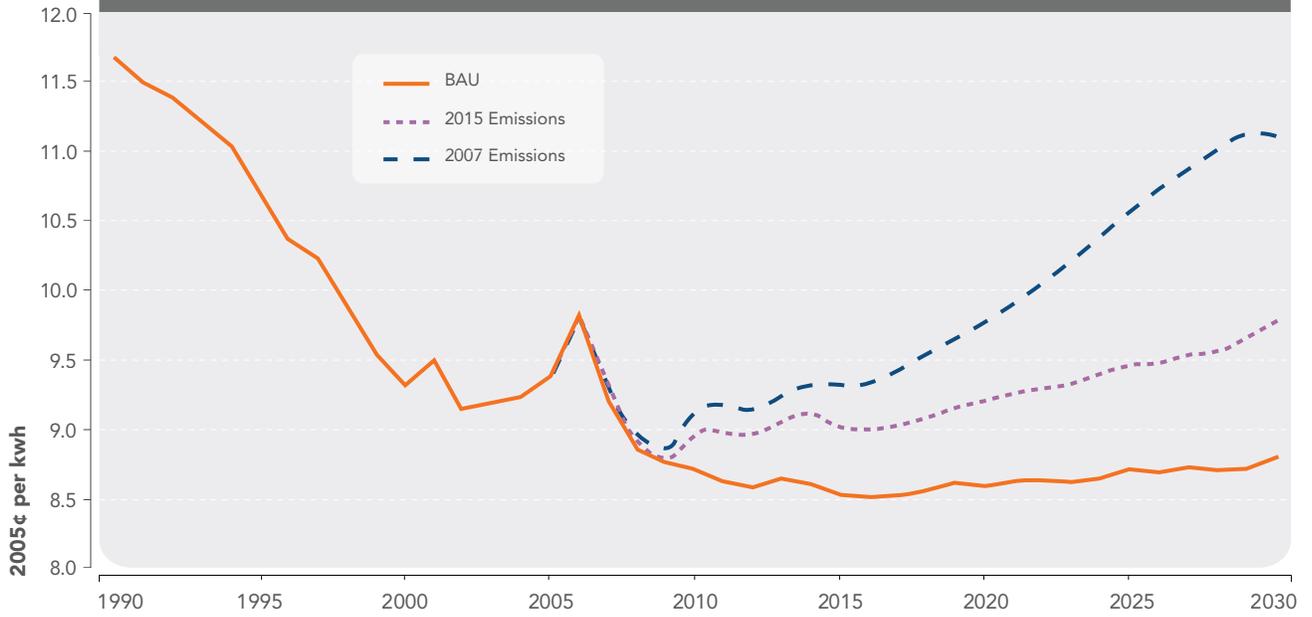
Not surprisingly, near-term (2015-2020) allowance prices for the MIT 2008 emissions case are similar to the EIA 2007 emissions case. As shown in the original MIT analysis, maintaining the target for an additional 20 years through 2050 increases the allowance price over time. The more stringent MIT 1996 and 1992 emissions cases yield much higher allowance prices. As in the EIA NEMS scenarios, however, the macro-economic GDP impacts, relative to the business-as-usual forecast, are small (in other words, a graph of the MIT results for overall GDP would produce virtually indistinguishable lines, as in Figure 7). In percentage terms, estimated GDP impacts for 2015 range from two-tenths to seven-tenths of 1 percent. Consumption falls more than GDP, as the cap-and-trade policies stimulate additional investment relative to business as usual. In 2030, GDP in the most ambitious 1992 emissions case is \$144 billion below the business-as-usual forecast, but consumption is nearly \$400

billion below business as usual. Again, sector-level impacts are somewhat more significant as can be seen in Figure 11, which illustrates the modeled impact on electricity prices. The MIT model does not produce estimates of employment impacts.

## Putting Costs in Context

Economists assess the efficiency of policies by comparing the cost of the last incremental effort (marginal cost) with the benefit of that last unit of effort (marginal benefit). A policy is efficient—that is, it maximizes net monetized benefits to society—when the benefit and cost of the last incremental effort are the same. It is beyond the scope of this issue brief to evaluate recent analyses of the benefits of reducing GHG emissions, but a brief comparison of recent cost estimates with efforts to estimate the benefits of an efficient policy can be instructive. William Nordhaus of Yale University has modeled the benefits and costs of climate change policy for several decades. In his most recent analysis of climate change policy, he finds that the optimal price on GHG emissions (in 2005 dollars) starts at \$6.40 per metric ton of CO<sub>2</sub> in 2007 and increases steadily over time to more than \$80 per metric ton of CO<sub>2</sub> in 2050 and about \$200 per metric ton in 2100. Richard Tol conducted a recent survey of the relevant economic literature and found that most estimates of the benefits of

**Figure 13** Electricity prices under three EIA NEMS cases



**Figure 14** Natural gas prices under three EIA NEMS cases



mitigating GHG emissions do not exceed \$14 per metric ton of CO<sub>2</sub>-equivalent in the near term. The recent *Stern Review: The Economics of Climate Change* arrives at larger estimates for the benefits of mitigating emissions, on the order of \$85 per metric ton of CO<sub>2</sub>.

In the political arena, of course, debate tends to focus on energy-price impacts, rather than on abstract notions of cost and benefit. To provide context for that discussion, Figures 12–14 illustrate price impacts for gasoline, electricity, and natural gas in the three EIA cases relative to both the business-as-usual forecast and actual price trends since 1990. These figures show that the modeled policies cause a change in energy prices that is not insignificant, but that is considerably more gradual than the energy price spikes experienced in recent years.

A final prism through which to view the costs of domestic policy options is in relation to the costs being incurred by other countries that are trying to limit GHG emission. The European Union launched its Emissions Trading Scheme (EU ETS) in 2005. The program covers most large point sources of CO<sub>2</sub> emissions, such as power plants and industrial boilers. In the first 18 months of Phase I of the ETS (2005–2007), allowance prices ranged between \$10 and nearly \$30 per metric ton of CO<sub>2</sub>. During the summer of 2007, EU ETS allowances for 2008 traded at about \$19–\$21 per metric ton

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Based on an array of cost measures, the modeling analyses reviewed here indicate that a modest policy designed to ramp up over time (either through more stringent emissions caps or an increasing emissions tax) would not adversely affect the U.S. economy.

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CO<sub>2</sub> (about \$26–\$29 per metric ton at current exchange rates). These allowance prices are similar to those estimated over the next two decades by EIA (for its 2007 emissions scenario) and by MIT (for its 2008 emissions scenario).

## Important Cost-Related Issues and Questions Outside the Scope of the Models

It is important to note that most efforts to model cost are optimistic to the extent that they assume efficient policies and cost-effective abatement. Thus, for example, all the studies summarized here implicitly assume zero transaction costs for trading. They further assume that all cost-effective abatement opportunities are pursued and realized throughout the economy. This emphasis on complete *where*, *when*, and *what* flexibility may not accurately describe the actual implementation of a cap-and-trade program. In addition, it ignores the costs incurred by firms (and borne by shareholders and consumers) for monitoring emissions, engaging in trading (or submitting tax payments), and other related administrative costs. These costs could be a substantial share of compliance costs, depending on firm size (small firms have fewer emissions over which to spread their fixed costs) and on the nature of required monitoring technology (continuous emissions monitors, such as on power plant smokestacks, are relatively expensive, whereas monitoring fuel use and applying emissions factors is relatively cheap).

In the real world, of course, the idealized conditions described above may not obtain. Moreover, policies as actually proposed and eventually implemented may differ from the policies modeled. The aggregated nature of available energy-economy models, both across time and across industries, inevitably requires that a number of simplifying assumptions be made in the modeling process. For example, most models cannot account for the Lieberman-McCain proposal's use of a size threshold (10,000 metric ton CO<sub>2</sub>-equivalent per year) to determine whether a facility is covered by the cap-and-trade program. Models that account for offsets typically have to make ad hoc assumptions about the cost and supply of offsets outside the modeled program. Finally, a variety of other components in many current policy proposals, such as technology programs and supply regulations, would have effects on the economy and on energy markets that are distinct from setting an emissions cap and cannot be readily captured by the models. Incorporating all these factors may influence predicted economic impacts, although it is not immediately clear whether more detailed

modeling of a given policy would tend to increase or reduce associated cost estimates.

An important source of uncertainty in interpreting model results relates to how labor markets are likely to respond to higher energy prices. Some of the high costs that have been estimated for domestic climate change policies over the past 10 years are largely driven by an assumption that labor supply is quite responsive to energy prices. In some models, energy price increases resulting from the imposition of a cap-and-trade program or emissions tax reduce the effective real wage of workers, causing a reduction in labor supply. Economists continue to disagree about the magnitude of this effect—a smaller labor response to higher energy prices would lower the costs of domestic climate change policy (but also diminish the benefits of using revenues from such a policy to lower payroll taxes), whereas a greater labor response would increase costs. In other models, an increase in energy prices is assumed to have recessionary effects. Similar disagreement exists among economists as to whether such recessionary effects, which have occurred in the past after large, unexpected price increases, would hold for the kind of gradual, expected price increases that would be associated with a GHG reduction policy.

Another important driver of future costs that is difficult to predict with confidence concerns technology responses to higher energy prices and, in particular, the impacts of a likely increase in R&D investments. Several recent climate-change policy proposals have set emissions caps through at least 2050. In some models, the economy experiences large costs because of the stringency of the emissions caps that are assumed to apply in the distant future—especially relative to current forecasts of business-as-usual emissions 40+ years out. These models do not include detailed characterizations of the R&D process. Over this kind of timeframe, one might reasonably expect more rapid development of low-carbon and zero-carbon technologies in response to credible domestic climate change policies. Accelerated progress in developing and deploying climate-friendly technologies would in turn lower the costs of a given climate change policy, so long as related R&D efforts do not draw too much capital away from other important and productive investments that promote economic growth.

Finally, two further questions are relevant in a discussion of cost, but are outside the scope of the models presented here. The first relates to the fact that most models used to evaluate climate change policy do not explicitly model uncertainty; the

second concerns the interaction of state and federal policy. With respect to uncertainty, several current policy proposals include program elements that are expressly designed to address concerns about cost certainty. Examples include the safety valve in the Bingaman-Specter and Udall-Petri proposals and the borrowing provisions in the Lieberman-McCain proposal. Additional analyses that can account for the effects of uncertainty may show the benefits of such mechanisms in maintaining reasonable costs and illustrate the potential use of safety valve or borrowing provisions in a future policy regime.

Any federal policy to limit GHG emissions is likely to co-exist, at least in the early years of implementation, with a number of state and regional climate initiatives. Examples include the Regional Greenhouse Gas Initiative in the Northeast and mid-Atlantic states and California's adoption of state-level emission-reduction targets. Potential interactions between these efforts and a federal program are not accounted for in most modeling analyses of domestic climate change policy. The incremental cost of a national GHG mitigation policy may be lower than would be indicated by modeling analyses that fail to account for state efforts because emissions reductions would occur in those states even in the absence of the national policy.

## Conclusion

Implementing a domestic cap-and-trade program or tax on GHG emissions will impose costs on the U.S. economy. Based on an array of cost measures, the modeling analyses reviewed here indicate that a modest policy designed to ramp up over time (either through more stringent emissions caps or an increasing emissions tax) would have seemingly manageable effects on the U.S. economy as a whole, although adverse impacts in certain sectors may occur. Energy prices would increase, but with only modest effects on GDP and employment. Additional analysis can highlight sectoral, demographic, and regional impacts that may be important but that are obscured by aggregated national-level analysis. It is also important to recognize that available models provide only a stylized representation of the likely economic impacts of different policies—some of the details in various proposals that are not accounted for in the models could have a significant impact on overall costs.