SEPTEMBER 2010

NEPI National Energy Policy Institute

RESOURCES FOR THE FUTURE

Toward a New National Energy Policy: Assessing the Options

EXECUTIVE SUMMARY

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RFF

Resources for the Future (RFF) is an independent, nonpartisan think tank that, through its social science research, enables policymakers and stakeholders to make better, more informed decisions about energy, environmental, and natural resource issues. Founded in 1952 and headquartered in Washington, DC, its research scope comprises initiatives in nations around the world.

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NEPI

The National Energy Policy Institute (NEPI) is a nonpartisan independent energy research organization, based at the University of Tulsa and funded by the George Kaiser Family Foundation. NEPI conceived of this project to undertake a comprehensive study of energy strategies, based on a rigorous application of common metrics to determine comparative cost.

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The Challenges Facing Us

Since the 1950s, the United States has almost tripled its annual energy consumption and far exceeded the country's ability to meet its own oil demands. Today, America imports more than half the oil it consumes and relies on countries that are often politically unstable and hostile to U.S. interests. This reliance on imported oil has destabilized our economy in the past and, according to many serious studies, including one by the Council on Foreign Relations, constrains our foreign policy choices. For 35 years, U.S. political leaders have called for freedom from this dependence on foreign—and particularly Middle Eastern—oil. Most experts now agree this freedom can only be obtained by reducing our overall reliance on oil as an energy source.

Meanwhile, the international scientific community now issues near unanimous warnings about the danger of unchecked accumulations of greenhouse gases (GHGs), particularly carbon dioxide (CO_2), in the atmosphere, largely a result of burning fossil fuels. The United States, with five percent of the world's population, is the second largest global emitter of GHGs, only recently surpassed by China.

From these twin challenges emerges a clear message: reducing our reliance on traditional fossil fuels must be central to any strategy to meet the goals of improving energy security and combating global warming. Despite numerous congressional proposals to control GHG emissions and promote alternative sources of energy, we have yet to pass and implement a comprehensive energy policy.

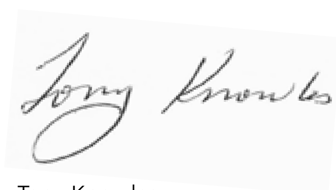
With the recent volatility in the price of oil, continued warnings about climate change, and the tragic and damaging oil spill in the Gulf of Mexico, the time is ripe for a rigorous, wide-ranging analysis of U.S. energy policy options. Complicating matters is a bewildering array of alternatives. Some are substitutes for one another and others could reinforce each other; some directly target oil and others focus on emissions. How should policymakers choose among them?

The analysis presented here helps meet this challenge. Carried out by Resources for the Future and the National Energy Policy Institute with support from the George Kaiser Family Foundation, it assesses 35 different policies and policy combinations based on their societal costs and their ability to reduce oil consumption and CO_2 emissions. Each is evaluated and ranked using a consistent and rigorous methodology. The results provide policymakers with a wealth of valuable information for developing a coordinated national energy policy.

This summary gives an overview of the findings contained in the main report, which is built around three key chapters: one exploring the effects of oil policy options, focusing on transportation; another detailing impacts of policies to reduce CO_2, focusing on the electricity sector and energy efficiency; and a third that examines the results of combining policies to reduce both oil use and CO_2 emissions.

The foundation of the effort is a series of technical papers commissioned by the study leaders and conducted by a cadre of notable researchers with expertise in each of the policies examined. These technical papers are listed in more detail at the end of this summary, and are available online at the Resources for the Future website (www.rff.org) and the National Energy Policy Institute website (www.nepinstitute.org). Both the main report and the technical papers rely on runs of the NEMS-RFF model and all were subject to thorough peer review.

We now challenge interested observers to participate in rationalizing and creating their own appropriate energy policy, using the information and interactions presented here to think strategically through the most effective and cost-effective options.



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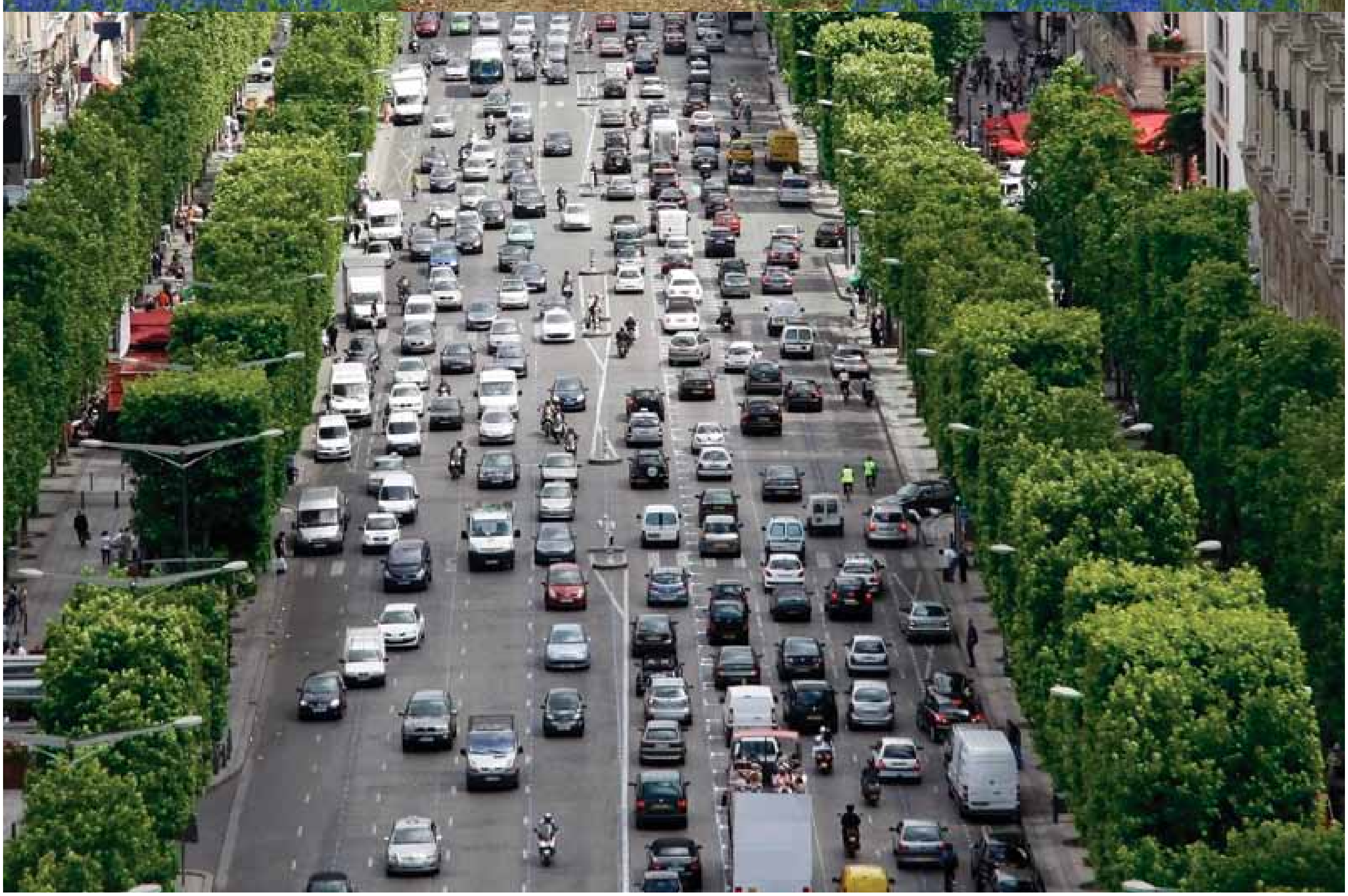


What Is Distinctive About This Study

Several important features of this study distinguish it from other assessments of U.S. climate and energy options.

- First, our research focuses explicitly on *policy design and evaluation*. Many previous studies have examined the technical feasibility of alternative fuels, new technologies, and future pathways to reduce oil use and CO_2 emissions. However, it is essential to look beyond engineering estimates or availability of particular fuels and technologies, and consider the mechanisms that will bring about those reductions, namely, the specific government policy instruments that will drive changes in private markets, our key focus. Without an understanding of how these policies work, decisionmakers have no clear guidance on how to move forward.

- Second, we use a *consistent economic modeling approach,* which is the backbone of the study. This model, which we call NEMS-RFF, is an RFF version of the U.S. Department of Energy/Energy Information Administration's National Energy Modeling System (NEMS). We developed this version with the assistance of OnLocation, Inc. By using the same model with the same underlying assumptions, we can score different policies, making apples-to-apples comparisons. We based our scores on two effectiveness metrics—reduction in barrels of oil consumed[1] and reduction in tons of CO_2 emitted—as well as the cost of each policy.

- Third, the study is *wide-ranging,* taking into account a broad menu of policies. Unlike some other studies, we also examine an array of crosscutting policies that combine multiple individual policies. We examined 35 policy scenarios, including 4 crosscutting policy options, against a reference case. Although no study can be completely comprehensive, we believe this report covers many of the relevant energy policy options currently facing policymakers.

- Fourth, a hallmark of this study is its *examination of economic or "welfare" costs,* based on fundamental microeconomic principles in which *cost* is the value of the resources that society gives up to achieve a given reduction in oil use and/or CO_2 emissions. These costs could include, for example, producing electricity with cleaner but more expensive fuels, driving less, or adopting more energy-efficient technologies. Many studies calculate direct expenditure changes from scenarios in which one fuel substitutes for another or one energy-efficient technology replaces another, less efficient one. Others, particularly those looking at broad-based policies such as carbon taxes or cap-and-trade programs, assess changes in gross domestic product (GDP). Although such

[1] Many studies focus on reducing oil imports. We look at total oil consumption, because we agree with the position taken by the Council on Foreign Relations that the policy objective should be to lower our reliance on oil generally, rather than simply reducing imports.

metrics provide useful information, they may not reflect the true economic burden of the policy. Welfare costs, on the other hand, fully represent this overall economic burden. We provide a more detailed explanation of welfare costs at the end of this summary, with additional detailed calculations in the main report.[2]

With both cost and effectiveness measures in hand, we then compare the *cost-effectiveness* of various policies, meaning the average cost per barrel of oil reduced and the average cost per ton of CO_2 emissions reduced. This helps us to identify those policies that can produce the biggest "bang for the buck," or perhaps more accurately, the lowest buck for the bang.

- Fifth, for relevant policies, we consider three cases as possible explanations for the "energy paradox" (see Box 1), the observation that consumers appear reluctant to make investments in energy efficiency unless they see a payoff well before the lifetime of the investment. We distinguish these cases by degree of market failure: complete, partial, or none. Many advocates of energy efficiency standards believe that market failures can entirely explain the energy paradox—our *complete* case—and they argue for using a very low discount rate in valuing the energy savings. On the other hand, some economists are skeptical of this argument and believe that markets work fine—our *no market failure* case; they advocate using a much higher discount rate that is consistent with observed behavior (or alternatively, allowing for various "hidden costs" in the evaluation of energy efficiency investments). In the main study, we discuss costs for both of these bounding cases, as well as a compromise, a *partial market failure* case, which we report here.

There are some important questions we did not attempt to answer. Although we examine the social costs of the various policy options to reduce CO_2 emissions and oil dependence, we do not attempt to estimate the potential social benefits of these policies. Rather, we ask the question, if the national goal is to reduce U.S. oil use and CO_2 emissions, which policies get us closest to those goals and how much will they cost?

We also ignore certain broader factors that affect the net costs of policies, because they are outside the scope of this study. For example, we do not address the cost implications of alternative uses of revenue from oil tax policies or cap-and-trade systems with allowance auctions, nor do we examine other possible benefits, like reductions in local pollution, that might occur with implementation of a policy. Where appropriate, we discuss them, but they are not part of our main quantitative assessments. Finally, we do not address the distributional effects of policies across different types of households, industrial sectors, regions of the country, or other groupings.

Policies Examined

We provide a detailed list of the 35 policies we evaluated in Table 2 (see pp. 28–31). Some policies are aimed primarily at reducing oil consumption—largely focusing on the transport sector, where 70 percent of oil is consumed—while others are intended primarily to reduce CO_2 emissions. However, the effects of all policies on both oil use and CO_2 emissions are shown in Figures 3 and 4.

Policy options include the following:

- broad transportation policies, such as fuel taxes, taxes on all petroleum products, corporate average fuel economy (CAFE) standards, and feebates, which feature fees/rebates for fuel inefficient/efficient vehicles;
- policies to encourage the deployment of hybrid and plug-in hybrid light-duty vehicles, as well as heavy trucks fueled by liquefied natural gas (LNG);
- policies to encourage energy efficiency, such as building codes and incentives for space heating and cooling technologies;

[2] This cost is reported as the present discounted value (PDV) of welfare cost due to the change in policy over the 2010–2030 study period. Fuel cost savings are considered beyond 2030, however (up to the lifetime of the investment or 2050, whichever is sooner).

- policies that encourage clean fuels to generate electricity, such as renewable and clean energy portfolio standards;
- policies to expand nuclear power;
- broad policies targeted at CO_2 emissions, such as carbon taxes and cap-and-trade programs with alternative coverage of emissions sources; and
- various crosscutting policy combinations (described on pp. 21–23) designed to reduce both oil consumption and CO_2 emissions simultaneously by combining promising individual policies.

As a baseline, we compared all policies to a NEMS-RFF reference case that we adapted from the Energy Information Administration's 2009 Annual Energy Outlook (AEO 2009). We included the 2009 federal stimulus package in our reference case. We also assumed that average new

Box 1. Alternative Interpretations of the Energy Paradox

Many studies have shown that investing today in energy efficient technologies will return fuel savings that significantly outweigh the initial investment cost over the lifetime of the purchase—but that businesses and consumers often reject such investments. This inconsistency is referred to as the energy paradox, and it appears to occur because of possible hidden costs or market failures. As a result, businesses and consumers may demand payback periods of perhaps 4 years or less on investments with lifetimes of 15 to 50 years, implying required rates of return that are well above market rates, perhaps as high as 40 percent. In this summary, we report costs for the partial market failure rate.

The alternative explanations for this paradox can be modeled in different ways (see the Cost Appendix in the main report), where the easiest model to understand is the use of alternative discount rates. A discount rate represents how much consumers would be willing to pay today for a benefit they will receive in the future. Higher discount rates mean that consumers value the future benefit less than they would with a lower discount rate.

Our no market failure case is based on observed behavior of consumers. We can summarize their reluctance to invest in energy efficiency by using discount rates, embodied in the NEMS-RFF model, that are much higher than market interest rates. Underlying the use of these high rates is the idea that consumer behavior is rational because there are unpriced or hidden costs associated with the technology. For example, perhaps the new technology proves to be unreliable or performs its task less well than the technology it replaces.

In contrast, the complete market failure case can be represented by using the social discount rate (5 percent) to value energy savings over the lifetime of the investment. In this case, the energy paradox is explained entirely by market failures (for example, imperfect information about energy saving benefits). In the absence of any policy, there would be inadequate investment in energy efficiency because consumers as individuals value it less than society does. A lower interest rate increases the social value of fuel savings, implying a lower cost for any policy that promotes energy efficiency investments. Indeed, costs could even become negative.

The no and complete market failure cases provide upper- and lower-bound estimates of the net costs of efficiency investments. Our third case, the partial market failure, represents a compromise between these two bounding cases. Here the discount rate is 10 percent or the study experts' best judgment about how much of the energy paradox can be explained by market failure versus hidden costs.

light-duty vehicle fuel economy would reach 35.5 miles per gallon by 2016 (four years earlier than originally planned), as ordered by President Obama in 2009. Results from various sensitivity analyses to this reference case—including the effects of a low future oil price or enhanced supplies of natural gas—are described in the main report.

We compared the effectiveness of policies to this reference case in the years 2020 and 2030 and looked at cumulative effects through 2030, putting more emphasis on the annual reductions in the case of oil and on cumulative reductions in the case of CO_2.[3] This comparison to a future reference is critical to emphasize. Even if there is no policy action, technological advances, energy price increases, population growth, policies already in law, and other factors will cause some changes in the energy picture anyway. To make a fair comparison, we must account for these factors, both in the policy cases and in the baseline.

Setting Targets

This study uses ambitious targets for reducing oil consumption and CO_2 emissions as benchmarks for comparing policies' effectiveness, and also to provide a context for setting the stringency of policies. These targets should not be considered as policy recommendations; rather, we used them as guideposts to examine how well each policy would perform.

The target reduction was set at 4 million barrels of oil per day from a baseline year of 2007 for the years 2020 and 2030. This represents an overall reduction of 20 percent of oil use, a 36 percent reduction of imports (assuming all oil reductions are from reductions in imports), and a reduction in the oil import share from 57 to 36 percent.[4] If the United States accomplished a 4-million-barrel-per-day (mmbd) reduction by 2030, it would reduce the world's projected increase in oil usage by 50 percent. If the rest of the world were to equal that reduction, projected global oil consumption over the next 20 years would remain roughly flat.

Notably, even in the absence of further policy changes, our baseline scenario results in total petroleum consumption that is 2 mmbd lower in 2030 than in 2007. This is the result of rising oil prices, tighter automobile fuel economy standards, and substitution of ethanol for oil to meet the renewable fuel standards set by the U.S. Environmental Protection Agency (EPA). We therefore look for the policies—or, more likely, the crosscutting policy combinations—examined in this study to reduce oil consumption by an additional 2 mmbd beyond the baseline reduction in 2030.

We did not establish targets for all GHGs, but instead concentrated on reductions in domestic energy-related CO_2 emissions. This is partly because many of the policies examined in this study affect only CO_2 (rather than all GHGs), but also because the costs and potential for valid reductions through non-CO_2 GHGs and emissions offsets (domestic and international) are highly uncertain.[5]

Our benchmark goal for domestic energy-related CO_2 emissions is a cumulative reduction by 2030 of around 12,400 million metric tons (mmtons). These CO_2 reductions are approximately consistent with those in recently proposed federal legislation: a 17 percent reduction in total GHG emissions by 2020 and a 42 percent reduction in GHG emissions by 2030, when compared against a 2005 baseline.

Figures 1 and 2 show recent oil consumption and GHG emissions by sector.

[3] When calculating cost-effectiveness, there were cases in which investments made during the project period (2010–2030) led to longer-term energy savings. In those instances, we carried those additional savings out to the full lifetime of the investment, or 2050 at the latest.

[4] Figures generated from data in the EIA 2010 Annual Energy Outlook.

[5] In the main report, however, we do briefly discuss the effects of cap-and-trade systems or emissions taxes on total GHG emissions.

Figure 1. Total Oil Consumption by Sector, 2007

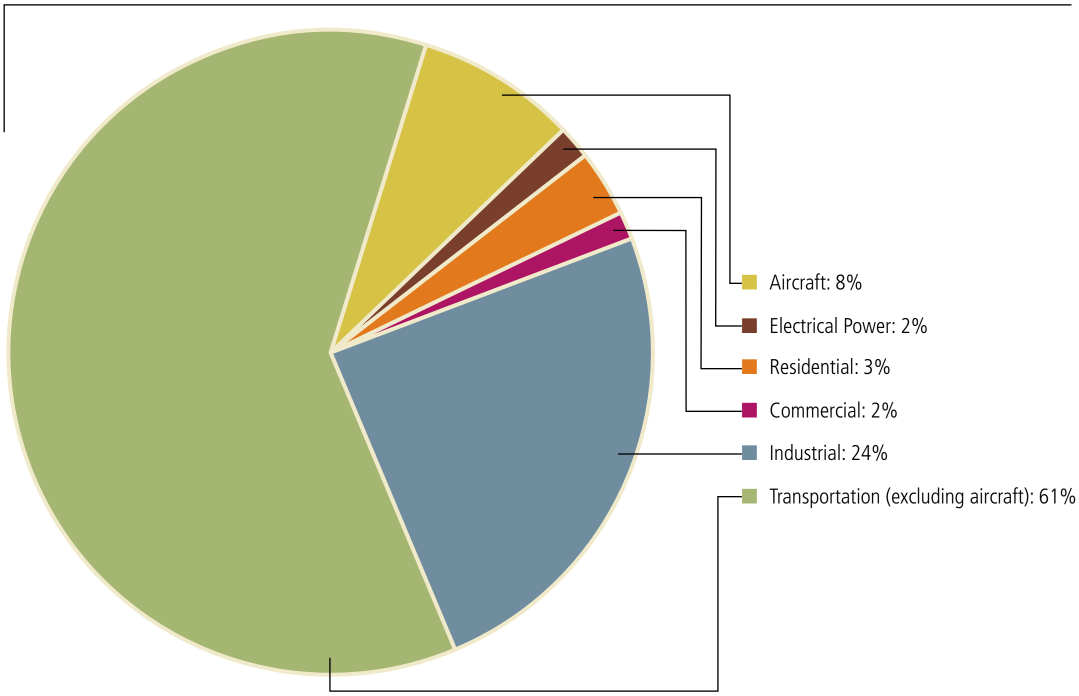
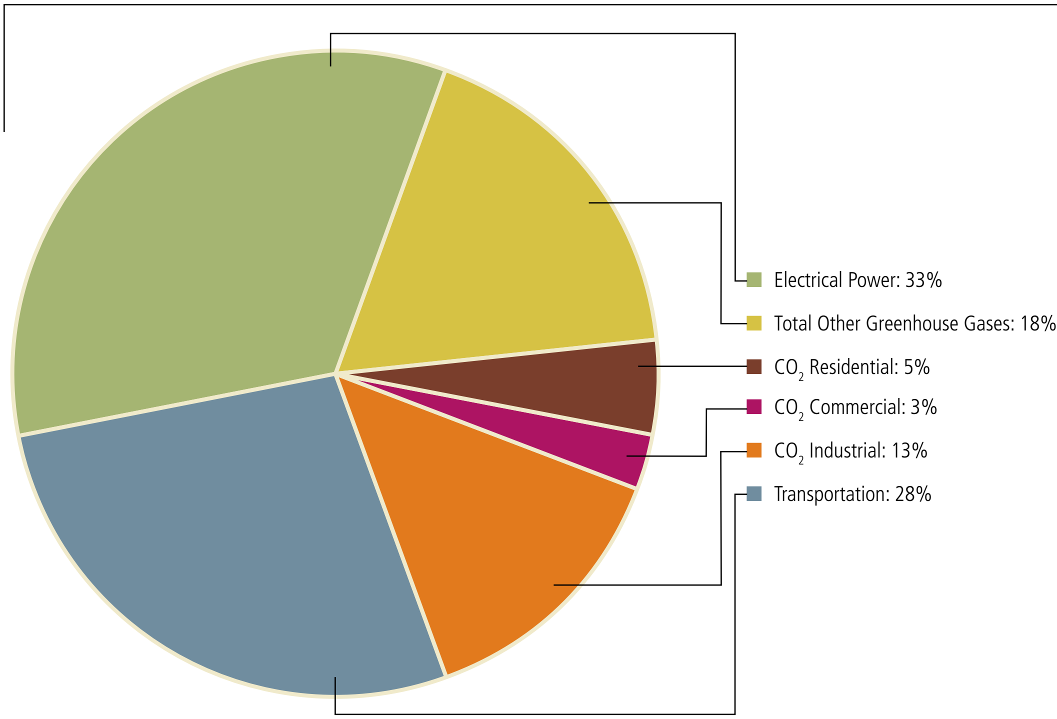


Figure 2. Total GHG Emissions by Sector, 2007



Figures 1 and 2 illustrate which sectors used oil and emitted greenhouse gases (largely carbon dioxide, but also including other GHGs such as methane) in 2007. Note the tiny share of oil used to produce electricity. Note also how CO_2 emissions are spread fairly evenly throughout the economy. Policy choices should build on this basic information.


Key Findings

Individual and Combination Policies

Figure 3 summarizes the projected effectiveness of individual policies in reducing oil use in 2030 and their projected cost-effectiveness (welfare cost per barrel) averaged over the 2010-2030 period, using the partial market failure case applied to policies significantly affecting energy efficient investments. Figure 4 shows similar information for energy-related CO_2 reductions, with effectiveness measured in terms of cumulative CO_2 reductions from 2010 to 2030 and cost-effectiveness as welfare cost per ton. In both figures, we arrayed the policies in order of their effectiveness, from largest impact on the left to smallest on the right. (See the Key Metrics Table, Table 3 on pp. 32–35, for all the numbers depicted in these figures.)

As shown in Figure 3, transportation policies generally deliver the greatest oil reductions, although carbon-pricing policies also reduce oil consumption significantly (both directly through higher oil prices and indirectly through, for example, reducing rail transport for coal). The largest oil reductions come from our aggressive scenario mandating penetration of heavy-duty trucks fueled by liquefied

Figure 3. Effectiveness (in 2030) and Cost-Effectiveness (2010–2030) in Reducing Oil Consumption

This figure combines effectiveness and cost-effectiveness of each policy. Bar height indicates effectiveness in reducing oil consumption; bar color indicates the cost/barrel reduced. Cost-effectiveness is calculated at the partial market failure rate.

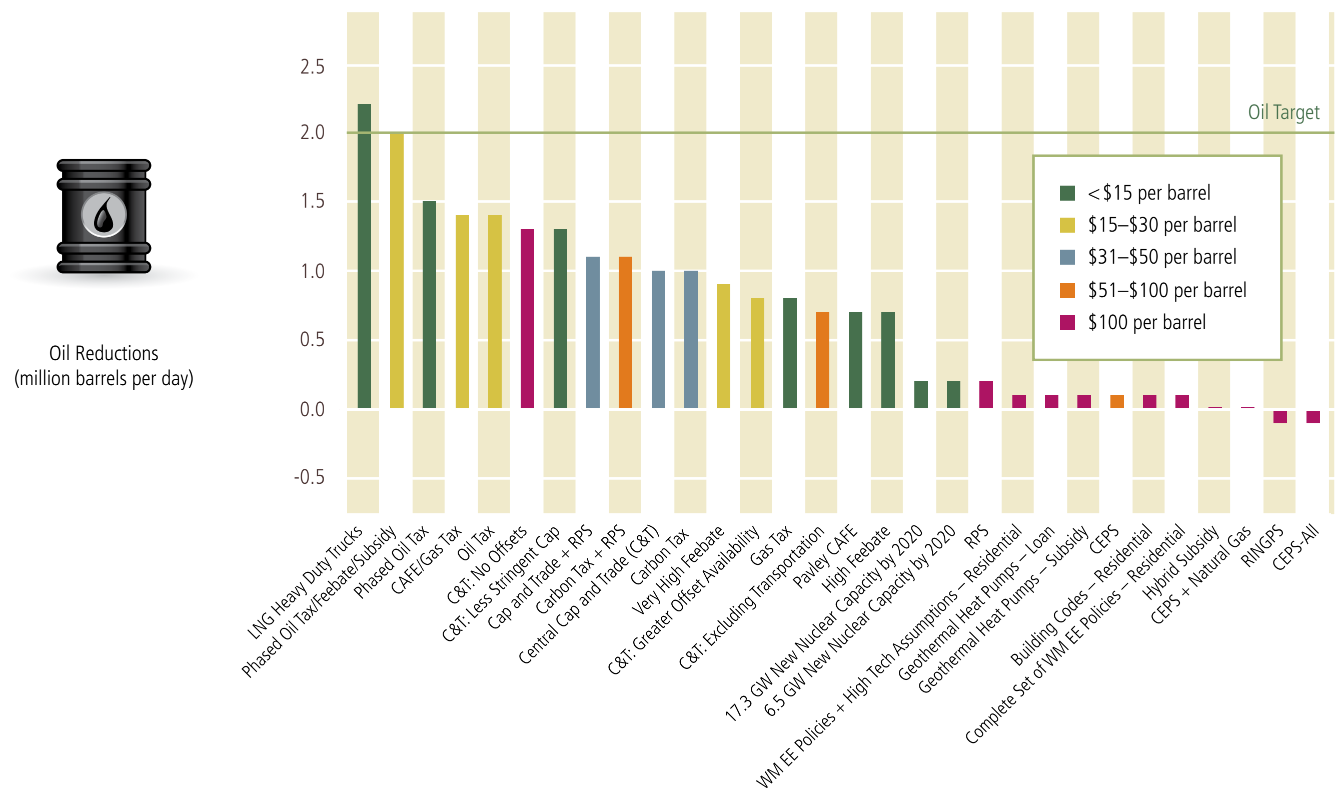
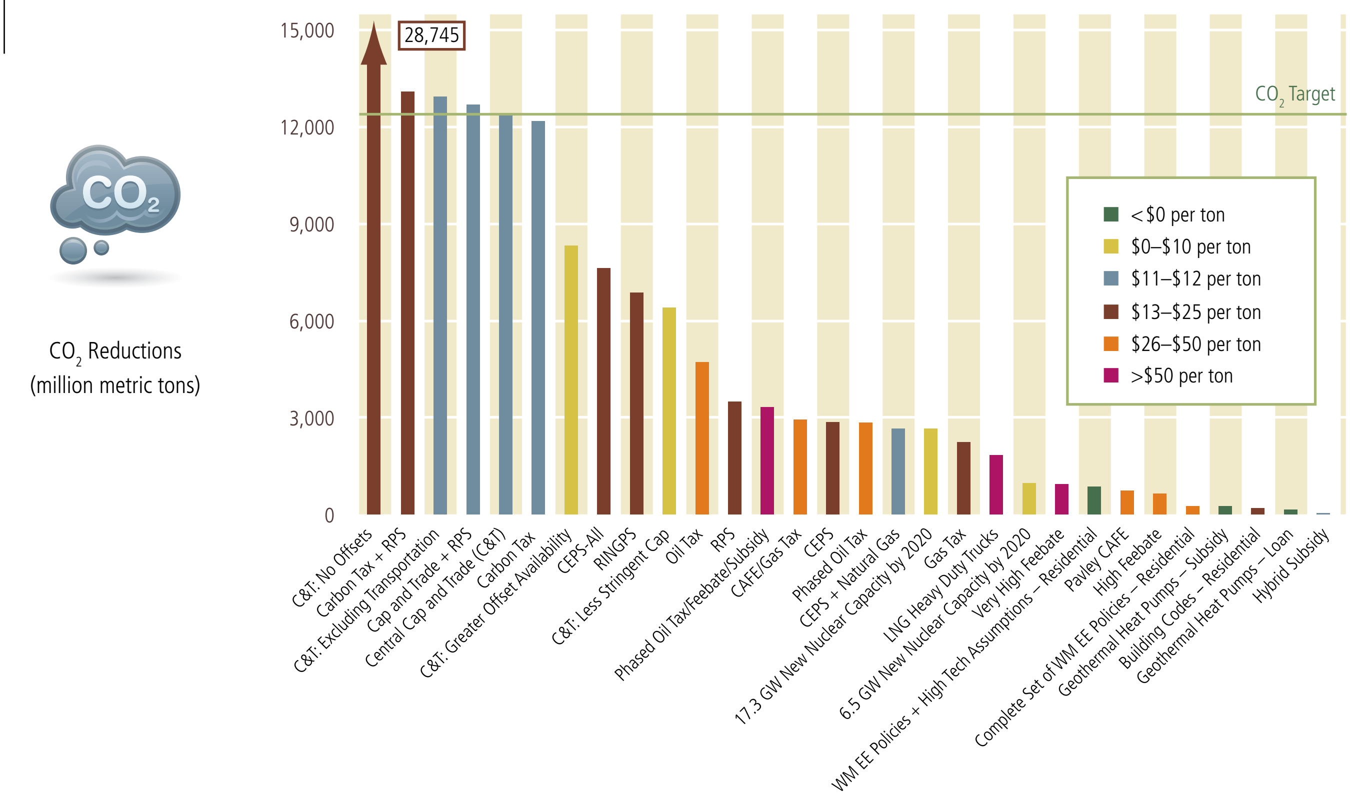


Figure 4. Effectiveness and Cost-Effectiveness in Reducing CO_2 Emissions, 2010–2030

This figure combines effectiveness and cost-effectiveness of each policy. Bar height indicates effectiveness in reducing CO_2 emissions; bar color indicates the cost/ton reduced. Cost-effectiveness is calculated at the partial market failure rate.



natural gas into the U.S. fleet (see Box 2), which delivers over a 2 mmbd reduction in 2030.

The Phased Oil Tax/Feebate/Hybrid Vehicle Subsidy combination is nearly as effective. The feebate gives a direct boost to efficiency in the light-duty vehicle market, while the Phased Oil Tax operates on all behavioral margins (including vehicle mileage and oil consumption outside the automobile sector) to reduce oil consumption. In terms of average welfare cost per barrel, LNG Trucks again look quite competitive, as do the Phased Oil Tax and the Gasoline Tax[6] (in the latter policy, gasoline taxes are increased immediately rather than progressively over time).

Figure 4 shows that cap-and-trade policies or a carbon tax would be most effective in reducing energy-related domestic CO_2 emissions over the project period. This is particularly true without offsets or in cases where we permitted the cap (in terms of GHGs) to be met only with domestic energy-related CO_2. Cost-per-ton reductions are also lowest for the cap-and-trade family of policies, although some energy efficiency policies feature negative costs and cost-effectiveness. Other power-sector policies, such as the Renewable Portfolio Standard (RPS) and Clean Energy Portfolio Standard (CEPS) do well on cost-effectiveness grounds but achieve comparatively few reductions in CO_2.

[6] In this policy scenario, the tax is also applied to ethanol and diesel fuels to avoid a large shift in the light-duty sector from gasoline to diesel vehicles. Although the diesel tax also affects heavy trucks, NEMS-RFF projects very little response from the trucking sector. In the oil tax scenarios described below, we apply expert judgment to better represent responses outside of the light-duty sector. Therefore, it is most accurate to describe our Oil Tax scenario as applying to all oil products and the Gasoline Tax as applying only to light-duty vehicles.

Box 2. Promoting the Use of LNG Trucks

Targeting oil use by the nation's heavy-duty diesel truck fleet appears to make sense, as these trucks have particularly low gas mileage and travel so many miles per year. Recent focus has been on improving fuel economy of these diesel vehicles. However, beginning to develop a fleet of liquefied natural gas (LNG) fueled heavy-duty trucks should be considered, according to our results, because of its effectiveness in reducing oil use and its relatively low welfare cost.

The LNG Trucks policy represents an aggressive penetration rate of LNG-fueled heavy-duty trucks (replacing diesel-fueled trucks)—a 10 percent penetration of new LNG heavy-duty (Class 7 and 8) trucks beginning in 2011, rising over a 10-year period at an additional 10 percent per year each year, until 100 percent of new truck purchases are natural-gas-fueled by 2020. While NEMS-RFF does not explicitly model policies that would lead to such a penetration, we consider this modeling as equivalent to a subsidy or mandate sufficient to bring about such a change. By 2030, this "policy" results in LNG trucks making up over 70 percent of the entire heavy-duty truck fleet.

Achieving such a penetration rate would lead to significant reductions in oil use (2.2 mmbd in 2030 compared to the reference case). The switch from diesel to LNG would also reduce CO_2 emissions by 1,821 million metric tons between 2011 and 2030. We estimate the present discounted value of policy costs to be $186 billion. These costs translate into a cost per barrel of oil reduced of around $14 (counting cost savings and oil reductions that continue beyond 2030 as a result of the policy).

Several factors have limited the use of liquefied natural gas in trucks up until now. LNG vehicles are much more expensive than their diesel or gasoline counterparts. Although natural gas tends to cost less than gasoline or diesel fuel, these prices can be unstable. Problems with the energy paradox have so far limited penetration of these vehicles into the fleet. While there is some concern with the safety of handling, distribution, and use of LNG (since it must be kept at extremely low temperatures to remain in liquid form), the high energy density of LNG (as opposed to compressed natural gas) is necessary to give these trucks driving range comparable to that of diesel.

Probably the greatest roadblock to LNG truck penetration is the lack of a fueling infrastructure for natural gas that is comparable to what is available for gasoline or diesel fuel. Yet infrastructure concerns may diminish over time, as the long-haul trucking industry is turning increasingly to a hub-and-spoke system with centralized drop-off/pickup locations, instead of relying on individual truckers to move goods fully across country. This system would enable refueling at a limited number of hubs. However, it is necessary to learn more about the cost and feasibility of developing a fueling infrastructure before anyone can predict widespread penetration of this type of vehicle.

Also on the horizon, the price of LNG trucks could fall with increased production levels and, depending on the costs of bringing shale gas to market, fuel costs could either fall or rise more slowly than they otherwise would.

In the main report, we discuss cost-effectiveness estimates for our two market-failure bounding cases (complete and none). For policies affecting energy efficient investments with very long lifetimes and where the ratio of investment cost to annual fuel savings is relatively low, these two cases lead to substantially lower and higher costs, respectively, than our partial market failure case. The New Construction Building Code policy is a good example. With complete market failure, this policy has a cost-effectiveness of -$15 per ton CO_2 against our partial market failure case of $25 per ton and our no market failure case of $51 per ton. Alternatively, for LNG Trucks, costs are lower by only 10 percent and higher by only 12 percent.

Pricing Policies

Pricing policies that directly target oil use or CO_2 emissions have an advantage because they exploit all the ways in which oil and CO_2 can be reduced throughout the economy by conserving on the use of energy-intensive products, adoption of energy-saving technologies, and switching away from fossil fuels. It is not surprising that they do well against our metrics. The Phased Oil Tax achieves a 1.5-mmbd reduction in oil consumption by 2030 at a welfare cost of $13 per barrel, with total welfare costs of $88 billion over the period. Our Central Cap-and-Trade program delivers CO_2 reductions that meet our CO_2 target at $12 per ton, at a total cost of $142 billion.

Within the category of pricing policies, we offer several additional observations:

- *Comparing gasoline taxes versus oil taxes:* Taxing only gasoline, rather than all oil products, overlooks more than half of the oil market, which also includes uses of oil by industry, trucking, aviation, and other sectors. We find that the Gasoline Tax option reduces oil use by 0.8 mmbd in 2030, while oil taxes of the same scale in 2030 reduce oil use by 1.4 mmbd. Taxing products other than gasoline is usually not a part of the policy conversation; our results suggest that it should be.

- *The importance of offsets in cap-and-trade regimes:* Allowing offsets in a cap-and-trade system substantially lowers costs to domestic emitters. We have quantified this cost reduction: $559 billion (in present value terms over the 2010–2030 time period) with no offsets permitted, compared to only $142 billion with 1 billion offsets permitted, where both policies achieve the same total level of reductions in GHG emissions. Indeed, with 2 billion offsets, twice as many as in the central cap-and-trade case, costs fall to about half of this amount. Given these differences in cost, our estimates (and those of other studies) illustrate the critical importance of handling the issues—namely, measurement and verifiability concerns—that remain in the international and domestic offset markets.

- *Options for revenue neutrality:* It is politically challenging to levy new taxes, particularly on commodities that are as fundamental to the American economy as oil. To make such a tax more politically and socially palatable, tax revenues might be returned or "recycled" back to the public. Some economists recommend using new revenues to offset existing taxes, like income taxes, that distort labor supply and capital investment decisions. Another option would be to return revenues in the form of rebate checks (referred to as "lump-sum recycling"). Several of the scenarios modeled here include this lump-sum recycling option.

How the revenues from all the tax policies are used has significant implications for the overall costs and feasibility of these policies, as well as for the burden they impose on different household income groups. However, the NEMS-RFF model is limited in its ability to analyze the cost and distributional implications of recycling revenues. (Chapter 8 of the main report provides some broad quantitative sense of the significant trade-offs involved in alternative revenue-recycling options.)

Alternatives to Pricing Policies

Federal policymakers seem reluctant to adopt policies that overtly raise the price of energy. While doing so is an effective means of promoting conservation—and conservation plays an important role in any cost-effective approach to

Box 3. The Clean Energy Portfolio Standard – All

Our most aggressive CEPS policy, called CEPS-All, requires a given amount of power generation to be produced by fuels other than coal and accounts for relative CO_2 emissions of such fuels. The scope of CEPS-All is larger than the other Clean Energy Portfolio Standard policies we consider and includes generation from new and existing non-coal generators.

Of the individual portfolio standard policies, CEPS-All achieves the greatest aggregate CO_2 reductions at 7,632 mmtons. While this reduction is only 62 percent of the CO_2 emissions reductions of cap-and-trade—because CEPS-All only covers electricity generation and does little to reduce electricity demand—it is relatively low cost at $15 per ton of CO_2 reduced, versus $12 per ton for our Central Cap-and-Trade policy. Notably, in a side case testing CEPS-All against a Cap-and-Trade policy scaled down to get equal CO_2 emissions reductions, we find that CEPS-All costs are 68 percent higher than the scaled Cap-and-Trade scenario.

reducing oil use or GHG emissions—an evaluation of alternatives to pricing is a necessary and practical component of our study.

In terms of oil use, the Pavley [7] CAFE and High Feebates policies are about equally effective and also cost-effective. Feebates, however, provide greater ongoing incentives than Pavley CAFE for manufacturers to improve the efficiency of individual vehicles, as each vehicle that exceeds the feebate's pivot point—the level of fuel economy at which vehicles switch between paying a fee and receiving a rebate—earns money. This is in contrast to Pavley CAFE, where fuel economy can be sacrificed on some vehicles as long as the fleet-wide standard is met. For this reason, feebates are also more compatible with other policies like incentives for hybrids, while fuel savings from selling more hybrids tend to be offset under Pavley CAFE as manufacturers can lower the fuel economy of their gasoline vehicles and still be in compliance.

Our welfare cost calculations indicate that current rules for implementing CAFE are sufficiently flexible that it no longer has a cost disadvantage relative to the high feebate. Both policies, for example, encourage the equalization of marginal compliance costs across different manufacturers.

Here again, whether there are market failures associated with fuel economy investments makes a significant difference to the costs of these policies; without market failures, the Pavley CAFE policy, for example, costs $33 per barrel, or about double the cost of the Phased Oil or Gasoline Tax. However, with partial market failures, Pavley CAFE becomes competitive with pricing policies.

In terms of carbon, implementing a broad-based Cean Energy Portfolio Standard (the CEPS-All policy described in Box 3) is a promising alternative to a Cap-and-Trade program or Carbon Tax, assuming that credit trading provisions are in place.

What is the potential role for nuclear power? We know there are carbon advantages to nuclear power, but no one knows yet whether a streamlined approval system, new technologies, and investor confidence will combine to win rapid approvals and relatively quick operational status for the many planned plants. Our research findings suggest that using loan guarantees to spur new nuclear plant construction appears to be a very low-cost way to reduce carbon emissions. A loan guarantee that reduces the required return on equity (ROE) to potential investors to 14 percent has an average cost of just $0.43 per ton of CO_2 reduced, while a policy that reduces the ROE to

[7] These standards are modeled on and named after requirements already adopted in California under the Pavley bill.

11 percent has an average cost of $1.59 per ton.[8] But effectiveness is low; the 14 percent ROE policy leads to a cumulative CO_2 reduction of just 958 mmtons, while the 11 percent ROE policy leads to a cumulative CO_2 reduction of 2,643 mmtons. In addition, more research is needed on the important issues associated with risks and waste storage.

The energy efficiency policies we analyzed centered mainly on residential and commercial building codes, although we also evaluated an option that included some additional minor lighting and appliance codes. We draw two main conclusions about them. First, the options are not very cost-effective at a cost per ton of $25 (under the partial market failure case); these high costs are due primarily to the fact that the codes apply to new buildings and thus take a while to have an impact. However, the model also predicts that the costs of meeting the code, through changes in building shells, appliances, and equipment, are relatively high. Second, under alternative high-tech model assumptions or the complete market failure case, the costs of the energy efficiency policies are greatly reduced (or even negative). This highlights the need for an analysis of the technology investments needed to bring about these high-tech outcomes.

We also explored the impacts of a small-scale energy efficiency policy: incentives to purchase geothermal heat pumps, considered a promising technology to reduce the amount of energy used to heat and cool indoor spaces. We evaluated a straightforward subsidy to buy these systems for residential use, as well as a policy that would provide zero-interest loans with a seven-year payback period to buy the systems. (Loans could be reflected by an added charge on one's electric bill, for example.) Although this amortization approach leads to less penetration of the technology than does the subsidy, its welfare cost is about $25 per ton lower. This type of policy is similar to ideas embodied in the federal government's Property Assessed Clean Energy program, in which households pay back upfront investments in energy efficiency over time in their property tax bills. Our results suggest that this approach should be explored for other energy efficiency investments.

Less Promising Alternative Policies and Policy Combinations

We aimed not only to identify the most promising policies and policy combinations, but also to identify policies that are high-cost, relatively ineffective, or even redundant. Illustrations of these less promising approaches follow.

Policies to stimulate purchase of hybrid-electric and plug-in hybrid vehicles are not very effective. In the presence of binding CAFE standards, these policies result in lower efficiency gains from gasoline vehicles such that overall fuel economy and oil use stay roughly the same. Moreover, the NEMS-RFF baseline shows a significant penetration of hybrid vehicles in the future, even in the absence of policy incentives beyond CAFE requirements already in place.

The combination of a Renewable Portfolio Standard (RPS) and a cap-and-trade system, which is part of some proposed legislation, is not particularly effective or cost-effective. In the presence of a cap on carbon, an RPS is redundant and increases costs.

It is worth noting that some technologies not in widespread use, including plug-in hybrid vehicles, many kinds of renewable energy, and geothermal heat pumps, may benefit from greater demand (to spur technological progress) or the cost reductions that come from both experience and economies of scale. Although this is a possible rationale for implementing policies that favor these technologies, this choice may come with substantial costs. Policymakers need to judge whether the benefits are worth the costs.

[8] These costs do not take into account liabilities in case of default.

Crosscutting Policies

Our findings illustrate that there is no single policy, no magic bullet, that will simultaneously and significantly reduce oil consumption and CO_2 emissions. We also need to avoid a buckshot approach, however, in which several uncoordinated policies are implemented that may cancel out any intended benefits or even make things worse. Perhaps of greatest use to policymakers, and distinctive among most other similar studies, we assessed an array of policies in combinations and have created four key crosscutting options:

1. *Pure Pricing:* This combination examines how individual high-performing oil and carbon pricing policies work in conjunction with each other.

2. *Pricing + Energy Efficiency (EE):* This combination builds on the pricing options above, but combines them with residential building efficiency and automobile fuel economy policies to more directly target possible market failures associated with energy efficiency investments.

3. *Regulatory Alternatives to Pricing:* It is typically difficult to obtain enough political support to enact pricing policies, whereas regulatory alternatives tend to be popular with legislators, so we examined a suite of alternatives to pricing.

4. *Blended Portfolio:* This combination blends both pricing and regulatory options, including some of the best-performing individual policies, particularly on the oil side.

Table 1 shows the crosscutting policy combinations we examined. We provide descriptions of the individual policies in Table 2, on pp. 28–31.

We also created variants for two of the options, which exclude the LNG Trucks policy. This policy is separable from all the others, in that NEMS-RFF (and the original NEMS model) does not permit any policy or economic changes to spur demand for LNG trucks. Therefore, none of the crosscutting policies cover LNG truck penetration unless

Table 1. Crosscutting Combination Policies

1. Pure Pricing	Combines the Phased Oil Tax with Carbon Tax.
2. Pricing + EE Measures	Combines the Phased Oil and Carbon Taxes with the Residential Building Code provisions and Pavley CAFE policy.
3. Regulatory Alternatives	Combines the LNG Truck Policy, Building Code Provisions, Pavley CAFE policy, and CEPS-All.
4. Blended Portfolio	Combines the Phased Oil Tax, High Feebate, Hybrid Subsidy, Building Code provisions, GHP subsidy, and CEPS-All with a modified LNG Truck policy at half the original penetration rate (5 percent per year rather than 10 percent).

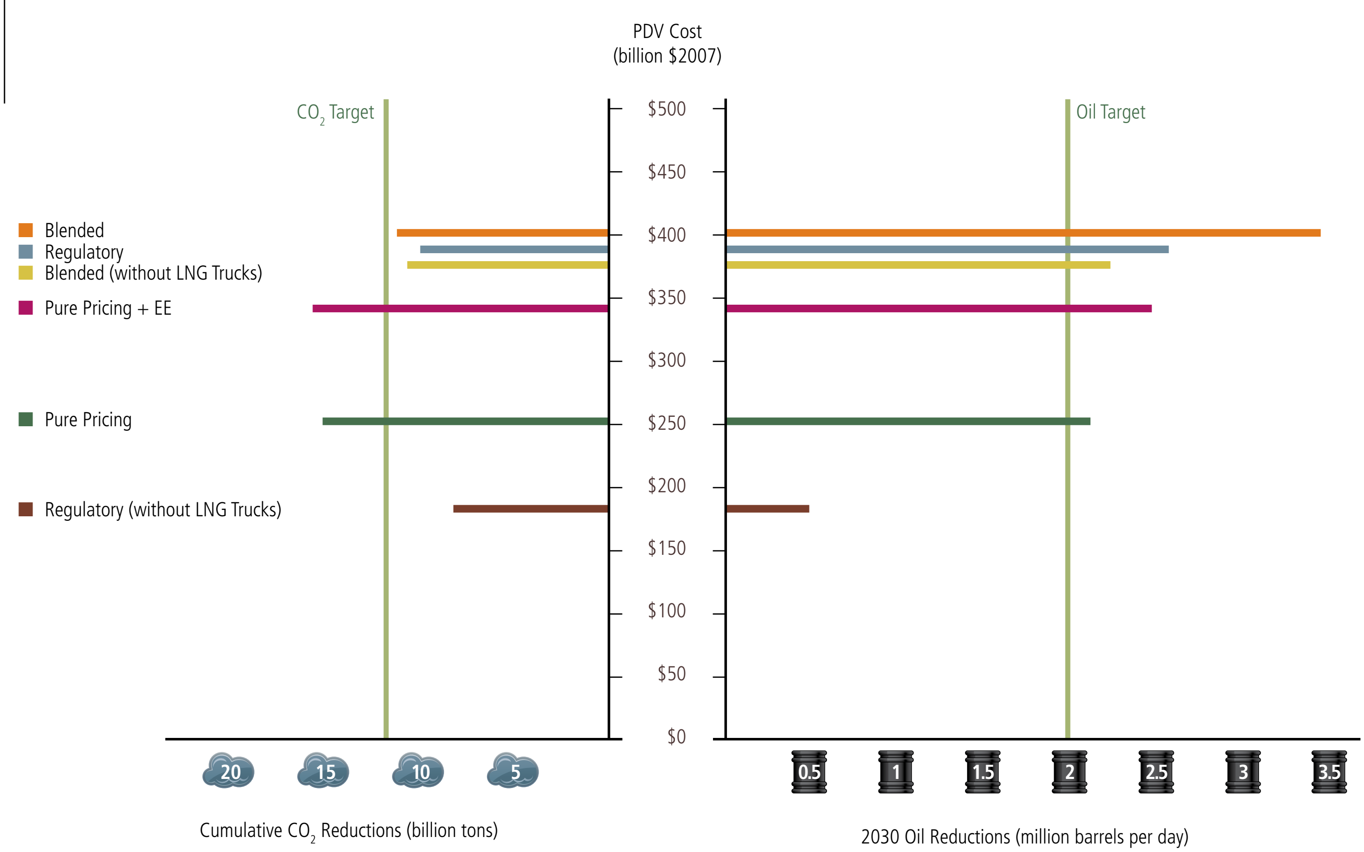
we explicitly force the model to do so, which we do for the regulatory and blended options but not the pricing options. To make an apples-to-apples comparison among all four crosscutting policies, we illustrate how the Regulatory Alternatives and Blended Portfolio perform without the LNG Truck policies included.

Figure 5 summarizes how well each crosscutting combination fares in terms of the study's key effectiveness metrics (along the horizontal axis) and the present discounted value (PDV) welfare cost metric (along the vertical axis), all for the partial market failure case. Because the combined policies are intended to reduce oil use and CO_2 emissions, with neither measure dominating, we can no longer use cost-effectiveness measures as we did when examining individual policies. As a result, we focus on PDV of welfare cost as our cost metric.

Broadly speaking, each of the main crosscutting combinations (with the exception of Regulatory Alternatives without LNG Trucks) achieves oil reductions in excess of 2 mmbd in 2030 compared to the reference case (or 4 mmbd compared to 2007). Only the Pure Pricing and Pure Pricing + EE meet and exceed the cumulative CO_2 reduction target, although the Blended Portfolio (with or without LNG Trucks) comes close. Pure Pricing and Regulatory Alternatives without LNG Trucks are the least expensive, at $253 billion and $183 billion respectively over the projection period (although the latter does poorly on effectiveness).

Adding the energy efficiency policies to the pricing instruments (Combination 2) increases total costs by proportionately more than reductions in emissions and oil use. Oil reductions in 2030 in our second crosscutting combination are 19 percent greater and cumulative CO_2 emissions reductions are 3 percent greater compared to the Pure

Figure 5. Effectiveness and PDV Costs of Crosscutting Policy Combinations (Partial Market Failure)



Pricing option, but costs are 35 percent higher. Both of the energy efficiency policies included in this combination—Building Codes and Pavley CAFE—have long-lasting benefits well beyond 2030, which is worth keeping in mind when interpreting these results. Nonetheless, the findings emphasize the additional costs incurred by adding these efficiency policies on top of pricing policies (although using the complete market failure case would turn these costs negative).

The Regulatory Alternative combination performs poorly compared to the Pure Pricing and Pure Pricing + EE combinations, with higher costs and far lower CO_2 reductions. This is primarily because of the lack of energy conservation incentives; putting a price on carbon, because it raises energy prices, spurs households and businesses to reduce their overall energy use. This incentive is lacking in our regulatory alternative. Oil reductions exceed those of the pricing options, but when we remove the LNG Truck policy, oil reductions are minimal, and costs drop considerably.

Our fourth policy combination blends both pricing and regulatory policy options and results in significant reductions in both CO_2 emissions and oil consumption. In fact, this combination leads to the greatest reduction in oil use of any policy or policy combination tested in this study, largely because it combines our Phased Oil Tax with a modified LNG Truck Mandate. Even with the LNG truck penetration rate at half the level initially analyzed, this combination results in a reduction of 3.4 mmbd beyond reference case levels in 2030 (5.4 mmbd measured from 2007 levels). This reduction is 62 percent greater than that of the Pure Pricing combination. Without the LNG Trucks option, the Blended Portfolio loses 35 percent of its effectiveness in reducing oil but still reaches the established target.

The Blended Portfolio nearly reaches the CO_2 emissions reduction target (98 percent)—a noteworthy achievement, given that it does not contain a carbon tax or cap-and-trade program. These significant reductions are largely a product of CEPS-All, which leads to 62 percent of the CO_2 reductions found in our central cap-and-trade case, and a combined reduction in oil use (and accompanying CO_2 emissions) spurred by the various transportation policies.

Cautions and Opportunities in Mixing Policies

Policymakers obviously might want to consider policy combinations other than the ones we investigated. We urge caution, however, in using the results of our individual policy analyses to simply sum the oil and CO_2 reductions and the costs to obtain an estimate for a combination. One problem with this approach may be called the starting point issue. With the performance of two policies measured from the same starting point—the baseline reference case in our study—the estimated costs may be quite different when they are measured individually and in combination. In the latter case, one policy starts where the other leaves off. If the marginal costs of obtaining carbon or oil reductions are rising (that is, it becomes more and more costly to get additional reductions), then the true costs of the combination of policies are greater than the sum of the individual policy costs. Because the costs are higher, it is also possible that overall reductions in oil and CO_2 will be lower than would be suggested by adding reductions from the individual policy analyses.

In addition to the starting point issue, there are also problems related to prices. Some policies have impacts on prices that affect the cost of other options in the combination. On the one hand, when combined with oil tax policies, the net costs of LNG Truck mandates are lower because higher prices for diesel imply a greater value from replacing diesel use with LNG. On the other, increased pressure on natural gas prices due to the LNG mandate increases the costs of policies, like CEPS-All, that involve switching from coal to natural gas in power generation.

The NEMS-RFF model accounts for these market interactions when assessing the impacts of the policy combinations, and we also accounted for them in our welfare cost calculations. In general, we found that effectiveness is lower for the combination policies, but the difference is generally modest. In contrast, costs of the policy combinations can exceed those summed over their individual policies by over $70 billion (for the Blended Portfolio without LNG Trucks), while some combinations (pricing) show no noticeable difference.

The annual costs of the crosscutting policy combinations range from $48 to $117 per capita, based on 2007 U.S. population figures.


Summarizing the Results

We emphasize two broad conclusions from our policy analyses.

- **A single policy instrument will not efficiently reduce both oil use and CO_2 emissions to meet the selected targets.** We find that policies that target oil use—even broad-based pricing policies such as an oil or gasoline tax—do provide some CO_2 benefits, but they are far less beneficial in this regard than direct carbon policies. Similarly, although carbon pricing policies lead to some reductions in oil use, the remaining carbon policies (energy efficiency, nuclear, and renewables) do little if anything in this regard.
- **Combinations of policies, in contrast, are more effective at reducing both oil use and CO_2 emissions, meeting or exceeding both reduction benchmarks laid out in this study.** Costs differ widely depending on the underlying policies included, which creates opportunities to choose efficient solutions to our energy problems. Pricing policies deliver the greatest reductions in oil use or CO_2 emissions for a given cost, achieving 33 percent more carbon reductions than the study target, while also meeting the target oil reduction. Although challenges remain for approaches—such as an oil tax for reducing oil consumption or a cap-and-trade program (or carbon tax) for reducing CO_2 emissions—no single regulatory substitute makes the same level of progress on all of this study's key metrics. These pricing instruments do well on costs because they provide incentives on all margins of behavior, including fuel substitution, energy efficiency, and conservation. They also spur industry and consumers to find the most cost-effective combination of these approaches.

Several regulatory policies can complement pure pricing in ways that achieve greater reductions than pricing alone. For example, the combination of the Phased-In Oil Tax, CEPS-All, an LNG Heavy Trucks mandate (at half the penetration rate used in the Regulatory option), and other efficiency policies achieves a 70 percent greater oil reduction than the study target and 62 percent more than the Pure Pricing mechanism. It also nearly meets (98 percent) the CO_2 target (albeit at a higher cost).

The relative weight given by policymakers to reducing oil consumption versus CO_2 emissions, as well as the political feasibility of various policies, are key additional considerations in evaluating combinations of policies.

As for the individual policies, there are several other results that merit emphasis:

- **Several alternatives to Cap-and-Trade appear to be reasonably cost-effective, and some of these also achieve substantial reductions in emissions, or both.** In particular, the Clean Energy Portfolio Standard (CEPS-All) does reasonably well when compared to Cap-and-Trade.
- **Compared to policies targeting CO_2 reductions, fewer options exist to efficiently reduce oil use.** Further gains from tighter CAFE standards for light-duty vehicles appear limited and to come at high cost, given the ramp-up that has already been adopted in recent years. Similarly, feebates, which are a more flexible alternative to Pavley CAFE, provide only limited oil reductions relative to a broad-based oil tax.
- **Hybrid subsidies alone show no progress on reducing oil use.** Although they lead to market penetration of hybrids, they ease the burden on manufacturers of meeting CAFE standards with conventional gasoline-powered vehicles.
- **The cost-effectiveness of energy efficiency policies depends critically on how we interpret observed market behavior.**

Consumer reluctance to invest in energy efficient equipment could stem from hidden costs associated with such equipment or market failure (see Box 1). We found the welfare cost estimates to vary significantly with these assumptions, in some cases ranging from negative average costs (that is, savings in lifetime energy expenditures that outweigh upfront purchase costs) to positive and comparatively high average costs. Given the enormous importance of energy efficiency to overall energy use and the array of policy options for promoting energy efficiency in vehicles, buildings, appliances, and other equipment, we feel strongly this issue needs additional research attention.

A Cautionary Note About Uncertainty

In most cases, forecasts of energy use and CO_2 emissions generated by NEMS-RFF for our various policy scenarios are presented as single-point estimates, but a great deal of uncertainty surrounds these numbers. Explicit and implicit model parameters—such as elasticities of demand, elasticities of substitution across fuels, underlying resource estimates, appliance and equipment costs, and a host of other factors—are all uncertain to varying degrees, as are future oil prices, GDP, and technological advances across fuels and sectors. The NEMS model, however, is not set up to incorporate these uncertainties or to provide a distribution of outcomes; instead, the model's management team at EIA chooses best-estimate parameters and produces outputs that use those parameters.

We were able to capture some aspects of uncertainty, however. We identified factors that we believe had the greatest relevance for our results and ran the model under alternative assumptions. These assumptions included an alternative low oil price scenario; natural gas resource estimates that incorporated new shale gas resources and the possibility of associated lower extraction costs; lower hybrid vehicle battery costs; "high-tech" assumptions for our energy efficiency analysis; and alternative discount rates.

These sensitivity analyses revealed some interesting results. Low oil prices will make it much more difficult for any policy to reduce oil consumption, especially to the level of the aggressive targets laid out in this study. We found that greater natural gas resources affect a variety of policies but not always in straightforward ways. Assumptions about rapid improvement in technology and lowering of battery costs altered the cost-effectiveness of the Energy Efficiency and Hybrid policies, respectively, and highlighted the benefits that could be achieved if research and development were to bring about those technological advances.

While we acknowledge the inherent uncertainty in our findings, we feel confident about our policy comparisons—which are the heart of our study—because they are based on the same assumptions and modeling algorithms; they are apples-to-apples comparisons. Although changing oil prices or technology costs may lead to more or less progress toward our effectiveness targets, they are unlikely to change the order in which policies may be ranked. Thus, users of these data may opt to put more faith in the relative comparisons of costs and effectiveness across policies than in the absolute levels of these metrics.

A Note on Calculating Welfare Costs

As detailed in the main report and the welfare cost appendix, we calculated costs based on principles of welfare economics, which is the standard approach among economists to measure policy costs. We used formulas worked out as far back as Harberger (1964)[9]. According to this definition, cost is the value of the resources society gives up to take a course of action. In the context of reducing dependence on foreign oil or meeting a CO_2 emissions cap, welfare costs summarize the costs to the economy of all different actions taken to reduce fossil fuel use. This would include, for example, such direct costs as producing electricity with cleaner but more expensive fuels. Welfare costs also include the less obvious

[9] Arnold C. Harberger. "The Measurement of Waste," *American Economic Review* 54 (1964): 58–76.

costs to households from driving less or using fewer energy-driven devices and services (such as keeping thermostats lower) than they would otherwise prefer.

To apply the formulas, we need to know only three things (as read from the NEMS-RFF model output):

- the magnitude of important sources of distortions that already exist in the economy, such as tax rates that cause differences between consumer and producer prices, or the extent of market failures;
- any quantity changes in markets affected by these preexisting distortions; and
- new sources of distortions created by policies in directly affected markets.

The formulas do not provide exact welfare measures, but they do provide reasonable approximations. For example, the formulas are based on the assumption that demand and supply curves in markets affected by new policies are linear over the range of behavioral responses, which may not be exactly correct.

It is often easier to define welfare costs by what they are not. They are not measured in terms of job losses in industries most directly affected by new policies. Usually, many of those jobs are made up by other sectors of the economy eventually. Welfare costs also are not measured by changes in GDP. Welfare economics in general is associated with impacts on private consumption and production, but GDP includes investment and government spending. GDP fails to capture nonmarket effects, such as environmental damages, that can be important for welfare costs and benefits. GDP can also sometimes be misleading. A regulation or policy that leads to use of a higher-priced alternative and raises product prices may actually increase GDP, but this provides little information about the actual costs of the policy. For broad-based policies, such as cap and trade, that make their impacts felt across many markets and sectors of the economy, GDP can be a somewhat useful metric, but it is problematic for other policies.

Welfare costs measure only true opportunity costs, not who pays and who receives. Transfers of funds between producers and consumers or between consumers and the government and tax revenues raised through oil or gasoline taxes are not considered welfare costs, to the extent that they are offset by higher private-sector tax payments. These are simply transfers from one segment of society to another.

The welfare cost (or social cost) concept has been endorsed by governments around the world to evaluate regulations, government investments, taxes, and other policies. In the United States, a series of executive orders, dating from the Carter administration to the present, has made it mandatory for government agencies to perform cost-benefit analyses using welfare economics to determine whether major regulations they are considering can be justified from society's point of view. Hundreds of Regulatory Impact Analyses are performed every year, with welfare cost estimates as a key component.

Table 2. Policies Modeled	
Reference Case	The reference case is based on AEO 2009 + stimulus and also includes advancing of fuel economy standards mandating that new light-duty vehicles achieve 35.5 mpg from 2020 to 2016.
Transportation/Oil Policies	
Gasoline Tax	Raises the gasoline tax by $1.27 per gallon in 2010 and increases it in real terms at an annual rate of 1.5 percent a year, adding $1.73 to the cost of a gallon by 2030. The revenues from this tax, and taxes or auctioned allowances described below, are returned in lump-sum payments to individuals (they are therefore considered to be revenue neutral). We discuss the implications of alternative revenue recycling possibilities in the main report.
Immediate Oil Tax	Applies the above level of gasoline tax to all refined oil products used in the United States, including imported petroleum products (exported products are exempt). The tax is based on British thermal unit (Btu) equivalence. This tax is revenue neutral.
Phased Oil Tax	A variant of the immediate oil tax, which eventually reaches $1.73 per gallon of gasoline equivalent on all oil products by 2030. This tax begins at 8 cents per gallon in 2010 and rises by approximately 8 cents per gallon each year out to 2030. This tax is revenue neutral.
Pavley CAFE	Features an increase of 3.7 percent a year in fuel economy standards for both cars and light trucks for 2017 through 2020. From 2021 to 2030, the policy further tightens standards by 2.5 percent a year, reaching an average standard of 52.2 mpg for light-duty vehicles in 2030.
High Feebate[10]	Fee assessed on vehicles that do worse than the Pavley CAFE standard in each year and rebate to those vehicles that do better. Basic rate is $2,000 per 0.01 gallons/mile, phased in progressively between 2017 and 2021 and thereafter rising (in real terms) at 2.5 percent a year, so that it reaches $2,969 per 0.01 gallons/mile in 2030.
Very High Feebate	Sets the feebate rates in each year exactly twice as large as in the high feebate case.
Hybrid Subsidy	Establishes a vehicle purchase subsidy of $3,000 for each 0.01 gallon/mile saved between the hybrid electric or plug-in hybrid electric vehicle and its gasoline-equivalent vehicle, with the subsidy constant in real terms from 2010 to 2030.
Pavley CAFE/Gasoline Tax	Combines the Pavley CAFE policy with the Gasoline Tax.
Oil Tax/Feebate/Hybrid Subsidy	Combines the Phased Oil Tax, High Feebate, and Hybrid Subsidy.

[10] In this study, we assumed that feebates were imposed at the manufacturer level. Alternatively, they could be imposed at the consumer level, though either would be equivalent within the NEMS-RFF modeling framework (as would some combination of consumer and manufacturer feebates, for which there are advocates).

Table 2. Policies Modeled (continued)	
LNG Trucks	Assumes that 10 percent of new Class 7 and 8 heavy-duty trucks bought in 2011 run on natural gas, rising to 20 percent of new trucks bought in 2012, up to 100 percent of new trucks bought in 2020 and beyond. This case is modified in one of the policy combinations to rise at half the penetration rate (rising by 5 percent per year to reach 100 percent by 2030 rather than 2020). This scenario can be viewed as a policy mandate or subsidy.
CO_2 Pricing Policies	
Central Cap-and-Trade (C&T)	Reduces all GHGs by 17 percent below 2005 levels in 2020 and 40 percent below this base by 2030; covers all energy-related CO_2 and all industrial and agricultural sources of non-CO_2 emissions; covers all major sectors; allows 500 million tons each for domestic and international offsets per year; allows banking and borrowing of allowances with a zero bank balance in 2030; and auctions allowances, returning the revenue to households in lump-sum rebate checks.
C&T: Excluding Transportation	Same requirements for total cumulative reductions under the cap, but excludes the transportation sector from the policy.
C&T: Alternative Cases for Offset Availability	One case allows 1 billion tons each of domestic and international offsets per year, and another does not allow the use of any offsets in meeting the overall cap.
C&T: Less Stringent Cap	Required cumulative reductions for all GHGs are 33 percent lower than in the central case.
Carbon Tax	A tax per ton of CO_2 emissions that mimics the time path of allowance prices under the central C&T policy.
Energy Efficiency (EE) Policies	
New Construction Building Codes	Calls for a 30 percent reduction in energy use by new buildings upon enactment of the law, a 50 percent reduction from residential buildings by 2014 and from commercial buildings by 2015, and a 5 percent reduction at 3-year intervals thereafter up until 2029. This policy is consistent with the Building Code provisions in the Waxman-Markey (WM) bill, H.R. 2454.
Complete Set of WM Energy Efficiency Policies	Adds retrofit requirements; standards for outdoor lighting, portable light fixtures, and incandescent reflector lamps; and new standards and testing procedures for appliances to Building Code provisions similar to those represented by the Energy Information Administration's analysis of the WM bill.
Complete Set of WM EE Policies + "High Tech" Assumptions	A modification of the set of WM energy efficiency policies, which assumes accelerated technical progress (beyond that already found in the reference case) across the board. This manifests in higher efficiencies for most energy-using equipment.

Table 2. Policies Modeled (continued)	
Energy Efficiency (EE) Policies (continued)	
Residential Geothermal Heat Pumps—Subsidy	Models a $4,000 direct consumer subsidy for the purchase and installation of a geothermal heat pump (GHP) system in the residential sector.
Residential Geothermal Heat Pumps—Loan	Models a zero-interest $4,000 loan for the purchase and installation of a GHP in the residential sector, paid back over a seven-year period.
Nuclear Power: Loan Guarantee	
6.5 Gigawatt (GW) New Nuclear Capacity by 2020	Reduces the return on equity assumed in NEMS-RFF from 17 percent (in the reference case) to 14 percent, which leads to an expansion of 6.5 GW of nuclear power by 2020.
17.3 GW New Nuclear Capacity by 2020	Reduces the return on equity assumed in NEMS-RFF from 17 percent (in the reference case) to 11 percent, which expands nuclear power by 17.3 GW by 2020.
Renewable Energy Technologies	
Production Tax Credit	Models an extension of the current production and investment tax credits for renewables (a 2.1-cent tax credit for wind, geothermal, and closed-loop biomass, and a 1.1-cent tax credit for landfill gas, other forms of biomass, and hydrokinetic energy).
Renewable Portfolio Standard (RPS)	Calls for 25 percent of total generation (excluding generation from hydro and municipal solid waste [MSW] plants) to come from non-hydro renewables nationwide by 2025, with interim targets leading up to this ultimate goal. Renewable Energy Credits (RECs) are used as a way to achieve these targets.
Clean Energy Portfolio Standard (CEPS)	Broadens the portfolio standard to include other "clean" fuels besides renewables, including incremental generation from nuclear power plants and natural gas and coal plants that have carbon capture and storage (CCS) technology.
CEPS-NG	Broadens the CEPS to include new natural gas capacity (without CCS) in the portfolio. New natural gas capacity receives a fraction of a clean energy credit, dependent on the CO_2 emissions from the technology.
RINGPS	Combines a 25 percent RPS with a 20 percent Incremental Natural Gas Portfolio Standard, meaning that 25 percent of total electricity generation (excluding generation from hydro and municipal solid waste plants) must come from renewables and 20 percent must come from new natural gas plants.
CEPS-All	Seeks to replicate the share of generation produced by technologies other than coal (with the exception of coal with CCS) obtained under the central cap-and-trade policy. The scope of CEPS-All is larger than CEPS and includes generation from new and existing noncoal generators. Unlike the CEPS and CEPS-NG policies, no cap on the price of clean energy credits, and the clean generation share target is applied to all generation, including hydro and MSW.

Table 2. Policies Modeled (continued)	
Renewable Energy Technologies (continued)	
Cap-and-Trade + RPS	Combines the 25 percent RPS with the Central Cap-and-Trade Policy.
Carbon Tax + RPS	Combines the 25 percent RPS with the Carbon Tax policy.
Crosscutting Policy Combinations	
Pure Pricing	Combines the Phased Oil Tax with the Carbon Tax.
Pure Pricing + EE Measures	Combines the Phased Oil Tax and Carbon Tax with the Building Codes and the Pavley CAFE policy.
Regulatory Alternatives	Combines the LNG trucks policy, the Building Codes, the Pavley CAFE policy, and CEPS-All.
Blended Portfolio	Combines the Phased Oil Tax, High Feebate, Hybrid Subsidy, Building Code provisions, GHP subsidy, and CEPS-All with a modified LNG Truck policy at half the original penetration rate (5 percent per year rather than 10 percent).

Table 3a. Key Metrics, by Policy—Oil Consumption

	Progress on Oil Target		Cumulative Reductions	PDV Welfare Cost	Cost Effectiveness: Oil	Cost Effectiveness: CO_2
	Reduction from 2007 (mmbpd)		CO_2 Emissions (mmt CO_2)	($2007, billions)	($2007/barrel)	($2007/ton CO_2)
	in 2020	in 2030	to 2030	to 2030	a.	a.
Reference Case	2.1	2.0	–	–	–	–
	Incremental Reductions to Reference case					
Policies to Reduce Oil Consumption						
TRANSPORTATION POLICIES						
Phased Oil Tax	0.9	1.5	2,828	88.0	13	29
Oil Tax	1.6	1.4	4,715	200.5	18	40
Gas Tax	0.8	0.8	2,224	53.3	10	22
Pavley CAFE	0.1	0.7	722	44.6	12	31
High Feebate	0.1	0.7	637	41.9	12	35
Very High Feebate	0.2	0.9	919	116.8	23	67
Hybrid Subsidy	0.0	0.0	0	-8.2	–	–
CAFE/Gas Tax	0.8	1.4	2,919	134.2	17	31
Phased Oil Tax/Feebate/ Subsidy	1.0	2.0	3,319	250.0	24	54
NATURAL GAS VEHICLES						
LNG Heavy-Duty Trucks	1.1	2.2	1,821	186.4	14	76

Table 3b. Key Metrics, by Policy—Carbon Dioxide Emissions

	Progress on Oil Target		Cumulative Reductions	PDV Welfare Cost	Cost Effectiveness: Oil	Cost Effectiveness: CO_2
	Reduction from 2007 (mmbpd)		CO_2 Emissions (mmt CO_2)	($2007, billions)	($2007/barrel)	($2007/ton CO_2)
	in 2020	in 2030	to 2030	to 2030	a.	a.
Reference Case	2.1	2.0	–	–	–	–
	Incremental Reductions to Reference case					
Policies to Reduce Carbon Dioxide Emissions						
CARBON PRICING POLICIES						
Central Cap and Trade (C&T)	0.3	1.0	12,366	142.3	45	12
C&T: Excluding Transportation	0.2	0.7	12,948	153.3	71	12
C&T: Greater Offset Availability	0.2	0.8	8,320	68.1	28	8
Carbon Tax	0.2	1.0	12,181	141.6	47	12
C&T: No Offsets	0.6	1.3	28,745	559.4	119	20
C&T: Less Stringent Cap	0.3	1.3	6,404	45.8	14	7
ENERGY EFFICIENCY POLICIES						
Building Codes – Residential	0.0	0.1	179	15.7	b.	25
Complete Set of WM EE Policies – Residential	0.0	0.1	249	26.6	b.	34
WM EE Policies + High Tech Assumptions – Residential	0.0	0.1	847	-42.2	b.	-17
Geothermal Heat Pumps – Loan	0.0	0.1	138	-11.7	b.	-36
Geothermal Heat Pumps – Subsidy	0.1	0.1	245	-5.1	b.	-9
NUCLEAR POWER: LOAN GUARANTEE						
6.5 GW New Nuclear Capacity by 2020	0.0	0.2	958	0.7	1	<1
17.3 GW New Nuclear Capacity by 2020	0.0	0.2	2,643	4.5	6	2

Table 3b. Key Metrics, by Policy—Carbon Dioxide Emissions (continued)

	Progress on Oil Target		Cumulative Reductions	PDV Welfare Cost	Cost Effectiveness: Oil	Cost Effectiveness: CO_2
	Reduction from 2007 (mmbpd)		CO_2 Emissions (mmt CO_2)	($2007, billions)	($2007/barrel)	($2007/ton CO_2)
	in 2020	in 2030	to 2030	to 2030	a.	a.
Reference Case	2.1	2.0	–	–	–	–
	Incremental Reductions to Reference case					
Policies to Reduce Carbon Dioxide Emissions (continued)						
RENEWABLES POLICIES						
RPS	0.0	0.2	3,489	47.5	106	14
CEPS	0.0	0.1	2,851	40.2	100	14
CEPS + Natural Gas	0.0	0.0	2,652	29.8	377	11
RINGPS	0.0	-0.1	6,860	162.1	–	24
CEPS-All	0.1	-0.1	7,632	116.2	4,385	15
Cap-and-Trade + RPS	0.2	1.1	12,697	151.0	46	12
Carbon Tax + RPS	0.3	1.1	13,103	170.0	52	13

Table 3c. Key Metrics, by Policy—Policy Combinations

	Progress on Oil Target		Cumulative Reductions	PDV Welfare Cost	Cost Effectiveness: Oil	Cost Effectiveness: CO_2
	Reduction from 2007 (mmbpd)		CO_2 Emissions (mmt CO_2)	($2007, billions)	($2007/barrel)	($2007/ton CO_2)
	in 2020	in 2030	to 2030	to 2030	a.	a.
Reference Case	2.1	2.0	–	–	–	–
	Incremental Reductions to Reference case					
Policy Combinations						
Pure Pricing	1.0	2.1	15,070	253.4	c.	c.
Pure Pricing + EE Measures	1.1	2.5	15,544	341.0	c.	c.
Regulatory Alternatives	1.2	2.7	10,077	388.6	c.	c.
Blended Portfolio of Policies	1.4	3.4	12,102	401.4	c.	c.
Regulatory Alternatives —no LNG Trucks	0.1	0.5	8,256	183.0	c.	c.
Blended Portfolio of Policies—no LNG Trucks	0.8	2.3	11,192	376.3	c.	c.

[a] Oil and emissions reductions counted over investment lifetime or to 2050, whichever comes sooner.
[b] Cost per barrel for policies in this category are not calculated because of small cumulative reductions in oil use.
[c] Cost-effectiveness is not calculated for crosscutting combinations, as costs cannot be assigned to individual effectiveness measures.


Acknowledgements

The study authors wish to thank many colleagues and supporters who participated in the production of this report. Chief among these is the George Kaiser Family Foundation, which funded all research, writing, and publication efforts. In addition, the authors of the study's technical and background papers generated invaluable research on which to build this report. These experts include the following:

Gary Allison, University of Tulsa
Max Auffhammer, University of California–Berkeley
Stephen P.A. Brown, Resources for the Future
Joel Darmstadter, Resources for the Future
John Deutch, Massachusetts Institute of Technology
Ruud Egging, University of Maryland
Steven Gabriel, University of Maryland
Lawrence H. Goulder, Stanford University
Mun Ho, Resources for the Future
Hillard G. Huntington, Stanford University
Xiaobing Liu, Oak Ridge National Laboratory
Virginia McConnell, Resources for the Future
Karen Palmer, Resources for the Future
Geoffrey Rothwell, Stanford University
Alan Sanstad, Lawrence Berkeley National Laboratory
Kenneth A. Small, University of California–Irvine
Rich Sweeney, Resources for the Future
Tom Turrentine, University of California–Davis
John Williams, University of Tulsa

OnLocation, Inc., provided numerous hours of support in creating, running, and interpreting the NEMS-RFF model. Key contacts at OnLocation, Inc., included Kara Callahan, Lessly Goudarzi, Niko Kydes, Sharon Showalter, and Frances Wood.

Peer reviewers of the full report included Alan Beamon, Laurie Johnson, Tracy Terry, and John G. Williams. Peer reviewers of the technical reports included Michael Eaves, Michael Gallagher, John German, Mark Holt, Michael D. Jackson, Matthew Kotchen, Erin Mansur, Walter McManus, Mitchell Pratt, Greg Roche, and Roger von Haefen.

Valuable advice was provided by NEPI staff, including Director Brad Carson and Administrative Director Mary Haddican. RFF Research Assistants Maura Allaire and Gina Waterfield provided significant research support. Additional guidance was provided by the project's Advisory Committee: Phil Sharp (president, Resources for the Future), Robert Fri (former president, Resources for the Future), Ray Kopp (senior fellow, Resources for the Future), and George Kaiser (president of GBK Corporation).

We would also like to thank participants at our Technical Workshop in March 2009, including Roger Blais, Dallas Burtraw, Mark Cohen, John Conti, John Cymbalsky, Francisco de la Chesnaye, Meredith Fowlie, Howard Gruenspecht, Bill Harlow, Jim Hewlett, Andy Kydes, Molly Macauley, John Maples, David Montgomery, Chris Namovicz, Kate Probst, Heather Ross, Jhih-Shyang Shih, Kay Smith, and Glen Sweetnam.

Finally, significant editorial and publication support was provided by Peter Nelson, Felicia Day, Stan Wellborn, and Adrienne Foerster from RFF's Communications Department, as well as editorial consultant Karen McClure. The report layout and graphics were designed by FIREBRAND, LLC, under the direction of Scott Rodgerson.

Technical and Background Papers

The findings in this study draw on various technical and background papers commissioned by Resources for the Future and the National Energy Policy Institute as part of this project. These papers are available on the RFF website (www.rff.org) and the NEPI website (www.nepinstitute.org).

- *Oil and Gas Security Issues.* John Deutch (Massachusetts Institute of Technology)
- *Reassessing the Oil Security Premium.* Stephen P.A. Brown (Resources for the Future) and Hillard G. Huntington (Stanford University)
- *The Future of Natural Gas.* Steven Gabriel (University of Maryland)
- *Abundant Shale Gas Resources: Some Implications for Energy Policy.* Stephen P.A. Brown (Resources for the Future), Steven Gabriel (University of Maryland), and Ruud Egging (University of Maryland)
- *Energy Policies for Passenger Transportation: A Comparison of Costs and Effectiveness.* Kenneth A. Small (University of California–Irvine)
- *Hybrid Vehicles and Policies to Reduce GHG Emissions.* Virginia McConnell (Resources for the Future) and Tom Turrentine (Center for Transportation Studies, University of California–Davis)
- *The Prospective Role of Unconventional Liquid Fuels.* Joel Darmstadter (Resources for the Future)
- *Economics, Energy and GHG Implications of LNG Trucks.* Alan J. Krupnick (Resources for the Future)
- *Using Cap-and-Trade to Reduce Greenhouse Gas Emissions.* Lawrence H. Goulder (Stanford University)
- *Energy Efficiency in the Residential and Commercial Sectors.* Maximilian Auffhammer (University of California–Berkeley) and Alan H. Sanstad (Lawrence Berkeley National Laboratory)
- *Residential Retrofit Ground Source Heat Pump Benefits Assessment.* Xiaobing Liu (Oak Ridge National Laboratory)
- *Nuclear Energy in the US National Energy Modeling System: 2010–2030.* Geoffrey Rothwell (Stanford University)
- *Modeling Policies to Promote Renewable and Low Carbon Sources of Electricity.* Karen Palmer, Maura Allaire, and Richard Sweeney (Resources for the Future)
- *The Effects of State Laws and Regulations on the Development of Renewable Sources of Electric Energy.* Gary Allison (University of Tulsa) and John Williams (University of Tulsa)

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