CHAPTER 7

We Can Do It: Analyzing Solutions to Global Warming

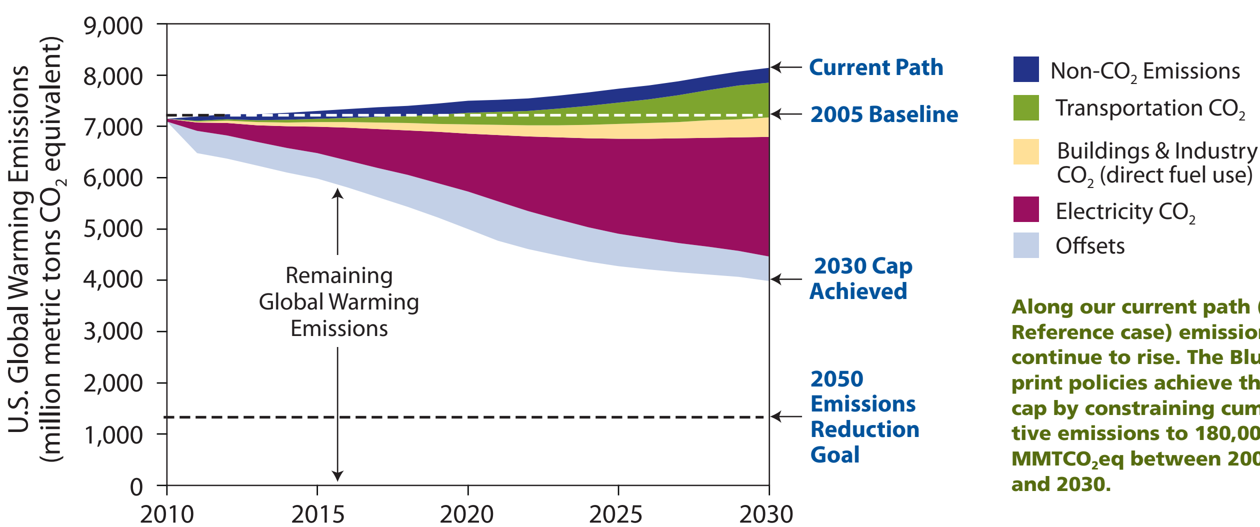
This chapter presents the results from implementing the Blueprint—a comprehensive suite of climate, energy, and transportation policies that tackle most sources of heat-trapping emissions in the electricity, residential, commercial, industrial, and transportation sectors, and that also allow a limited amount of offsets based on storing carbon in the agriculture and forest sectors (see Box 7.1).

Using the UCS-NEMS model and other analyses, we compared the impact of the Blueprint to that of a Reference case that assumes no new federal and state policies beyond the existing ones.[74] We also analyzed a No Complementary Policies case, which investigated the impact of stripping out all the sector-based complementary policies, and compared that case with the Blueprint case. (See Chapter 2 for more information.)

Our results include carbon prices and revenues under a cap-and-trade program, changes in energy use by fuel and sector, improvements in energy security (through reduced oil imports and a more diverse energy mix), and costs and benefits to consumers and businesses (see page 127).

Overall, our analysis shows that the Blueprint achieves significant cuts in net U.S. heat-trapping emissions in a timely manner while saving consumers and businesses significant amounts of money.

FIGURE 7.1. **Net Cuts in Global Warming Emissions under the Climate 2030 Blueprint**



Along our current path (the Reference case) emissions continue to rise. The Blueprint policies achieve the cap by constraining cumulative emissions to 180,000 $MMTCO_2eq$ between 2000 and 2030.

74 The Reference case includes policies that had become law by October 2008. The Reference case does not include the impact of the American Recovery and Reinvestment Act because it was passed after that date. However, the Reference case does include the (significant) impact of the 2007 Energy Independence and Security Act, as well as the effects of a variety of state renewable energy standards and the existing nuclear loan guarantee program.

BOX 7.1.

Climate 2030 Blueprint Policies[a]

Climate Policies

Economywide cap-and-trade program with:

- Auctioning of all carbon allowances
- Recycling of auction revenues to consumers and businesses[b]
- Limits on carbon "offsets" to encourage "decarbonization" of the capped sectors
- Flexibility for capped businesses to over-comply with the cap and bank excess carbon allowances for future use

Industry and Buildings Policies

- An energy efficiency resource standard requiring retail electricity and natural gas providers to meet efficiency targets
- Minimum federal energy efficiency standards for specific appliances and equipment
- Advanced energy codes and technologies for buildings
- Programs that encourage more efficient industrial processes
- Wider reliance on efficient systems that provide both heat and power
- R&D on energy efficiency

Electricity Policies

- A renewable electricity standard for retail electricity providers
- R&D on renewable energy
- Use of advanced coal technology, with a carbon-capture-and-storage demonstration program

Transportation Policies

- Standards that limit carbon emissions from vehicles
- Standards that require the use of low-carbon fuels
- Requirements for deployment of advanced vehicle technology
- Smart-growth policies that encourage mixed-use development, with more public transit
- Smart-growth policies that tie federal highway funding to more efficient transportation systems
- Pay-as-you-drive insurance and other per-mile user fees

a See Chapters 3, 4, 5, and 6 for more details on these policies.

b We could not model a targeted way of recycling these revenues. The preferred approach would be to target revenues from auctions of carbon allowances toward investments in energy efficiency, renewable energy, and protection for tropical forests, as well as transition assistance to consumers, workers, and businesses moving to a clean energy economy. However, limitations in the NEMS model prevented us from directing auction revenues to specific uses. Instead, we could only recycle revenues in a general way to consumers and businesses.

7.1. The Reference Case: Significant Growth in Carbon Emissions

In the Reference case, U.S. global warming emissions rise from 7,181 million metric tons carbon dioxide equivalent (MMTCO_2eq) in 2005 to 8,143 MMTCO_2eq in 2030—an increase of 13.4 percent. Total U.S. energy use rises by nearly 16 percent over the same period, or an average of 0.74 percent per year, with fossil fuel use growing 10 percent.

Most of the increase in carbon emissions and energy use in this scenario stems from greater use of coal to generate electricity and produce liquid fuels for the transportation and industrial sectors. Growth in the use of natural gas in industry and buildings also makes a modest contribution to rising carbon emissions.

The use of oil and other petroleum products declines in the Reference case, as policies in the 2007 Energy Independence and Security Act improve the efficiency of vehicles and expand the use of biofuels. The nation's reliance on renewable energy from wind, solar, geothermal, and biomass resources more than triples by 2030 under the Reference case. Contributions from nuclear energy and hydropower remain relatively flat. However, overall, the nation continues to rely heavily on both fossil fuels and nuclear power to provide 89 percent of its energy.

7.2. The Big Picture: The Blueprint Cuts Carbon Emissions, Saves Money, and Reduces Energy Use

7.2.1. Significant Near-Term and Medium-Term Cuts in Emissions

Under the Blueprint, the nation achieves significant near-term and mid-term cuts in global warming emissions at a net savings to consumers. Blueprint policies reduce U.S. carbon emissions enough to meet a cap set at 26 percent below 2005 levels in 2020, and 56 percent below 2005 levels in 2030 (see Figure 7.1).

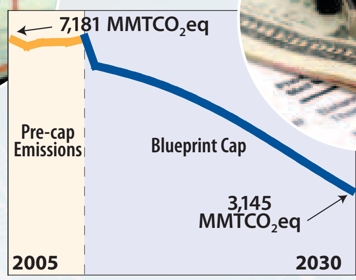
In Figure 7.1, the actual year-by-year trajectory of cuts in emissions differs from the trajectory specified under the cap-and-trade program, because that program gives companies the flexibility to bank extra carbon allowances in early years and withdraw them in later years.[75] However, cumulative heat-trapping emissions from 2000 to 2030 remain the same under both

75 See Section 7.3.2 for a fuller explanation of how the banking and withdrawing occurred in our results. Further information is available in Appendix B online.

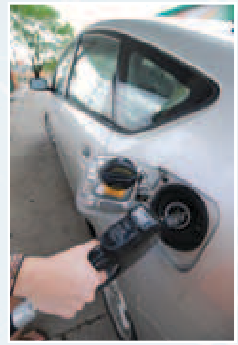
Major Findings of the Climate 2030 Blueprint

IN 2030, THE UNITED STATES CAN:

#1 Meet a phased-in cap on global warming emissions representing a 56 percent drop from 2005 levels, at a net annual savings of $464 billion to consumers and businesses.



#2 Reduce annual energy use by one-third compared with the Reference case.

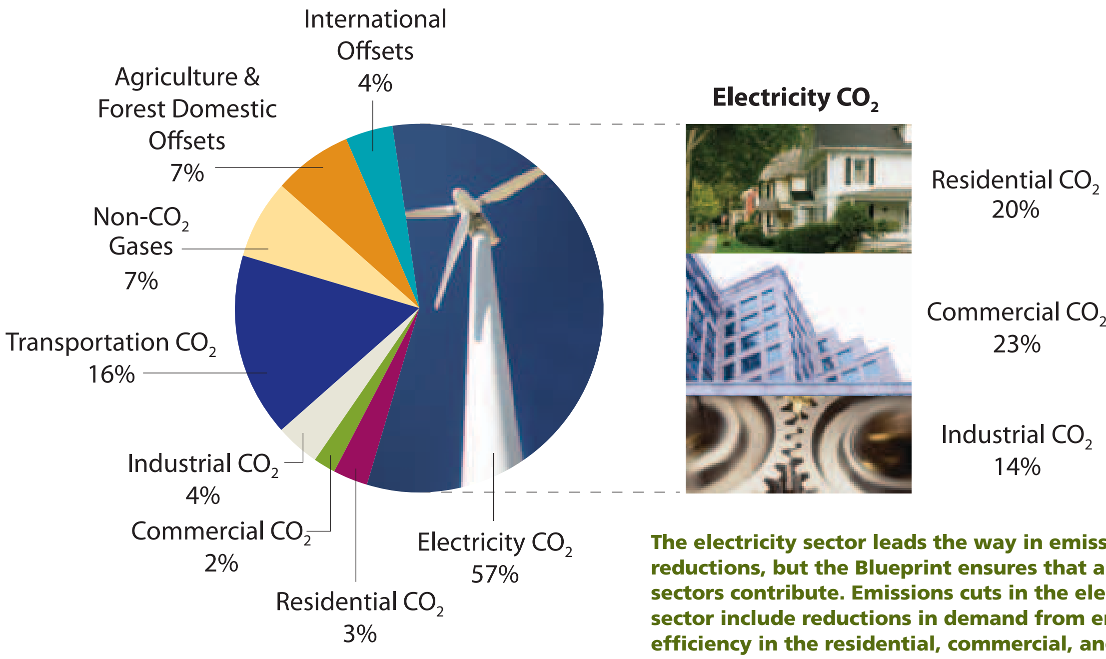


#3 Cut the use of oil and other petroleum products by 6 million barrels per day compared with 2005, reducing imports to less than 45 percent of our needs and cutting projected expenditures on those imports by more than $85 billion, or more than $160,000 per minute.

#4 Reduce annual electricity generation by 35 percent compared with the reference case, through the use of greater energy efficiency in buildings and industry, while producing 16 percent of the remaining electricity with combined heat and power and 40 percent with renewable energy resources, such as wind, solar, geothermal, and bioenergy.

#5 Rely on complementary policies to deliver cost-effective solutions based on efficiency, conservation, and renewable energy. Excluding Blueprint policies in the energy and transportation sectors reduces net cumulative consumer and business savings through 2030 from $1.7 trillion to $0.6 trillion.

FIGURE 7.2. The Source of Cuts in Global Warming Emissions in 2030
(Blueprint case vs. Reference case)



The electricity sector leads the way in emissions reductions, but the Blueprint ensures that all sectors contribute. Emissions cuts in the electricity sector include reductions in demand from energy efficiency in the residential, commercial, and industrial sectors.

Note: Refinery emissions have been allocated to the appropriate end-use sector. Transportation emissions do not include full well-to-wheel emissions, because UCS-NEMS does not account for emissions associated with products imported into the United States.

trajectories: about 180,000 $MMTCO_2eq$.[76] If the nation continues along the path of the cap modeled here, we could remain in the mid-range of the U.S. carbon budget in 2050 (165,000–260,000 $MMTCO_2eq$ from 2000 to 2050), with cumulative emissions of 216,000 $MMTCO_2eq$ by 2050.

Under the Blueprint, actual emissions are 30 percent below 2005 levels in 2020, and 44 percent below 2005 levels in 2030. Those reductions are 33 percent below those of the Reference case in 2020, and 51 percent below the Reference case in 2030 (see Figure 7.1). These reductions are a first and critical step to putting the nation on a path to achieving the 2050 targets needed to avoid the most dangerous effects of climate change.

In 2030, the largest cuts in carbon emissions (57 percent) come from the electricity sector (see Figure 7.2). Transportation delivers the next-largest reduction in global warming emissions, at 16 percent (or about 24 percent, if we remove cuts stemming from the 2007 Energy Independence and Security Act from the Reference case).[77]

Offsets from storing carbon in U.S. agricultural lands and forests, and international offsets mainly from avoided tropical deforestation, provide 11 percent of the cuts in carbon emissions. Reductions in emissions from direct fuel use in industry and buildings contribute 9 percent of the total drop. Cuts in non-CO_2 emissions deliver the remaining 7 percent.

7.2.2. National Consumer and Business Costs and Savings under the Blueprint

The Blueprint policies not only dramatically cut carbon emissions—they also save consumers and businesses money. Considering costs and savings together, consumers will see annual savings from the Blueprint of $464 billion in 2030 compared with the Reference case (see Table 7.1).

Americans will save $414 billion on their energy bills in 2030 (on their monthly electricity bills, and on

76 Apart from the Blueprint policies, the United States could spur another 10 percent reduction in global emissions by investing in forest protection in developing countries (Boucher 2008), and potentially an additional amount by investing in clean technology in those countries.

77 Cuts in heat-trapping emissions in the transportation sector include those from refining transportation fuels.

gasoline costs, for example), even though those bills include the cost of carbon allowances passed through to consumers and businesses in higher energy prices. These savings also take into account the costs of renewable electricity, carbon capture and storage, and renewable fuels that are passed on to consumers and businesses through slightly higher energy prices. Consumers and businesses save money because energy efficiency and conservation measures lower total energy use under the Blueprint.

Of course, these savings would not come free. In 2030, consumers and businesses would have to invest about $160 billion in more efficient appliances and vehicles, upgrades to buildings, improved industrial processes, and expanded transit. That would leave consumers and businesses with a net annual savings of $255 billion. What's more, revenues from auctioning carbon allowances would be recycled back into the economy, putting another $219 billion back into the pockets of both consumers and businesses.

The costs of implementing Blueprint policies include the nearly $8 billion that government and industry will have to invest in 2030 to cover R&D on energy efficiency and cleaner energy, plus tax credits and the implementation costs of pursuing other policies under the Blueprint (see Table 7.1).[78]

The costs and savings associated with Blueprint policies are spread throughout the economy. The net annual savings for consumers and businesses of $255 billion in 2030 include utility and gasoline bills that incorporate carbon costs, per-mile congestion fees, and the cost of energy-consuming products.

While our analysis recycled the revenues from auctioning carbon allowances back into the economy (half to consumers and half to businesses), that recycling could occur in ways that further lower costs or increase climate benefits. For example, government could use the funds to provide tax credits for purchases of more efficient vehicles and appliances, to increase renewable energy use, or to encourage land uses that store more carbon.

TABLE 7.1. Annual Blueprint Savings

(in billions of 2006 dollars)

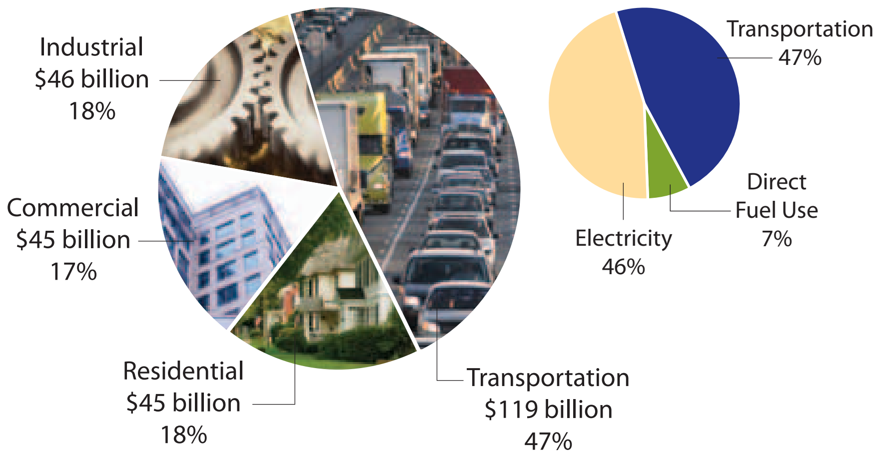
FEDERAL RESERVE NOTE	2015	2020	2025	2030
Energy Bill Savings	$ 39	$152	$271	$414
Energy Investment Costs	-40	-80	-123	-160
Net Consumer and Business Savings	$ -1	$ 72	$147	$255
Allowance Revenue Generated	+145	+181	+207	+219
Added Policy Implementation Costs	-9	-13	-8	-8
Blueprint Savings	$136B	$240B	$345B	$464B

Note: Values may not sum properly due to rounding.

Considering costs, savings, and recycling auction revenues, consumers and businesses will see annual savings from the Blueprint of $464 billion in 2030 (compared with the Reference case). These savings, of course, do not come for free. Consumers and businesses will need to invest in low-carbon energy technologies, efficiency, and conservation, and these investments quickly pay off with lower energy bills—using less electricity and fuel results in savings, even at slightly higher energy prices.

78 The cap-and-trade program will require moderate administrative costs. We were unable to quantify those costs explicitly in our analysis, but expect that they are too small to significantly influence our results.

FIGURE 7.3. **The Source of Savings in 2030**
(Blueprint case vs. Reference case)



Consumers and businesses see $255 billion in net annual savings in 2030 under the Blueprint (in 2006 dollars). Consumers and businesses in the transportation sector reap the largest share. Residential, commercial, and industrial consumers each gain just under 20 percent of the net savings, with nearly 90 percent of that amount—or $118 billion—stemming from lower electricity costs.

7.2.3. Distributing the Costs and Savings under the Blueprint

The costs and savings associated with Blueprint policies are spread throughout the economy. The net annual savings for consumers and businesses of $255 billion in 2030 include utility bills, gasoline bills, per-mile congestion fees, and the cost of energy-consuming products. However, those savings exclude any policy costs funded by general taxpayer revenues, the costs that utilities and fuel providers do not pass on to consumers, and the recycling of any revenues from auctions of carbon allowances.[79]

Based on end-use, transportation bears the largest portion of those costs, at 32 percent of the $160 billion in energy investment costs in 2030, followed by the commercial sector at 25 percent. Industrial and residential consumers each carry slightly less than 20 percent of the energy investment costs in 2030.

Transportation users reap the largest share—40 percent—of the $414 billion in savings on energy bills in 2030 under the Blueprint. Residential, commercial, and industrial consumers each receive about 20 percent of the total savings, with savings on electricity bills accounting for more than 70 percent of the total.

Households and businesses that rely on the transportation sector see nearly half of the net annual savings ($119 billion) in 2030 (see Figure 7.3). However, Blueprint policies ensure that consumers and businesses throughout the economy save money on energy expenses. Lower electricity costs are responsible for $118 billion in net annual savings for industrial, commercial, and residential customers.

The net savings in 2030 are split almost evenly between businesses ($128 billion) and consumers ($126 billion), and are spread throughout all regions of the country (see Figure 7.4). The consumer savings are also spread among the projected 140 million American households in 2030, cutting the annual household cost of energy and transportation by $900 that year compared with the Reference case.

7.2.4. National Economic Growth under the Blueprint

Under the Blueprint, gross domestic product (GDP) remains practically unchanged from the Reference case. In the latter, GDP grows from $11 trillion in 2005 to $20.2 trillion in 2030, an overall growth of 84 percent, and an average annual growth rate of 2.47 percent (in 2000 dollars).

Under the Blueprint, GDP grows from $11 trillion in 2005 to $19.9 trillion in 2030, an overall growth of 81 percent and an average annual growth rate of 2.41 percent. In the Blueprint case, GDP in 2030 is less than 1.5 percent below that in the Reference case—equivalent to only 10 months of economic growth over a 25-year period.[80] This shows that the nation can

79 A congestion fee of $0.006 per mile under the Blueprint would represent a charge to drivers for the cost of delays and pollution caused by congestion. The fees would be used to expand mass transit as an alternative to driving.

80 This means that, under the Blueprint, the economy reaches the same level of economic growth in October 2030 as the Reference case reaches in January 2030.

implement effective policies to tackle global warming without harming economic growth.

The Blueprint also shows practically the same employment trends as the Reference case. In fact, nonfarm employment is slightly higher under the Blueprint than in the Reference case (170 million jobs versus 169.4 million in 2030).

Many other studies have also shown that the effects of such policies on the economy are small (see Keohane and Goldmark 2008 for a summary). And small differences are swamped by the uncertainty inherent in predicting GDP as far out as 2030. As Keohane and Goldmark point out, predictions from different models of GDP in 2030 can differ by as much as 10 percent.

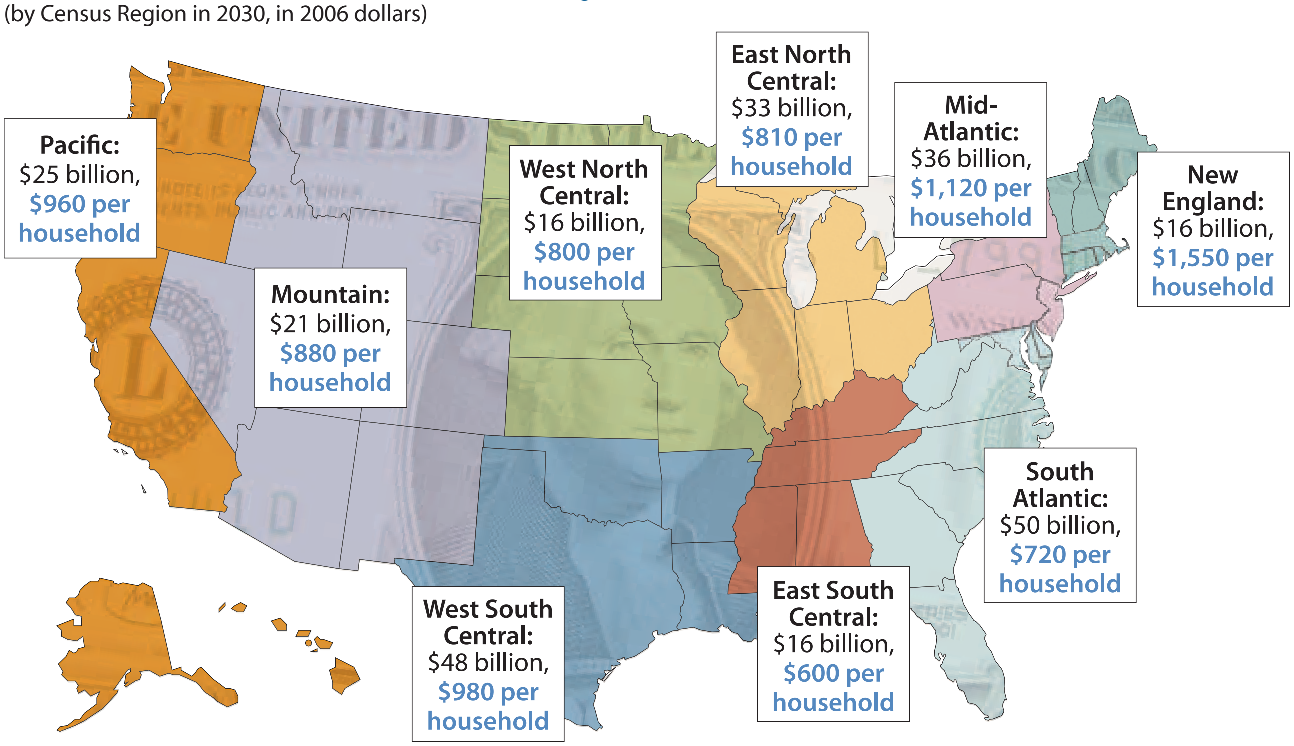
Meanwhile the 2006 *Stern Review of the Economics of Climate Change* found that the costs of unchecked global warming could range from 5 to 20 percent of worldwide GDP, depending on the severity of climate change, by the end of this century (Stern 2006).

What's more, the NEMS model itself has serious limitations in its ability to account for the impact of Blueprint policies on GDP. For example, it is unable to fully consider the positive effects on GDP from investments in the energy and transportation sectors that enable consumers and businesses to save money on energy bills and spend it more productively. The model also does not include the effects on GDP of unchecked global warming in the Reference case.

7.2.5. Significant Reductions in Energy Use under the Blueprint

Under the Blueprint, total energy use is one-third (39 quadrillion Btu) lower than under the Reference case by 2030, and 23 percent below 2005 levels, because of a significant increase in energy efficiency in all sectors and with all fuels, as well as cuts in car and truck travel (see Table 7.2). Use of non-hydro renewable energy is 25 percent higher than in the Reference case by 2030,

FIGURE 7.4. Net Consumer and Business Savings
(by Census Region in 2030, in 2006 dollars)



Net Annual Savings in 2030	**Total**	**$255 billion**
	Business	$128 billion
	Consumers	$126 billion
	Average Consumer	**$900 per household**

Note: Values may not sum properly because of rounding.

Consumers and businesses in every region of the country save billions of dollars under the Blueprint. Household numbers do not include business savings.

with that sector's share of total energy use rising to 21 percent by 2030, after accounting for improvements in energy efficiency.

Greater energy efficiency and use of renewable energy reduce coal use 85 percent by 2030 compared with the Reference case, with most of the cuts coming from the electricity sector. However, the Blueprint does show a modest increase in the use of advanced coal plants with carbon capture and storage before 2030 compared with the Reference case. That technology could play a more significant role if its cost declines faster than the Blueprint assumes, or if the nation does not pursue energy efficiency and renewable energy as aggressively.

Natural gas use is more than one-third lower in 2030 under the Blueprint compared with the Reference case, primarily because of energy efficiency improvements in industry and buildings, and more modest use of natural gas in power plants. Oil use is about 24 percent lower in 2030, with most of the reduction occurring in transportation and industry. The use of nuclear and hydropower, which do not produce carbon emissions directly, is similar to that in the Reference case.

7.2.6. Curbing Our Oil Addiction under the Blueprint

The Blueprint reduces demand for oil and other petroleum products in 2030 by about 6 million barrels per day—or 30 percent—compared with 2005 (see Figure 7.5). That drops imports to less than 45 percent of U.S. demand for petroleum, compared with more than 60 percent in 2005.

Because the United States is the world's largest petroleum consumer, cutting U.S. demand by 30 percent helps hold oil prices to $80–$88 per barrel from 2020 to 2030—about $10 per barrel below Reference case projections. As a result of lower oil prices and reduced

TABLE 7.2. Comparison of U.S. Energy Use

(Blueprint case vs. Reference case, in quadrillion Btu)

	2005	2020		2030	
Fuel		**Reference Case**	**Blueprint Case**	**Reference Case**	**Blueprint Case**
Petroleum	40.1	37.9	33.4	38.1	28.8
Natural Gas	22.6	23.8	18.5	23.6	15.7
Coal	22.8	25.2	15.1	29.3	4.5
Nuclear Power	8.2	8.8	8.8	8.6	8.5
Hydropower	2.7	3.1	3.1	3.2	3.2
Other Renewables[a]	3.5	9.1	10.7	13.0	16.2
Other[b]	0.2	0.2	0.2	0.3	0.3
Total	100.1	108.0	89.8	115.9	77.2
Energy Savings					
vs. Reference case			**17%**		**33%**
vs. 2005			**10%**		**23%**

Notes:

a "Other renewables" include grid-connected electricity from landfill gas, biogenic municipal waste, biomass, wind, geothermal, solar photovoltaic and thermal sources, and non-electric energy from biofuels and active and passive solar systems. These values exclude imported electricity generated from renewable sources and non-marketed renewable energy.

b "Other" includes non-biogenic municipal waste and net electricity imports.

The Blueprint policies reduce projected U.S. energy use one-third by 2030, with the help of efficiency and conservation. Carbon-free electricity and low-carbon fuels together make up more than 33 percent of the remaining energy use; other renewable energy sources increase by 25 percent while nuclear and hydropower stay relatively flat.

demand, the United States spends about $550 million per day on oil imports in 2030—about $450 million less than in the Reference case.

Those savings could end up higher or lower depending on a variety of factors not included in the NEMS-UCS model. If political instability rises, or if world demand exceeds supply, the resulting spikes in oil prices could mean dramatically higher savings under the Blueprint. In fact, reduced demand for oil is an insurance policy against exactly that scenario. If OPEC nations respond by reducing supply to drive up prices and thus siphon off some of our savings, the U.S. economy will be much more resilient in the face of such tactics.

7.2.7. Economywide Growth in the Use of Bioenergy under the Blueprint

Use of bioenergy is projected to more than triple by 2030 under the Blueprint. That increase is driven first by the production and use of biofuels in the transportation sector, and second by the use of biomass to generate electricity. Bioenergy use in the industry and buildings sectors does not change significantly in the Blueprint case (see Figure 7.6).

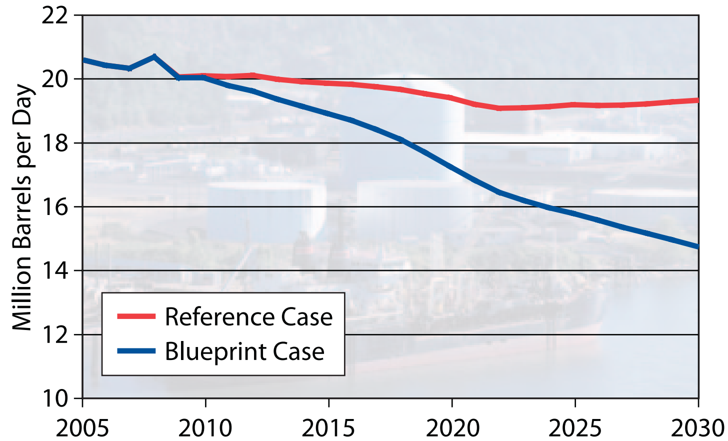
While significant, the growth in biofuel use is almost the same as that in the Reference case, because most of that use stems from the national renewable fuel standard included in the 2007 Energy Independence and Security Act. By 2030, nearly two-thirds of the U.S. supply of bioenergy is used for biofuels.

As a result, total bioenergy use in the Blueprint case is only 16 percent higher by 2020, and 3 percent higher by 2030, than in the Reference case. Almost all of this increase occurs in the electricity sector, where biomass is burned with coal in existing coal plants over the near-term and mid-term, and in dedicated biomass power plants over the longer term, to help meet the national renewable electricity standard.

Increases in bioenergy use under the Blueprint are modest, because we assumed certain limits on the amount of cellulosic crops grown for energy use, to minimize direct and indirect carbon emissions. These limits, and significant increases in demand for biofuels, mean that nearly all cellulosic crops and agricultural residues are used for transportation fuels by 2030 in the Reference case.

Growth in the use of bioenergy is also limited by the assumption in UCS-NEMS that use of forest, mill, and urban residues is restricted to the electricity sector. Finally, the use of corn for biofuels dropped under the Blueprint because that use does not reduce carbon emissions compared with gasoline. These factors limit the ability of the transportation sector to meet an even more stringent low-carbon fuel standard, which would have driven up the use of biofuels.

FIGURE 7.5. Demand for Petroleum Products



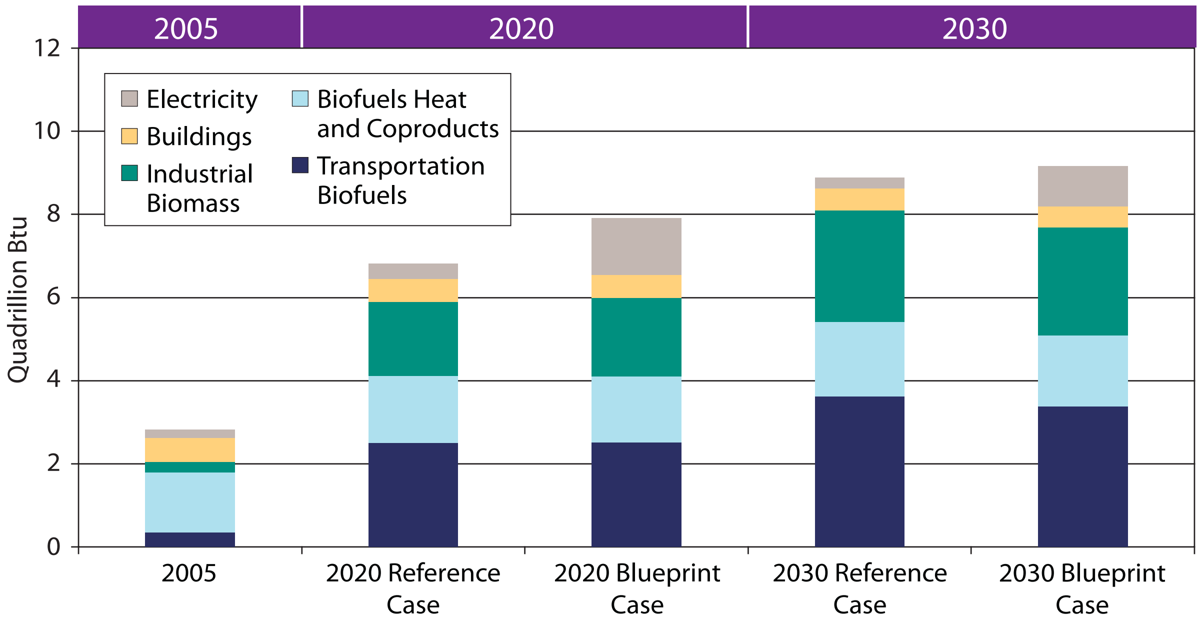
In 2030, the Blueprint cuts the use of petroleum products by 6 million barrels a day compared with 2005 levels. Because the United States is the world's largest petroleum consumer, cutting our demand this significantly could help lower oil prices.

Transitioning to a low-carbon energy system helps us kick our oil addiction and reduce our dependence on oil from politically troubled regions, such as the Middle East. By 2030, the Blueprint cuts the use of oil and other petroleum products by 6 million barrels per day—as much oil as the nation now imports from OPEC.

7.3. Detailed Results: The Blueprint Cap-and-Trade Program

The cap-and-trade program modeled as part of our Blueprint policies helps deliver the necessary level of cuts in global warming emissions. The next sections explore major findings related to key aspects of this program (described in Chapter 3).

FIGURE 7.6. **Bioenergy Use**
(Blueprint case vs. Reference case)



Note: Biofuels heat and coproducts represent the biomass energy that is left over from the process of turning that biomass into biofuels for the transportation sector. This energy ends up as useful heat, electricity, or animal feed.

U.S. bioenergy use is projected to more than triple by 2030 under the Blueprint, due mainly to increased use in the transportation and electricity sectors. While significant, the growth in biofuel use is similar to the Reference case because of the national renewable fuel standard included in the 2007 Energy Independence and Security Act. To minimize direct and indirect carbon emissions, the Blueprint assumed limits on the supply of energy crops; therefore, increases in bioenergy use are modest.

7.3.1. Prices of Carbon Allowances and the Resulting Revenues

The comprehensive policy approach in the Blueprint has a moderating effect on the prices of carbon allowances. These prices range from $18/ton in 2011 (the year the program starts) to $34/ton in 2020 to $70/ton in 2030 (all prices in 2006 dollars) (see Figure 7.9).

Those prices are well within the range that other analyses find, despite our stricter cap on economywide emissions. In addition, the Blueprint achieves much larger cuts in carbon emissions within the capped sectors because of the tighter limits that we set on offsets, and because of our more realistic assumptions about the cost-effectiveness of investments in energy efficiency and renewable energy technologies.

Under the Blueprint case, the revenues raised from auctioning 100 percent of allowances to emit carbon are significant, amounting to a cumulative total of $1.3 trillion by 2030 (in 2006 dollars, discounted at a 7 percent rate). Annual revenues range from $116 billion in 2011—the year the cap-and-trade program goes into effect—to $181 billion in 2020, and to $219 billion in 2030 (all figures in 2006 dollars).

We assumed that the government recycles these revenues directly back into the economy, so they represent a transfer payment rather than an actual cost of this policy. However, because of limitation in the UCS-NEMS model, we could not model a targeted way of recycling the revenues to specific purposes. We could only model recycling revenues in a general way to consumers and businesses.

The preferred approach would be to target revenues toward investments in energy efficiency, low-carbon technologies, and protection of tropical forests, as well as transition assistance to consumers, workers, and businesses to help them make the shift to a clean energy economy. Those uses would reduce carbon emissions and create additional economic benefits, such as savings on energy bills.

7.3.2. Banking and Withdrawing

We allowed companies subject to the cap-and-trade program to engage in unrestricted banking and withdrawing of carbon allowances, and assumed a final bank balance of zero in 2030. This is a flexibility mechanism that allows firms to choose a cost-effective path to cutting their emissions, and that reduces the volatility of the price of carbon allowances.

Our results show that the most cost-effective path to meeting the emissions cap is one in which firms overcomply with the cap requirements and accumulate banked allowances until 2024. That result is typical in modeling cap-and-trade programs. For example, the Energy Information Agency's modeling of the Lieberman-Warner Climate Security Act of 2008 also showed a similar build-up of banked allowances (EIA 2008).[81]

Under the Blueprint case, the revenues raised from auctioning 100 percent of allowances to emit carbon are significant, amounting to a cumulative total of $1.3 trillion by 2030 (in 2006 dollars, discounted at a 7 percent rate).

We also find that firms run down the allowance bank to zero in 2030, a result driven by our assumption of a zero terminal bank balance.

As a result of this banking and withdrawing, the actual trajectory of carbon emissions under the model diverges from the trajectory set in the cap. For example, in 2020 U.S. heat-trapping emissions are 30 percent below 2005 levels—higher than the 26 percent required by the cap. In 2030 they are 44 percent below 2005 levels: lower than the 56 percent required by the cap. However, cumulative emissions—the critical metric—are the same under both trajectories (see Figure 7.7).

7.3.3. Prices of Carbon Offsets

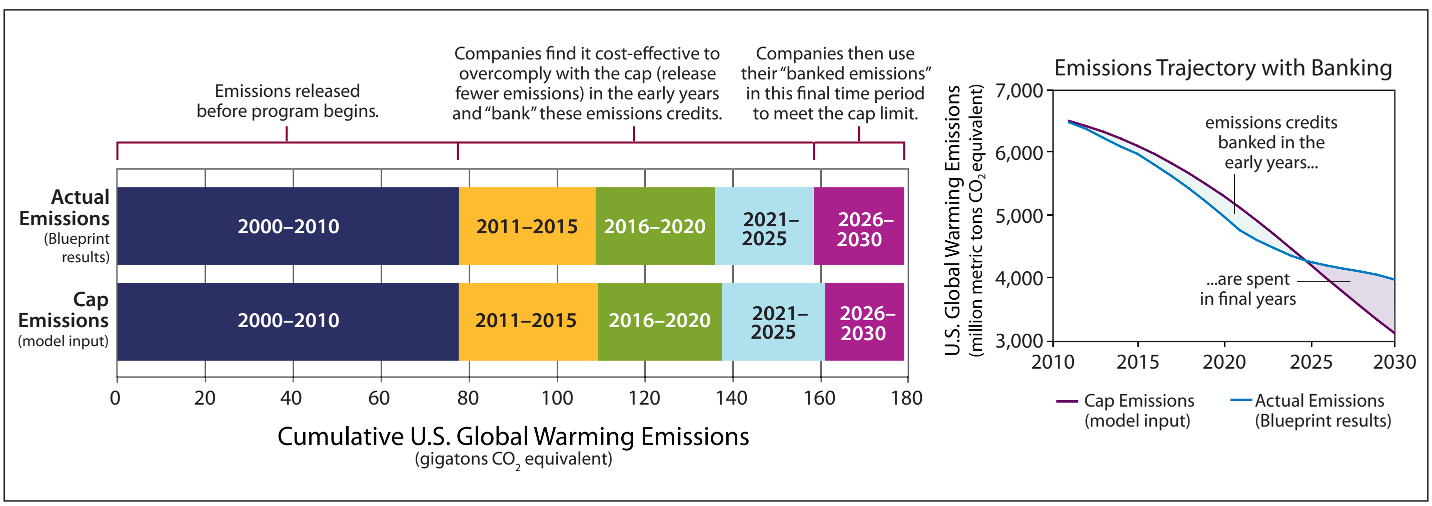
High-quality carbon offsets—if limited—can play an important role in a cap-and-trade program (see Chapter 3). Our results show that in the early years of the Blueprint cap-and-trade program, many cost-effective opportunities for cutting emissions are available within the capped sectors, so firms do not need to use the full amount of offsets available to them.

The limit on domestic offsets that we modeled—amounting to 10 percent of the cap on global warming emissions—becomes binding starting in 2020. Until that year, the price of domestic offsets is the same as

81 In fact, in that case, because the modeling imposed a positive final bank balance of 5 billion metric tons, the results show banking through 2030.

FIGURE 7.7. Actual Emissions Compared with Cap Emissions

(Blueprint results vs. model input, 2000–2030)



The bar graph shows two scenarios for cumulative emissions from 2000–2030. Although each scenario takes a slightly different path, the end point in 2030 is the same. The bottom bar in the graph corresponds to the cumulative emissions set under the cap, while the top is the actual cumulative emissions that emerged from our modeling results. From 2000–2010, before the start of the Blueprint cap-and-trade program, the cumulative emissions are the same in both cases. After 2010 the two trajectories diverge (actual cumulative emissions are lower than those required by the cap in the first three periods, and higher in the final period). What's important for the climate is that the United States stays within the emissions limits set by the cap-and-trade program.

the price of carbon allowances (for example, $18 per ton of carbon in 2011, and $34 per ton in 2020). After that point, the price of offsets drops below the price of carbon allowances, because offset providers now have to compete with each other to meet the limited demand. The price of domestic offsets drops to $26 per ton in 2025, and $18 per ton in 2030 (see Figure 7.8).

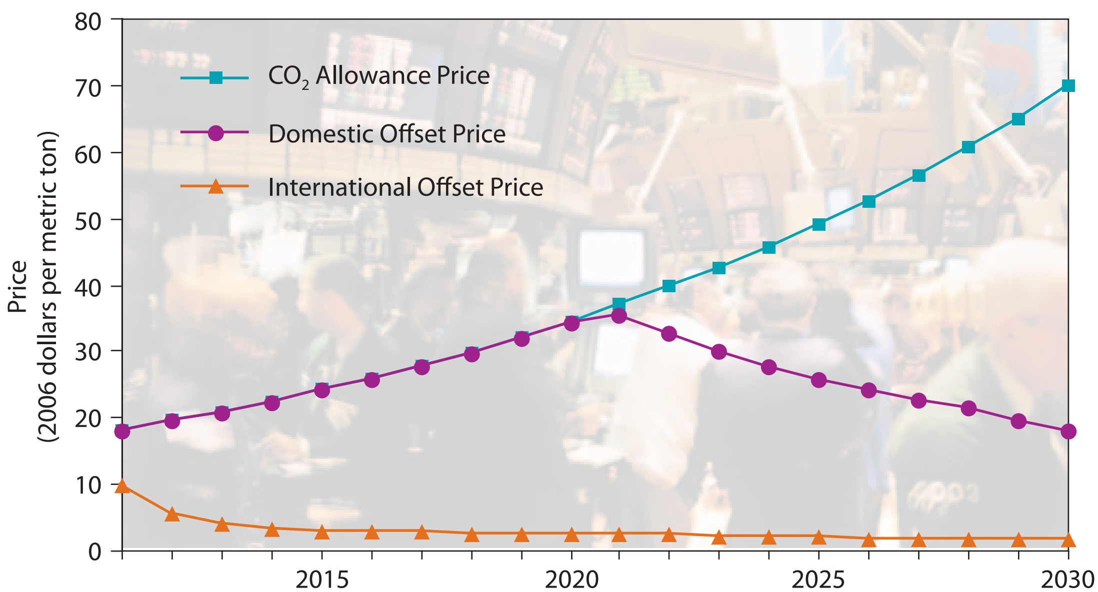
International offsets are available at a significantly lower price than that of carbon allowances and domestic offsets, based on our supply curve assumptions (see Appendix B online). The price of these offsets ranges from $10 per ton in 2011 to about $2 per ton in 2020, and to just more than $1/ton in 2030. Our limit on international offsets—amounting to 5 percent of the cap on emissions—becomes binding as soon as the cap-and-trade program begins.

Limits on offsets help ensure that the capped sectors make the needed long-term investments to reduce carbon emissions.

The domestic offsets we modeled are based on activities that increase carbon storage in agriculture and forests, such as changes in tillage practices, afforestation, and better forest management.[82] Because of scientific uncertainties in measuring emissions from these sectors, it is hard to cap the sectors directly, though they can be included in a cap-and-trade program as a (bounded) source of offsets. Forests and agriculture have a significant potential to contribute to U.S. global warming solutions, which specific (non-offset) policies targeting these sectors could encourage (see page 166).

Carbon storage in forests and soils is also subject to saturation or even reversal, so we cannot count on such offsets as a permanent solution to global warming. Eventually, forests and soils will stop absorbing carbon, and could even turn into net sources of carbon emissions.[83]

FIGURE 7.8. Prices of Carbon Allowances and Offsets under the Climate 2030 Blueprint

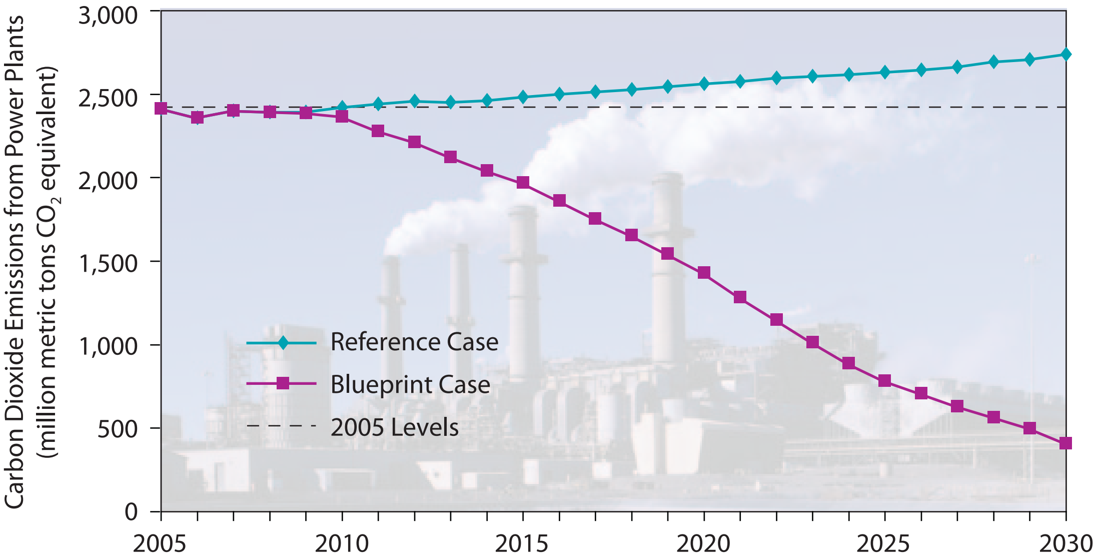


A cap-and-trade system generates a carbon price designed to encourage the capped sectors—such as electricity and oil refining—to lower their emissions and invest in clean technologies. The Blueprint also allowed a limited amount of offsets, both from the United States and other countries, as an alternative way for firms to comply with the cap. The prices of these offsets vary depending on their source, the relative cost of reducing emissions within the capped sectors, and whether the maximum limit on offsets is reached.

82 We used the supply curves for domestic offsets based on carbon sequestration in agriculture and forests embedded in the NEMS model. These, in turn, are based on information from the Environmental Protection Agency, derived from the FASOMGHG model (see Section 7.7.2). Although we have concerns about the criteria used to construct these supply curves, we were unable to find enough robust data to construct different ones.

83 Without policy intervention, many forests are poised to release carbon now, given droughts, fires, and pest outbreaks associated with global warming, as well as poor management practices.

FIGURE 7.9. Carbon Dioxide Emissions from Power Plants



Carbon emissions from power plants grow nearly 14 percent by 2030 under the Reference case, as coal use increases to help meet projected growth in electricity demand. Under the Blueprint, however, power plant carbon emissions are 84 percent below 2005 levels by 2030. Sulfur dioxide, nitrogen oxide, and mercury emissions from power plants are also significantly lower under the Blueprint, which, by improving air and water quality, would provide public health benefits.

The international offsets we modeled are based primarily on reduced emissions stemming from avoided tropical deforestation.[84]

7.4. Detailed Results: The Electricity Sector

7.4.1. Reference Case: Carbon Emissions from Power Plants Grow

Under the Reference case, carbon emissions from power plants continue to rise over time, as fossil fuel use increases to help meet growth in electricity demand (see Figure 7.9). By 2030, CO_2 emissions from power plants grow by nearly 14 percent over 2005 levels. The Reference case projects that U.S. electricity use will grow 25 percent from 2005 to 2030, because technologies and practices to encourage energy efficiency will be underused.

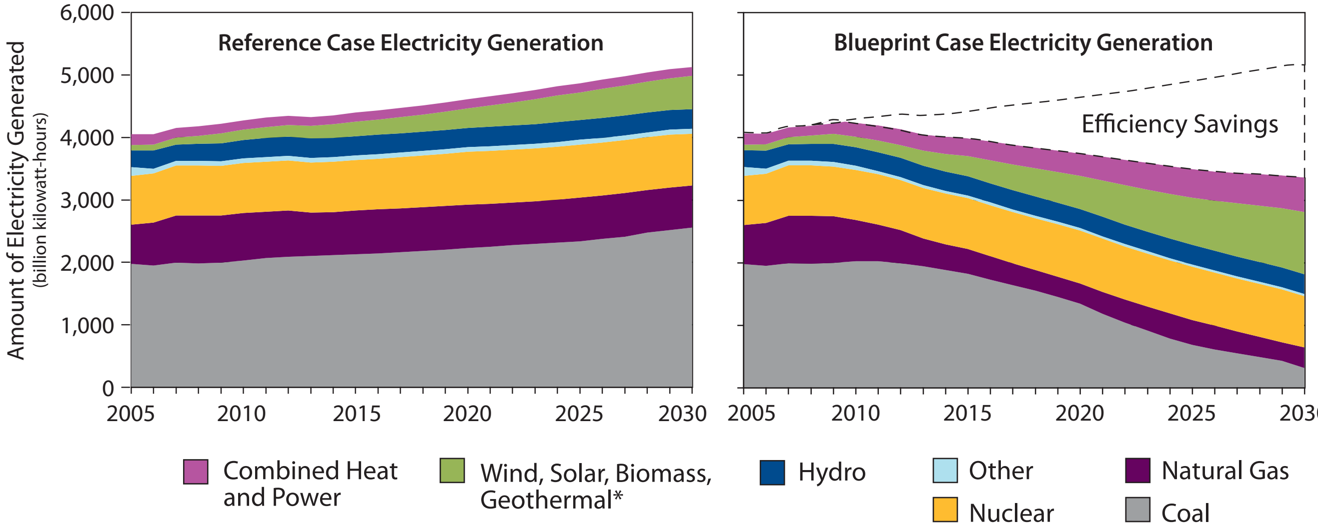
Nearly all of the increase in carbon emissions from power plants in the Reference case is due to expanded use of coal to produce electricity, which remains the dominant fuel for that use. Coal-based electricity grows 29 percent by 2030, as the nation builds 61 gigawatts of new capacity—the equivalent of more than 100 new 600-megawatt coal plants. That is considerably lower than the EIA's projection in 2008 that the nation will have 104 gigawatts of new coal capacity by 2030. However, it is about one-third higher than the agency's projection in 2009 that the nation will have 46 gigawatts of new capacity by 2030 (EIA 2008a; 2009).

Electricity produced from natural gas, nuclear, and combined-heat-and-power (CHP) plants all remain relatively unchanged in the Reference case (see Figure 7.10). While the nation adds 87 gigawatts of new natural gas capacity by 2030, most of these plants displace older, less efficient natural gas plants, or produce electricity only during periods of high demand. And while loan guarantees and tax credits available under current law spur construction of 4.4 gigawatts of new nuclear capacity (four new plants), this replaces a similar amount of nuclear capacity that will go out of service when the 20-year license extensions of today's plants expire.

Electricity from renewable resources, including wind, solar, geothermal, and biomass, expands from 3 percent of total demand in 2008 to about 10 percent in 2030 in the Reference case. That increase in market share is due largely to state renewable electricity standards, federal tax credits, and an increase in combined heat and power from new biofuel plants built under

84 For 2011 to 2015, we used the international offsets supply curve developed by the EIA for NEMS, which is based on data from the EPA (see footnote 9). For 2015 to 2030, we used a supply curve based solely on offsets from avoided tropical deforestation, developed by UCS analysts (see Appendix B online for more details).

FIGURE 7.10. Sources of Electricity
(Reference case vs. Blueprint case)



* Landfill gas and incremental hydro are also included in this category.

The Blueprint reduces electricity demand and diversifies our electricity mix. If we continue on our current path (as represented by the Reference case), electricity use continues to grow and this increased demand is met primarily by carbon-intensive coal-fired power plants. The Blueprint, conversely, reduces electricity demand 35 percent in 2030 through aggressive energy efficiency measures, while generation from efficient combined-heat-and-power plants more than triples over current levels, and renewable electricity expands to 40 percent of the nation's total electricity use.

the federal renewable fuel standard (see Section 7.6). Most of the increase in renewable electricity comes from wind and bioenergy, followed by geothermal and distributed solar photovoltaics (PV). Hydroelectric power remains relatively unchanged, providing 6 percent of U.S. electricity by 2030.

7.4.2. Blueprint Case: Dramatic Cuts in Power Plant Emissions

Under the Blueprint, the electricity sector makes the biggest contribution to reducing U.S. global warming emissions, providing 57 percent of all cuts in 2030, compared with the Reference case. Carbon emissions from power plants are 41 percent below 2005 levels by 2020, and 84 percent below 2005 levels by 2030. Sulfur dioxide (SO_2), nitrogen oxide (NOx), and mercury emissions from power plants are also significantly lower under the Blueprint, which would improve air and water quality and thus provide important public health benefits.

Most of the cuts in emissions in the electricity sector come from replacing coal plants with efficiency, combined heat and power, and renewable energy under the Blueprint (see Figure 7.10). By 2030, energy efficiency measures—such as advanced buildings and industrial processes, and high-efficiency appliances, lighting, and motors—reduce demand for electricity 35 percent below the Reference case. CHP based on natural gas in the industrial and commercial sectors is nearly 3.5 times higher than today's levels, providing 16 percent of U.S. electricity by 2030. Largely because of the national renewable electricity standard, wind, solar, geothermal, and bioenergy provide 40 percent of the nation's electricity use by 2030, after accounting for the drop in demand stemming from energy efficiency and CHP.

The increase in energy efficiency, CHP, and renewable energy spurred by the Blueprint policies—combined with a cap-and-trade program that requires owners of fossil fuel plants to buy allowances to emit carbon—significantly reduces coal-based power by 2030. Owners of many existing coal plants opt to co-fire biomass with coal, to reduce their emissions in the early years. A few existing coal plants are also replaced with advanced coal plants with carbon capture and storage. If the cost of this technology declines faster than the Blueprint assumes—or if the nation does not deploy energy efficiency measures and renewable energy as extensively—coal generation would not decline as much as Figure 7.10

shows, and coal-burning power plants would emit fewer carbon emissions.

Coal use in power plants declines from more than 1 billion tons in 2005 to 137 million tons in 2030 under the Blueprint, compared with an increase to more than 1.2 billion tons in the Reference case. The Blueprint displaces a cumulative total of more than 11 billion tons of coal use in power plants through 2030, producing important environmental and public health benefits (see Box 7.3).

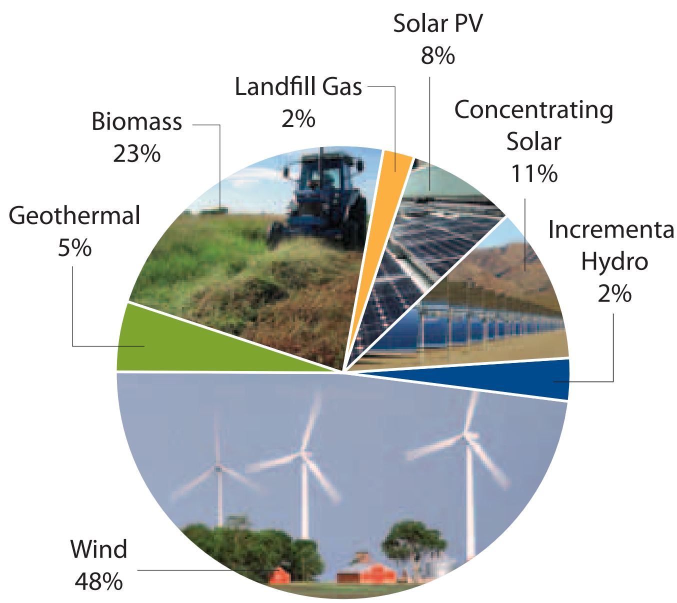
The Blueprint policies do not spur a widespread switch to natural gas from coal to produce electricity, as other studies have projected. In fact, the amount of electricity from stand-aloxne power plants burning natural gas is nearly one-third lower under the Blueprint than in the Reference case by 2030. However, an increase in electricity production from CHP based on natural gas in the commercial and industrial sectors more than offsets this drop. Electricity producers use less natural gas under the Blueprint because CHP plants use more waste heat than stand-alone power plants, and are therefore much more efficient.

Under the Blueprint, new advanced (integrated gasification combined-cycle) coal plants with carbon capture and storage (CCS), and advanced nuclear power plants, play a very limited role before 2030, as these technologies are not economically competitive with other options during that time frame. The Blueprint includes 7 gigawatts of capacity from new advanced coal plants with carbon capture and storage, including 4.8 gigawatts from eight large-scale plants built as a result of our recommended CCS demonstration program. The model also adds nearly 3 gigawatts of new natural gas capacity with CCS by 2030.

The model does not add any advanced nuclear plants by 2030 beyond the 4.4 gigawatts of new capacity added in the Reference case. However, almost all existing nuclear plants continue to operate, because they do not emit carbon, and their owners therefore do not have to purchase carbon allowances.

One in four children in Harlem suffer from asthma, and already poor air quality will likely get worse as temperatures rise. The Climate 2030 Blueprint dramatically improves air and water quality and protects public health by reducing carbon emissions from power plants, as well as emissions that cause acid rain, smog, and mercury pollution.

FIGURE 7.11. Blueprint Renewable Electricity Mix (2030)



7.4.3. Blueprint Case: Renewable Energy Diversifies the Electricity Mix

Because of the national renewable electricity standard (RES) in the Blueprint, power producers generate almost twice as much electricity from wind, solar, geothermal, and biomass as in the Reference case by 2030, using a more diverse mix of technologies (see Figure 7.11). Wind power makes the largest contribution, providing nearly half of all renewable electricity by 2030. While most of this wind power is land-based, the model projects that developers will build a small amount of offshore wind near the end of the period.

Biomass also makes a significant contribution. In the near-term, most biomass is co-fired with coal in existing coal plants. With a price on carbon emissions under a cap-and-trade program, cofiring becomes an attractive strategy, enabling owners of coal plants to meet near-term targets for cutting emissions. After 2020, cofiring declines as owners retire coal plants, and most biomass is used to produce biofuels in plants with

CHP, and to produce electricity in advanced biomass gasification plants.

Solar photovoltaics (PV) and concentrating solar thermal plants that can store electricity also expand significantly under the national RES, combined with the national solar investment tax credit, solar requirements in state RES policies, and other state policies in the Reference case. Together these policies spur deployment of solar, owing partly to greater economies of scale in manufacturing, constructing, operating, and maintaining it, making it competitive with other renewable energy technologies over time.

By 2030 the amount of variable power from wind and PV rises to 20 percent of the U.S. electricity supply,

BOX 7.2.

Public Health and Environmental Benefits of Reduced Coal Use

Cumulatively, the Blueprint displaces the need for more than 11 billion tons of coal for power plants by 2030 compared with the Reference case. Displacing that much coal would provide environmental and public health benefits roughly equivalent to:

- 280,000 premature deaths avoided
- 140,000 hospital admissions avoided
- 440,000 heart attacks avoided
- 6,400,000 asthma attacks avoided
- 1.1 million pounds of toxic mercury pollution avoided
- 12,600 square miles of surface mining avoided
- 130 square miles of Appalachian ridgeline saved
- 350 square miles of mountaintop removal mining avoided
- 5.6 billion gallons of mining slurry ponds avoided, equal to the volume of 520 Exxon Valdez spills

In December 2008, more than a billion gallons of fly ash sludge—a by-product of coal-fired electricity generation—breached a holding pond at a power plant near Harriman, TN. The sludge poured into the Emory River, flooding nearby homes and fields. Reducing reliance on coal plants over time by increasing efficiency and renewable energy yields the Blueprint's biggest carbon reductions, as well as significant environmental and safety benefits.

See Appendix D online for assumptions and sources.

after accounting for the drop in demand from energy efficiency and CHP. Several studies by U.S. and European utilities have found that wind power can provide as much as 25 percent of annual electricity needs without undermining reliability, and that the cost to integrate that power into the electricity grid would be modest (Holttinen et al. 2007). A 2008 study from the U.S. Department of Energy (DOE) found that wind power could provide 20 percent of U.S. electricity by 2030, with no adverse impacts on the reliability of the electricity supply or any need to store power. That study found that wind power would cost the average household an extra 50 cents per month—not including federal incentives or any value for reducing carbon emissions (EERE 2008).

While electricity from geothermal power plants more than triples from today's levels by 2030, virtually all of this increase occurs in the Reference case in response to existing state and federal policies. The vast majority of this development is new hydrothermal projects in the western United States. While geothermal makes an important contribution to electricity needs in that region, it makes a fairly modest contribution at the national level, because very little development of enhanced geothermal systems (EGS) is projected to occur before 2030. However, EGS has the potential to make a large contribution to reducing emissions after 2030, or if its cost declines faster than our analysis assumes. Electricity produced from landfill gas and incremental hydro (reflecting greater efficiency and expansion at existing plants) also makes a modest contribution to the national RES, given limited potential for these resources.

7.4.4. Blueprint Case: Significant Savings on Electricity Bills

Under the Blueprint, consumers and businesses in all sectors of the economy would see lower electricity bills compared with the Reference case. Annual savings would top $82 billion in 2020, and grow to $175 billion in 2030. Those savings would be offset somewhat by the cost of investments in energy efficiency and combined heat and power.[85] However, electricity customers would still see a net annual savings of $49 billion in 2020, and $118 billion in 2030. And the average household would see net annual savings of more than $110 in 2020, rising to $250 in 2030.

Under the Blueprint, average electricity prices are nearly 8 percent higher than in the Reference case by 2020, and 17 percent higher by 2030. Those price increases mainly reflect the cost of carbon allowances, which raise the cost of burning coal and natural gas to produce electricity, and the cost of replacing existing coal and natural gas plants with new renewable energy facilities and coal CCS projects from our demonstration program. However, while electricity prices are slightly higher under the Blueprint, consumers still save money on their energy bills because of reductions in electricity use from energy efficiency measures.

A 2008 study from the U.S. Department of Energy (DOE) found that wind power could provide 20 percent of U.S. electricity by 2030, with no adverse impacts on the reliability of the electricity supply or any need to store power.

7.5. Detailed Results: Industry and Buildings

7.5.1. Reference Case: Emissions Rise as Homes and Businesses Use More Energy

Buildings now account for 40 percent of U.S. primary energy use, while industry accounts for nearly one-third.[86] Under the Reference case, primary energy use rises by 22 percent in residential and commercial buildings, and 10 percent in industry, from 2005 to 2030, because measures to boost energy efficiency are underused.

Almost all of the increase in primary energy use in buildings results from more electricity use, noted above. The use of natural gas increases slightly and the use of oil declines slightly over time, primarily because oil prices rise faster than natural gas prices. In industry,

85 Electricity prices and consumer bills already reflect the additional costs of investments in new renewable energy, fossil fuel, and nuclear facilities for generating electricity.

86 Primary energy use includes direct fuel use by homes and businesses for heating, cooling, and other needs, as well as indirect fuel use for generating electricity, which is allocated to each sector based on its share of electricity demand.

BOX 7.3.

The Perfect Storm of Climate, Energy, and Water

The reductions in electricity from coal and other fossil fuels resulting from greater energy efficiency and reliance on renewable energy will save significant amounts of water (see Table 7.3). In 2030 the nation would see a net drop in water use of more than 1 trillion gallons—equivalent to today's annual water use by 32 million people, or nearly three times the volume of Lake Erie. Cumulative water savings between 2010 and 2030 would reach nearly 12 trillion gallons. Reductions in water use at coal and other fossil fuel plants would offset modest increases in water use at bioenergy and concentrating solar thermal plants. Those water savings will be important in regions such as the West and the Southeast, where water shortages and drought will become more severe with global warming.

TABLE 7.3. Water Savings in Electricity Generation (2030)[a]

(Blueprint case vs. Reference case)

Type of Power Plant	Billion Gallons of Water
	Reduced Water Use
Coal	1,210
Natural Gas	81
Oil	29
Subtotal	1,320
	Increased Water Use
Bioenergy[b]	43
Concentrating Solar Thermal[c]	7–64
Subtotal	50–107
Net Water Savings under Blueprint	1,183–1,241

Notes:

a Reductions in water consumption are based on a drop in electricity produced from fossil fuels and an increase in renewable generation under the Blueprint. See Appendix D online for assumptions and sources.

b This includes only water used at the power plant. Biomass residues require no additional water. The amount of water used to grow energy crops (mainly switchgrass) is negligible, as we assumed that energy crops would grow on land that does not need irrigation.

c The range represents the use of dry cooling versus wet cooling. Dry cooling is more common in the Southwest, where the vast majority of concentrating solar plants will be located.

In a warming world, more precipitation in mountain regions such as California's Sierra Nevada will fall as rain instead of snow; the snow that does fall will melt earlier, drastically reducing the spring snowpack that provides water for people and agriculture. Water shortages are likely to become acute and widespread, especially in the western and southeastern United States.

This Oregon, OH, coal plant sits on the shores of Lake Erie, situated there to take advantage of lake water for cooling. By reducing the amount of fossil-fuel-generated electricity, the Blueprint would save more than 1 trillion gallons of water in 2030—equivalent to nearly three times the volume of Lake Erie or the amount of water used today by 32 million people.

the increase in energy use is due mostly to an increase in the production of liquid coal and biofuels.

Growing use of fossil fuels in these sectors, combined with more electricity use in buildings, means that carbon emissions from buildings rise 17 percent above 2005 levels by 2030, while those from industry rise 7 percent.

7.5.2. Blueprint Case: Efficiency Greatly Reduces Energy Use

Under the Blueprint, industry and buildings are responsible for 9 percent of all reductions in global warming emissions from direct fuel use. Efforts by industry and building owners to increase efficiency, CHP, and renewable energy also drive a significant portion of the reductions in emissions from the electricity sector noted above. If we assign those cuts to industry and buildings, their share of total reductions in global warming emissions would rise to 18 percent for industry and 48 percent for buildings.

Energy use in industry and buildings is dramatically lower under the Blueprint because the suite of standards, incentives, and other policies spurs greater energy efficiency and use of combined heat and power. Primary energy use in industry is 37 percent lower by 2030 under the Blueprint compared with the Reference case. That includes a 69 percent reduction in fuel used to generate electricity, a 63 percent reduction in coal use, a 23 percent reduction in oil use, and a 19 percent reduction in natural gas use.

Primary energy use in buildings is 40 percent lower by 2030 compared with the Reference case. That includes a 40 percent reduction in the use of fuel to generate electricity, a 31 percent reduction in the use of natural gas, and a 35 percent reduction in the use of oil.

The reduction in natural gas use from energy efficiency measures is offset somewhat by an increase in natural gas use for CHP in the commercial and industrial sectors. However, the increase in CHP from natural gas reduces the need to purchase electricity from centralized power plants. Such plants are considerably less efficient because they typically do not use their waste heat, and because electricity is lost when transported from the power plant to the user. Therefore replacing these plants with CHP based on natural gas spurs a net drop in the use of natural gas and in carbon emissions.

7.5.3. Blueprint Case: Lower Energy Bills for Homes and Businesses

Under the Blueprint, the industry and buildings sectors would see lower energy bills compared with the Reference case. In 2030, total annual savings on energy (including the use of electricity, natural gas, oil, and coal) would reach nearly $243 billion. That figure includes $77 billion in the residential sector (or $550 per household), $87 billion in the commercial sector, and $79 billion in the industrial sector.

The cost of investing in energy efficiency measures would offset these savings somewhat. However, net annual savings would reach $136 billion in 2030, including $45 billion in the residential sector ($320 per

(continued on page 146)

Primary energy use in buildings is 40 percent lower by 2030 (compared with the Reference case) due to the Blueprint's strong suite of policies that increase energy efficiency and combined-heat-and-power systems in our homes, businesses, and industries. The Solaire Apartments in New York City's Battery Park are a case in point. This LEED Gold-certified complex achieved aggressive goals for reducing energy and water use as well as peak electricity demand by using daylighting, "Low-E" windows, programmable thermostats, and Energy Star appliances in each unit.

BOX 7.4.

SUCCESS STORY

Some Good News in Hard Times

Training opportunities in the renewable energy industry are expanding rapidly—such as at this wind turbine blade assembly plant in North Dakota—and many skills used in conventional industries are easily transferable to clean energy jobs.

General Electric's vice president of renewable energy made headlines in 2008 when he promised to hire every graduate of Mesalands Community College's wind power program for the next three years (*NMBW* 2008). Although a guaranteed job offer isn't standard for people training for careers in renewable energy, expected job growth in the industry is good news.

The solar industry estimates that more than 15,000 jobs were created in 2007 and 2008 (SEIA 2009), and the wind industry boasts more than 35,000 new direct and indirect jobs created in 2008 (AWEA 2009c). U.S. manufacturing of wind turbines and their components has also greatly expanded, with more than 70 new facilities opening, growing, or announced in 2007 and 2008. The industry estimates that these new facilities will create 13,000 high-paying jobs, and increase the share of domestically made components from about 30 percent in 2005 to 50 percent in 2008 (AWEA 2009b).

Although job numbers for the entire renewable energy industry are difficult to find, data from individual sectors such as solar and wind attest to demand for skilled labor. With the Obama administration's promise of green jobs spurred by federal policies designed to bring more renewables online, "clean-tech" careers will continue to grow—welcome news given that the U.S. economy shed 1.2 million jobs in the first 10 months of 2008 (BLS 2008).

Several studies have found that renewable energy projects can create more jobs than using coal and natural gas to generate electricity. For example, a recent Union of Concerned Scientists study found that a national renewable electricity standard of 25 percent by 2025 would create nearly 300,000 new jobs in the United States—or three times more jobs than producing the same amount of electricity from coal and natural gas (UCS 2009). The U.S. Department of Energy recently reported that the wind industry will create more than 500,000 new U.S. jobs if 20 percent of the nation's power comes from wind by 2030 (EERE 2008). A third study showed that manufacturing the components for wind, hydro, geothermal, and solar systems could create more than 381,000 U.S. jobs (Sterzinger and Svrcek 2005).

As demand for workers has grown, so too has the number of schools devoted to training people for jobs in renewable energy. Besides New Mexico's Mesalands—whose students are guaranteed employment with GE—Highland Community College in Illinois and Laramie County Community College in Wyoming introduced wind

The solar industry estimates that it created more than 15,000 jobs in 2007 and 2008; the wind industry boasts that it created more than 35,000 new direct and indirect jobs in 2008.

Flexible, thin-film solar photovoltaic cells, such as those produced at California-based Nanosolar Inc., allow more homes and buildings to harness sunlight to generate electricity.

Renewable energy and energy efficiency jobs can be found in every region of the country. Green For All (*www.greenforall.org*) promotes clean energy job training in communities with chronically high unemployment rates to ensure that a clean environment and a strong economy go hand in hand.

technician programs in 2008. Colorado's Solar Energy International instructs 2,500 students each year in alternative energy systems. And enrollment in engineering for alternative energy at Lansing Community College in Michigan has jumped from 20 to 158 students since 2005, according to program staff (Glasscoe 2009).

Although training programs for jobs in renewable energy have expanded, many skills used in conventional industries such as manufacturing are transferable with no additional training. After a small Iowa town lost more than 100 jobs with the closing of a local plant making hydraulics, for example, most found new employment with wind turbine manufacturer Acciona after it converted the plant to build turbines (Goodman 2008).

Near Saginaw, MI, Hemlock Semiconductor provides the raw materials for electronic devices such as cell phones and, increasingly, solar panels. When completed in 2010, Hemlock's expansion to serve its growing solar business means the company will add 250 full-time jobs and 800 temporary construction jobs in a state that shed more than 400,000 jobs from 2000 to 2007 (Fulton and Cary 2008; Hemlock Semiconductor Corp. 2007).

Jobs in renewable energy are also geographically diverse: from staffing geothermal energy systems in Alaska to manufacturing biomass pellets in Florida. And while renewable energy can provide an important source of income and jobs for rural areas where many projects are located, they can create new manufacturing, construction, operation, and maintenance jobs in urban areas as well. The national group Green for All, for instance, works with cities such as Richmond, CA, to offer free training programs in trade skills for renewable energy (Apollo Alliance and Green for All 2008; Lee 2008).

Expanding the nation's use of renewable energy is essential to reducing our carbon emissions. In difficult economic times, the job growth spurred by clean, homegrown energy offers even more reason to ramp up its development.

By 2030, net annual electricity savings would reach $118 billion for industrial, commercial, and residential consumers under the Blueprint. Minnesota's Great River Energy is a generation and transmission cooperative providing wholesale electric service to other co-ops. The company's LEED Platinum-certified headquarters combines energy efficiency with on-site renewable energy and modest amounts of grid-supplied clean power to reduce fossil fuel use by 75 percent, cut CO_2 emissions by 60 percent, and save nearly 50 percent on energy costs compared with minimum building and equipment standards.

household), $45 billion in the commercial sector, and $46 billion in the industrial sector.

7.6. Detailed Results: Transportation

7.6.1. Reference Case: Carbon Emissions Climb Despite EISA

Our Reference case shows that carbon emissions from the transportation sector will grow by 12 percent between 2005 and 2030 (see Figure 7.12). Emissions are almost flat during the first two decades, growing only 2 percent between 2005 and 2022. This is due largely to the 2007 Energy Independence and Security Act (EISA), which requires cuts in carbon emissions from the production of most biofuels through 2022, and better fuel economy for cars and light-duty trucks through 2020. Once these policies stall out, however, carbon emissions in the transportation sector begin to grow at near historic rates.

Fuel economy for light-duty vehicles remained essentially stagnant from 1985 to 2005, as the auto industry successfully fought back attempts to require improvements in that metric. EISA pushes the fuel economy of cars and light-duty trucks from about 25 miles per gallon in 2005 to more than 35 mpg in 2030. However, that falls short of the doubling in the fuel economy of new vehicles that existing technology could deliver. EISA also does not set specific efficiency targets for any other part of the transportation sector.[87]

EISA will help increase the share of low-carbon biofuels from just 0.1 percent of transportation fuel in 2005 to 9 percent by 2030. This significant increase highlights the importance of the requirement under the renewable fuel standard in EISA that limits carbon emissions from most biofuels. That requirement will bring low-carbon cellulose-based biofuels to scale, where they could become cost-competitive with petroleum.

Without EISA, we estimate that carbon emissions from the transportation sector would increase by about 30 percent instead of just 12 percent by 2030.[88] However, a transportation sector that simply runs in place on carbon emissions for a little over 10 years and then begins to increase again is not good enough. To actually cut carbon emissions compared with those in 2005, we need to go beyond the first step taken by EISA.

Even though the Reference case includes EISA, Blueprint policies will have to overcome the fact that emissions from cars and light-duty trucks drop only slightly in 2030 in the Reference case, while those from freight trucks and buses grow by nearly 40 percent, and those from airplanes rise by more than two-thirds (see Figure 7.13).

7.6.2. Blueprint Case: Driving Significant Cuts in Carbon Emissions

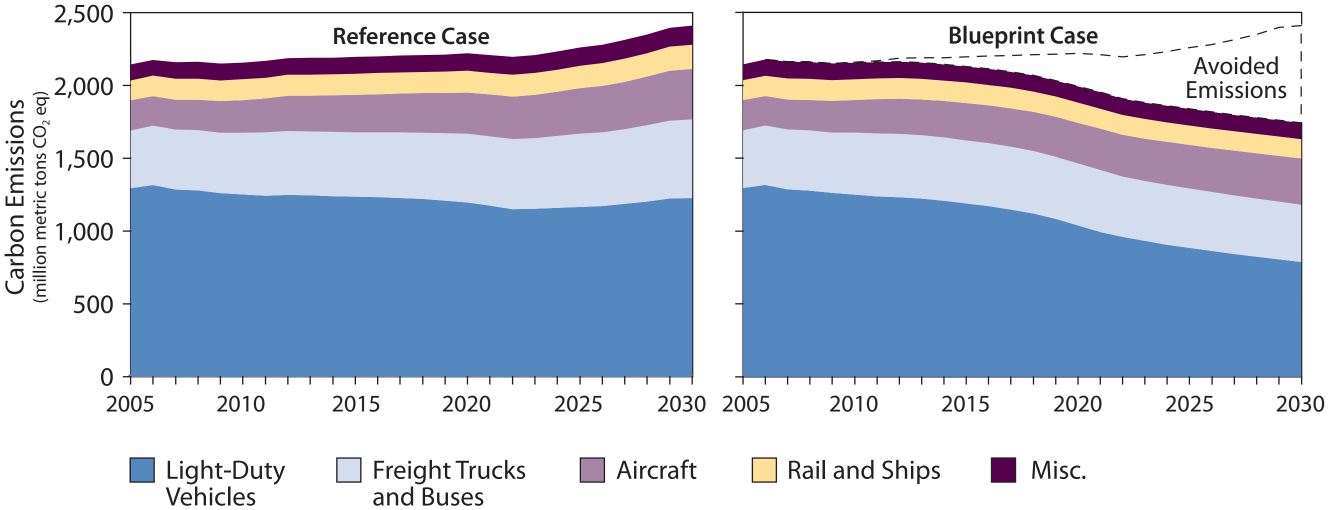
Blueprint policies for the transportation sector represent the essential next step after EISA. These aggressive but achievable policies address the three legs of the transportation stool: vehicles, fuels, and miles traveled for cars and light-, medium-, and heavy-duty trucks. When we add our Blueprint policies to the progress that occurs under EISA, the transportation sector can deliver a 19 percent reduction in carbon emissions in 2030 compared with 2005 (see Figure 7.12 and Figure 7.14).

That 19 percent drop stems from a cut in carbon emissions from transportation of more than 660 million metric tons in 2030—about 16 percent of the

87 EISA does require fuel-economy standards for medium- and heavy-duty trucks, but sets no specific minimum. EISA does not address fuel economy standards for planes, trains, off-road vehicles, or ships.

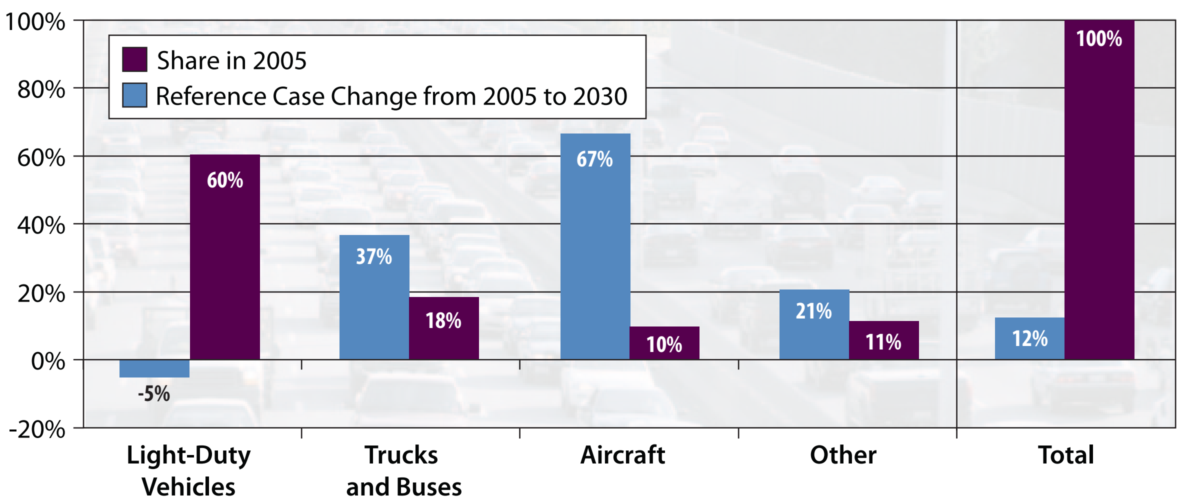
88 We estimate that EISA would reduce projected emissions by 350–450 $MMTCO_2$ in 2030. If automakers met the minimum EISA requirement of 35 mpg by 2020, emissions from transportation would decline by 250–300 $MMTCO_2$ in 2030. Wider use of low-carbon fuel under EISA is projected to save 100–150 $MMTCO_2$ in 2030.

FIGURE 7.12. Transportation Carbon Emissions
(Reference case vs. Blueprint case)



Emissions are almost flat during the next two decades, due largely to the 2007 Energy Independence and Security Act (EISA) that will cut carbon emissions using biofuels and better fuel economy. However, a transportation sector that simply runs in place on carbon emissions for a while and then increases again is not good enough. To actually cut carbon emissions compared with those in 2005, we need to do more.

FIGURE 7.13. Changes in Transportation Carbon Emissions
(Reference case)



Under the Reference case, which includes EISA, carbon emissions from cars and light-duty trucks drop only slightly in 2030, while those from freight trucks and buses grow nearly 40 percent and those from aircraft increase by two-thirds.

carbon emissions saved that year. If we include the cuts in emissions spurred by EISA, transportation's contribution to total reductions in 2030 rises to more than 1 billion metric tons—or 24 percent of the reductions that year.

7.6.3. Blueprint Case: Greater U.S. Energy Security

The Blueprint delivers more than cuts in carbon emissions: it also improves energy security by reducing U.S. demand for oil, making our economy less vulnerable to oil price shocks. While EISA keeps the amount of oil used for transportation from growing under the Reference case, Blueprint policies cut transportation's demand for oil and other petroleum products by 23 percent in 2030 compared with 2005.

Transportation provides more than half (53 percent) of the cuts in petroleum use achieved under the Blueprint. That represents savings of 3.2 million barrels per day in 2030, on top of the more than 3 million barrels of oil saved through EISA alone.

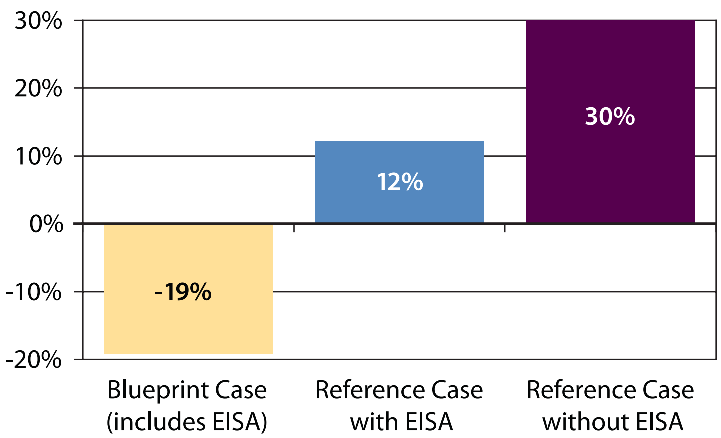
TABLE 7.4. Annual Consumer and Business Savings from Transportation

(in billions of 2006 dollars)

TRANSPORTATION SAVINGS	2020	2030
Fuel Cost Savings	$ 41	$ 172
Expense of Cleaner Vehicles and Reducing Vehicle Miles Traveled	-18	-53
Net Consumer and Business Savings	**$ 23B**	**$ 119B**

Savings at the pump from cleaner cars and trucks, better transportation choices, and low-carbon biofuels more than offset the costs of investing in these technologies. When these savings are spread out, the average U.S. household will save $580 per year by 2030 on annual transportation costs (versus the Reference case) and businesses that rely on transportation will save $38 billion.

FIGURE 7.14. Transportation Carbon Emissions (2030)



In 2030 the Blueprint delivers a 19 percent reduction in carbon emissions from the transportation sector compared with 2005. Under the Reference case, carbon emissions grow by 12 percent from 2005 to 2030. Had the 2007 Energy Independence and Security Act (EISA) not passed in 2007, transportation carbon emissions would have risen about 30 percent by 2030.

7.6.4. Blueprint Case: Saving Consumers and Businesses Money

By cutting fuel use through energy efficiency and reduced travel, and shifting transportation to cost-competitive, low-carbon fuels, Blueprint policies actually save consumers and businesses money while delivering cuts in carbon emissions. Through 2030, consumers and businesses will see their net annual expenditures on transportation—including the costs of fuel and vehicles—drop by about $120 billion compared with the Reference case (see Table 7.4). Of that savings, more than two-thirds—$81 billion—will end up in the hands of consumers in 2030, while businesses that rely on transportation will save $37 billion.

In other words, annual savings from the Blueprint transportation policies in 2030 not only cover the $53 billion cost of more efficient vehicles, better fuels, and new transportation alternatives, but also reward consumers and businesses who help cut carbon emissions.

Under the Blueprint, the average household will save $580 per year by 2030 on annual transportation costs versus the Reference case—and the average new vehicle will already get 35 miles per gallon in that baseline case. What's more, that figure excludes the potential for every vehicle owner to save as much as $150 per year on insurance costs owing to reduced driving (Bordoff and Noel 2008).

In earlier years, Blueprint policies ask consumers to invest in new technologies, such as better engines and transmissions and GPS monitoring systems, which will also enable pay-as-you-drive insurance. However, those technologies more than pay for themselves.[89] And total household savings would be even larger if they included the effects of recycling revenue from allowance auctions. For example, government could return such revenues as tax credits to consumers who purchase cleaner vehicles and fuels, or through other policies.

7.6.5. Blueprint Case: Keeping Gasoline Prices Down

Despite carbon allowances that cost as much as $70 per ton, gasoline prices rise only $0.10 per gallon under the Blueprint through 2020 compared with the Reference case, and no more than $0.24 from 2020 to 2030. Consumers pay up to $0.55 per gallon to cover the costs of carbon allowances passed on by oil companies. However, wholesale gasoline prices are $0.15-$0.40 per gallon below those of the Reference case from 2020 to 2030, owing to lower U.S. demand for oil and gasoline.

Those results contrast sharply with claims that a cap-and-trade program will significantly drive up fuel prices. The results point instead to changes in gasoline prices that are similar to or even lower than price spikes that have occurred within a few months or even weeks during the last few years. Including transportation in a cap-and-trade program will not significantly

89 These values assume that consumers pay the full incremental price of technologies the first year. Typical consumers will lease or obtain a loan on their vehicle, which would lower their costs in the early years.

Reducing emissions from the transportation sector will require some heavy lifting from highway vehicles—and they are up to the task. With cleaner cars and trucks, cleaner fuels, and better travel options, carbon emissions from cars and light-duty trucks can be cut by nearly 40 percent compared with 2005. Truck and bus emissions, which rose dramatically in the model scenario based on our current path, are held flat under the Blueprint despite the fact that the economy grows more than 80 percent.

drive up prices for fuels compared with the Reference case because Blueprint policies help drive down the price of oil.[90]

The one ironic impact of low gasoline prices is that they mute the ability of a cap-and-trade program to encourage consumers to purchase cleaner vehicles with better fuel economy, or to shift to other travel modes. Lower gas prices could therefore be seen as opening the door to more driving and urban sprawl. However, the Blueprint includes other policies that directly address those challenges, from limits on emissions from vehicles to per-mile driving fees, and those policies therefore deliver even more cost-effective cuts in carbon emissions (see Chapter 6).

7.6.6. Blueprint Case: Highway Vehicles Do the Heavy Lifting

The major Blueprint policies related to transportation focus on highway vehicles (cars, light-duty trucks, freight trucks, and buses). As a result, those vehicles deliver the majority of cuts in carbon emissions from transportation compared with the Reference case (see Figure 7.12).

Significant improvements in efficiency, cleaner fuels, and alternatives to today's travel patterns under the Blueprint allow cuts in carbon emissions from cars and light-duty trucks of nearly 40 percent in 2030 versus 2005 (see Figure 7.15). That represents a significant improvement over the Reference case reduction of only 5 percent.

Trucks and buses face an even bigger task: under the Reference case their emissions rise nearly 40 percent. Under the Blueprint, their emissions remain flat despite the fact that the U.S. economy grows more than 80 percent.

7.6.7. Blueprint Case: Carbon Emissions from Air Travel Continue to Climb

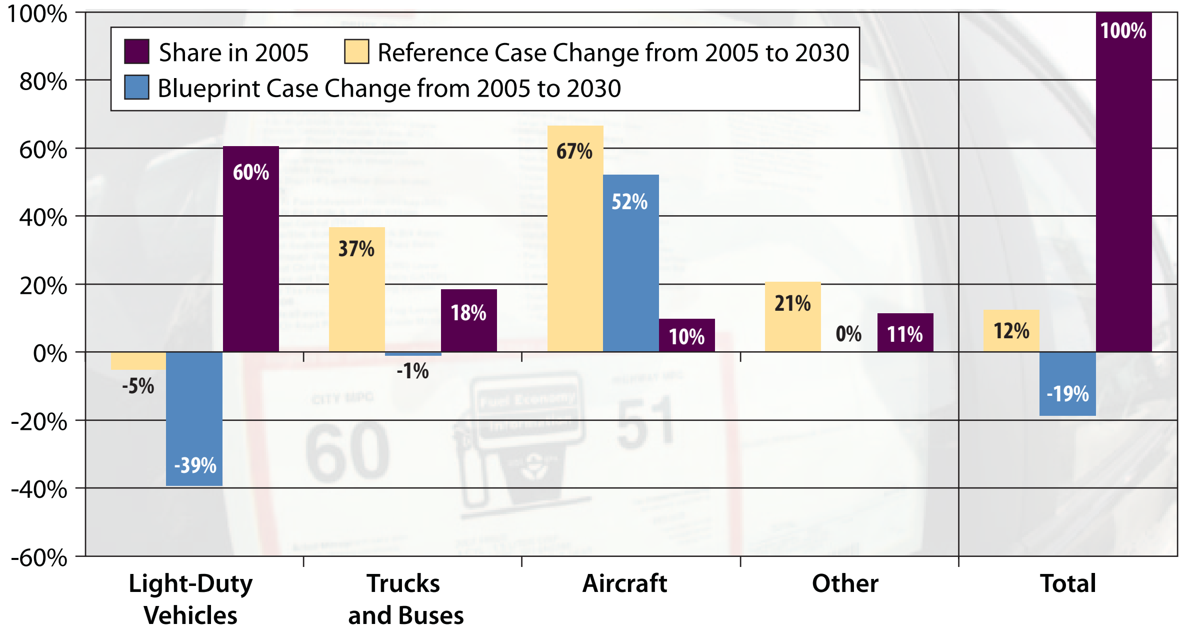
Aircraft are the worst performer under the Blueprint, with their carbon emissions climbing more than 50 percent by 2030. The main Blueprint policy that affects the airline industry is the cap-and-trade system, as it puts a price on carbon emissions. Ironically, the overall success of the Blueprint policies keeps the resulting impact small: jet fuel prices are only 5–10 percent higher as a result of the cap, and do not really affect the use of air travel compared with the near doubling of jet fuel prices from 2005 to 2030 in the Reference case.

To reduce carbon emissions from air travel, our analysis includes only options for improving aircraft efficiency. Including other options could lead to greater reductions. For example, logistics changes such as

90 As with all savings on the cost of oil in this analysis, NEMS does not account for instability in the oil market, which could cause price spikes. The model also does not account for potential attempts by OPEC to reduce the oil supply and drive up prices in response to other nations' attempts to lower demand.

FIGURE 7.15. **Changes in Transportation Carbon Emissions**

(Blueprint case vs. Reference case)



Transportation policies adopted under the Blueprint drive down carbon emissions nearly 20 percent in 2030 versus 2005. Cars and light-duty trucks lead the way with a near 40 percent reduction, while trucks and buses hold steady despite growth of 80 percent in the economy.

The carbon price under the Blueprint's cap-and-trade system encourages greater airplane efficiency but is too low to achieve bigger changes—these will require airplane carbon standards and cleaner fuels. Progress, however, can be made on the ground, where future airports can be more like the new Indianapolis airport terminal. Located in the middle of the airfield, planes taxi shorter distances and use less fuel. The terminal itself is also highly energy efficient, including, among other features, special windows that allow natural light and heat to enter the building in the winter and block it in the summer.

better routing to shorten flight distances, better scheduling to reduce congestion, and an update of the hub-and-spoke network (which relies on indirect stopovers and therefore increases fuel use) could have an impact.

High-speed electric rail can replace air travel between major commuting hubs, particularly in coastal regions and between major cities in America's heartland. However, large-scale investments in high-speed rail would have to accelerate significantly to affect global warming emissions by 2030. California will likely be the first state to build a high-speed electric rail system.

7.6.8. Blueprint Case: Low-Carbon Fuels Are on the Rise

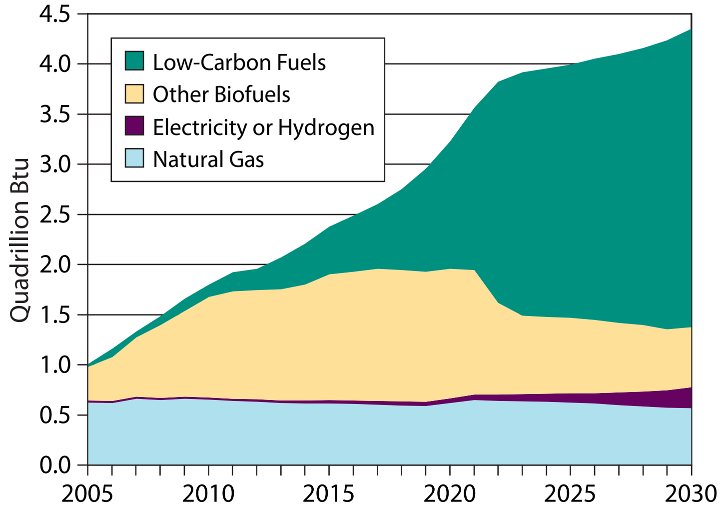
Low-carbon biofuels and renewable electricity play important roles in our transportation Blueprint. Use of those fuels will rise to about 3.5 quadrillion Btu by 2030—or about 14 percent of all transportation fuel, and 20 percent of all highway fuel (see Figure 7.16). Much of this progress will occur because of the low-carbon biofuel portion of the renewable fuel standard included in our Reference case.

The low-carbon fuel standard in our Blueprint case takes that a step further by accelerating the phaseout of corn-based biofuels, which do not reduce carbon emissions and may even increase them during our time frame. The low-carbon fuel standard also drives a 10 percent increase in the efficiency of oil refineries, lowering carbon emissions from refineries by 1 percent per gallon of gasoline or diesel fuel made. The low-carbon fuel standard also ensures that high-carbon fuels such as liquid coal—which could double carbon emissions per gallon—do not make inroads and therefore undermine progress on curbing global warming.

While total electricity use in the transportation sector remains relatively modest under the Blueprint, it does grow rapidly from 2020 to 2030. In fact, the low-carbon fuel standard—along with the requirement that 20 percent of new light-duty vehicles be plug-ins or other electric-drive vehicles by 2030—drive a 10-fold increase in the use of electricity for transportation. Nearly 20 million plug-ins or other electric vehicles are on the road by 2030.[91]

And that progress is only the beginning for electric-drive vehicles. Under the Blueprint, the electricity sector does not tap the full potential for using renewable resources to generate power. That means that significant capacity is available to produce clean electricity for more plug-ins or battery-electric vehicles, or to produce hydrogen for use in fuel cell vehicles, as electric-drive vehicles dominate the car and light-truck markets beyond 2030.

FIGURE 7.16. Mix of Alternative Fuels under the Climate 2030 Blueprint



Alternatives to gasoline and diesel grow by more than a factor of four under the Blueprint. The renewable fuel standard in the 2007 Energy Independence and Security Act is responsible for much of this growth, but the Blueprint's low-carbon fuel standard helps shift the mix away from corn ethanol, which does not cut carbon emissions, and toward low-carbon alternatives such as electricity and cellulosic biofuels.

7.6.9. Progress in Transportation Is Critical for Long-Term Success

While the transportation sector delivers significant cuts in carbon emissions under the Blueprint while saving the nation hundreds of billions of dollars, progress is still not as dramatic as in the electricity sector. Improvements in the latter will buy some time for progress in the transportation sector over the longer term.

However, that progress must begin today. The majority of benefits delivered under the Blueprint stem from solutions that have been available for a decade or more. Had the nation begun to phase in solutions such as more efficient vehicles, expanded transit, and reduced travel through per-mile pricing policies—and had we gotten serious about investing in low-carbon fuels and electric-drive vehicles two decades ago—many of the benefits of the Climate 2030 Blueprint would be available today.

91 The portfolio of potential advanced vehicles includes plug-in hybrids, battery-electric vehicles, and fuel cell vehicles. For ease of modeling, we used plug-ins as the sole technology, but other technologies with equal performance could be substituted.

BOX 7.5.

SUCCESS STORY

The Early Feats and Promising Future of Hybrid-Electric Vehicles

Hybrids combine the best elements of internal combustion engines with electric motors and batteries, and the best models can cut carbon emissions by 50 percent or more compared with conventional vehicles.

Hybrid-electric vehicles, which pair an internal combustion engine with one or more electric motors under the hood, first arrived in the United States 10 years ago. Since then the technology—and its popularity—have grown immensely.

Hybrids combine the best elements of internal combustion engines and electric motors to reduce carbon emissions by 30–50 percent compared with conventional vehicles, even while maintaining the performance, range, and other key features preferred by American drivers. While the hybrid concept is not new (patents were filed as far back as a century ago), it was only in the 1990s that batteries and onboard computers became advanced enough to permit successful hybrids.

The first modern, mass-produced hybrid was the Toyota Prius, a compact car brought to the Japanese market in 1997. Hybrids didn't reach the United States until three years later, when Honda unveiled its super-efficient two-seater Insight, followed promptly by Toyota with the Prius (Hall 2009). Both, however, were niche vehicles, with combined sales totaling less than one-tenth those of the top-selling model.

In 2004 hybrid technology finally reached a broader, mainstream U.S. audience. Toyota substantially redesigned its Prius, increasing not only its size but its fuel economy as well—an engineering feat that caught the attention of environmentalists and auto enthusiasts alike. Not to be outdone, Honda pushed its hybrid technology into the company's mainstream nameplates, releasing hybrid versions of the company's popular Civic and Accord sedans.

Annual U.S. sales steadily climbed as new models came to market, reaching 120,000 vehicles in 2005 (Ward's Auto Data n.d.). That same year Ford unveiled the Escape Hybrid as the first hybrid SUV. The range of consumer choices grew quickly: by 2006 the hybrid market consisted of 10 models representing five different vehicle classes. Today the U.S. hybrid market continues to expand. Sales climbed from roughly 20,000 in 2001 to more than 300,000 in 2008, with the Prius now ranked among the top-10 best-selling vehicles in the country (Ward's Auto Data n.d.).

That said, not all hybrid models have been successful. Honda abandoned its Accord Hybrid in 2006 (AP 2007);

sales for Toyota's Lexus brand "performance hybrids" have flagged; and Chrysler discontinued its Durango and Aspen hybrids after their first year (Doggett and O'Dell 2008). The critical difference between the hybrid standouts and the hybrid also-rans is this: hybrid vehicles that use the technology to boost power rather than increase fuel economy have failed to capture significant market share.

Responding to consumer preference, automakers are now moving their hybrid vehicles toward efficiency. Honda's 2009 Insight (a new, larger sedan bearing very little resemblance to its discontinued two-seater namesake), for example, will be a 40-plus-mpg vehicle selling for less than $20,000 (Honda 2009). Ford is entering the hybrid car market with a Fusion Hybrid in 2009 that offers better fuel economy than its midsize competitor, the Toyota Camry Hybrid. And Toyota is bringing out its third-generation Prius with an expected 50-mile-per-gallon fuel economy rating (Kiley 2008).

The next few years will likely see an even greater revolution in hybrid design, with major-manufacturer release of plug-in hybrid-electric vehicles (PHEVs). Plug-ins, as they're commonly known, have battery packs large enough to enable drivers to travel significant distances on electric power alone, and to recharge the vehicles at home through conventional power outlets. Yet their use of gasoline engines also allows the vehicles to meet consumers' requirements for range and refueling time.

In short, PHEV designs provide an overall improvement in fuel economy and the opportunity—with a clean-power grid—to dramatically reduce vehicles' carbon emissions. General Motors, Toyota, and Ford are slated to bring the first mass-produced plug-ins to market between 2010 and 2012. Although cost and battery-engineering challenges remain, a cleaner vehicle future looks promising.

The year 2030 should be viewed as a critical milepost on the path to reducing global warming emissions 80 percent or more by 2050. If transportation policies do not provide the cuts we outline by 2030, the nation has little chance of reaching the 2050 target.

7.7. Land-Use Implications of the Blueprint

Some Blueprint solutions, such as an increase in renewable electricity, the use of biofuels, and carbon offsets from agriculture and forests, have implications for land use. At the same time, a move away from heavy reliance on fossil-fuel-based energy will provide significant land-use benefits. This section outlines some of the key land-use implications of the Blueprint solutions.

We recognize that the use of land to reduce global warming emissions may inadvertently create new environmental or sustainability problems, economic effects such as higher prices for agricultural commodities, and even an indirect increase in heat-trapping emissions. We have deliberately restricted the kind and level of certain solutions, such as bioenergy and offsets, to minimize the possibility that the nation will divert land from productive uses and indirectly create adverse effects on land use in other countries.

7.7.1. Land Use and Energy under the Blueprint

While expanding the use of renewable electricity and biofuels will have important effects on land use, it will also reduce the effects on land use of producing, transporting, and using fossil fuels. The environmental impacts of using land to produce and burn fossil fuels tend to be much greater than those of producing renewable energy and storing carbon in soils and trees.

Under the Blueprint, the total land area needed to produce electricity from wind and solar power is 1,500–36,600 square miles, or about 0.04–1 percent of all U.S. land area. The low end of the range includes only the footprint of wind turbines and their supporting infrastructure and large-scale solar projects. It does not include the area occupied by distributed PV, which is typically installed on residential and commercial buildings, and therefore would not require any new land. The high end of the range includes both the footprint of the turbines and the land between them, which could still be used to grow crops or graze animals, as well as the area used by distributed PV.

By 2030, the cumulative reduction in coal use from increased energy efficiency and renewable energy under the Blueprint would result in nearly 13,000 square miles of avoided land use from both surface and mountaintop-removal coal mining. While state and

Under the Blueprint, the land needed to produce clean electricity from wind and solar power and transportation fuels from corn and switchgrass—as well as the land needed to sequester carbon in new forests and smart agricultural practices—would only require 2 to 6 percent of the total U.S. land area. At the same time, the Blueprint would significantly reduce the amount of land used for coal mining, oil and natural gas drilling, fossil fuel power plants, refineries, pipelines, waste disposal, and related infrastructure.

federal laws require reclamation of land permitted for coal mining, in practice the coal industry has reclaimed only a small portion of this land. And in many cases—particularly for mountaintop-removal mining—the reclaimed land does not resemble its original state.

Growing energy crops (switchgrass) and corn to produce biofuels for transportation under the Blueprint would require more than 52,000 square miles of land in 2030—or about 1.4 percent of all U.S. land area (see Figure 7.17). Energy crops would require about 39,000 square miles (25 million acres) of land by 2030, or about 2.5 percent of all land now used for agriculture in the United States. Most energy crops would be grown on pasture lands and would be used to produce cellulosic biofuels.

Overall, a reduction in land used for oil and natural gas drilling, fossil fuel power plants, refineries, pipelines, waste disposal, and related infrastructure would offset some of the increase in the amount of land used for renewable electricity and biofuels under the Blueprint. However, our analysis did not quantify these land-use benefits.

7.7.2. Land for Carbon Offsets from Agriculture and Forestry

All the domestic carbon offsets we modeled come from a category in the NEMS model called "biogenic sequestration offsets." These offsets are generated through increased storage of carbon in soils and vegetation in the agriculture and forestry sectors—primarily as a result of changes in soil management practices, better forest management, and afforestation. Of those, afforestation is the only one that would require diverting new land for this specific purpose. The other strategies involve changing practices on lands already used for the same purpose.

Although NEMS does not show what percentage of offsets stem from afforestation, we can try to estimate that percentage based on information from the Environmental Protection Agency's Forest and Agriculture Sector Optimization Model with Greenhouse Gases (FASOMGHG) (Murray et al. 2005).

Extrapolating from data from existing runs of FASOMGHG, at the carbon prices shown in the Blueprint, we estimate that roughly 50 percent of the domestic offsets in our results are likely to come from afforestation.[92] That means that of the 314 million metric tons of domestic offsets used by capped firms in 2030, 157 million metric tons come from afforestation.

Based on estimates of the amount of carbon that afforestation stores per acre (Birdsey 1996), we estimate that the added land area needed to sequester the 157 million metric tons in 2030 would range from 17 million to 71 million acres (with a midpoint of 44 million acres). Most of this afforestation would likely occur on marginal croplands, grasslands, and rangelands. The midpoint estimate of 44 million acres represents

92 This is a rough approximation based on extrapolation from existing model results in Murray et al. 2005. We did not conduct any new runs of the FASOMGHG model.

BOX 7.6.

Impact of the Blueprint Policies in 2020

A central insight from the Blueprint analysis is that the nation has many opportunities for making cost-effective cuts in carbon emissions in the next 10 years (through 2020). Our analysis shows that firms subject to the cap on emissions find it cost-effective to cut emissions more than required—and to bank carbon allowances for future years. Energy efficiency, renewable energy, reduced vehicle travel, and carbon offsets all contribute to these significant near-term reductions.

By 2020, we find that the United States can:

- Achieve, and go beyond, the cap requirement of a 26 percent reduction in emissions below 2005 levels, at a net annual savings of $240 billion to consumers and businesses. The reductions in excess of the cap are banked by firms for their use in later years to comply with the cap and lower costs.
- Reduce annual energy use by 17 percent compared with the Reference case levels.
- Cut the use of oil and other petroleum products by 3.4 million barrels per day compared with 2005, reducing imports to 50 percent of our needs.
- Reduce annual electricity generation by almost 20 percent compared with the Reference case while producing 10 percent of the remaining electricity with combined heat and power and 20 percent with renewable energy resources, such as wind, solar, geothermal, and bioenergy.
- Rely on complementary policies to deliver cost-effective energy efficiency, conservation, and renewable energy solutions. Excluding those energy and transportation sector policies from the Blueprint would reduce net cumulative consumer savings through 2020 from $781 billion to $602 billion.

about 4 percent of all cropland, grassland pasture, and rangeland in the United States.

7.8. Sectoral Policies Are Essential for a Cost-Effective Blueprint

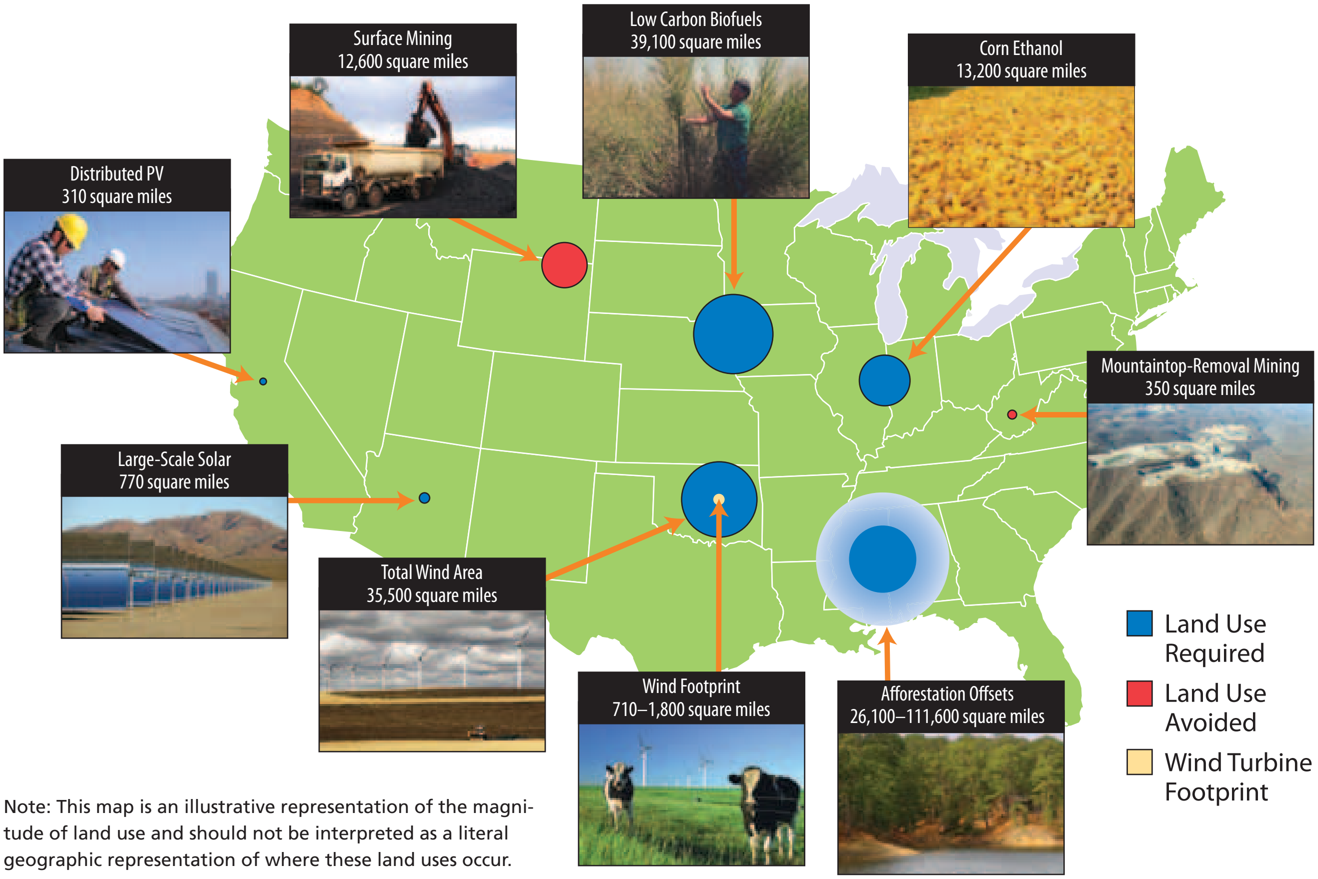
The Blueprint analysis reveals the benefits of pursuing complementary policies along with a cap-and-trade program. A cap on carbon emissions is critical because it establishes the level of cuts in global warming emissions regardless of the rest of the policy mix. However, adding sector-based policies helps deliver those reductions in a more cost-effective way. We demonstrated this finding by developing a sensitivity, or No Complementary Policies, case: that is, by running the model while excluding all the sector-based policies from the Blueprint.

As noted, because of limitations in the NEMS model, we were unable to model a critical feature that would help make a cap-and-trade program more cost-effective: namely, we could not target revenues from the auction of carbon allowances for specific purposes such as funding energy efficiency measures and low-carbon technologies. Instead, we could only assume that government recycles such revenues back into the economy, to consumers and businesses.

With that limitation in mind, our results show that if we exclude all sector-based policies, we are left with only a price for carbon emissions to drive global warming solutions into the marketplace. A carbon price alone will change the energy and technology mix and spur some improvements in energy efficiency and conservation. However, it will not provide all the needed cost-effective solutions because of other market barriers, such as consumers' aversion to risk and the up-front cost of more advanced technology (see Chapters 4–6). Sector-based policies are critical to overcoming those barriers, facilitating the development and deployment of clean and efficient technologies, and delivering them at a lower cost than a carbon price alone could do.

The next sections explore some of the findings of the No Complementary Policies case.

FIGURE 7.17. Total Land-Use Effects of Renewable Electricity, Biofuels, Avoided Coal Mining, and Afforestation Offsets in 2030
(Blueprint case)



Note: This map is an illustrative representation of the magnitude of land use and should not be interpreted as a literal geographic representation of where these land uses occur.

7.8.1. No Complementary Policies Case: Impact on Prices of Carbon Allowances

A comparison of the results of the Blueprint case with those of the sensitivity case shows that stripping out the complementary policies leaves a basic cap-and-trade system without targeted recycling of revenues—and that the prices of carbon allowances more than double (see Figure 7.18). The lower prices of allowances under the complete Blueprint allow consumers to see much smaller increases in the rates they pay for electricity and fuels.

Each sector's policies play a significant role in cutting the prices of carbon allowances. With the transportation sector's policies stripped out, allowance prices rise by about 33 percent. If we also strip out policies related to the electricity, industry, and buildings sectors, allowance prices rise by almost another 66 percent.[93]

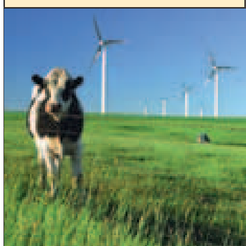
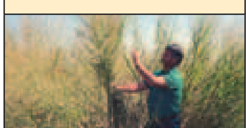
The reason for these lower prices is straightforward: energy efficiency, clean technologies, and conservation play far more significant roles in our Blueprint results than would be possible with only a carbon price signal, and encourage the adoption of cost-effective solutions that have a dampening effect on the prices of both allowances and fuel. Energy efficiency technologies cost more up-front, so risk-averse consumers can be more reluctant to purchase them despite the long-term financial savings they can provide.[94]

(continued on page 160)

93 In our sensitivity case, we stripped out the transportation policies first and then stripped out the other policies. Had we stripped out the policies related to electricity, industry, and buildings first and those related to transportation second, the changes in allowance prices might have been different.

94 The Congressional Budget Office estimates that fuel prices would need to rise by 46 cents per gallon to reduce gasoline use by 10 percent (CBO 2004).

TABLE 7.5. Land Needed for Renewable Electricity, Biofuels, and Afforestation Offsets (2030)

	Technology	Land Area:[a] Increase over Reference Case (square miles)	Land Area:[a] Total New plus Existing (square miles)	Percent of Total U.S. Land Area
	Electricity			
	Total Area for Wind[b]	16,341	35,466	1.0%
	Wind Footprint[b]	327–817	709–1,773	0.02–0.05%
	Central Photovoltaics	122	126	0.004%
	Distributed Photovoltaics[c]	78	312	0.01%
	Concentrating Solar Thermal	482	647	0.02%
	Electricity Subtotal[d]	931–17,023	1,482–36,551	0.04%–1.03%
	**Low-Carbon Biofuels**[e]	0	39,063	1.10%
	**Corn Ethanol**[f]	– 33	13,160	0.37%
	**Afforestation Offsets**[g]	26,121–111,608	26,121–111,608	0.74–3.16%
	Total	**27,019–128,598**	**79,826–200,382**	**2.26–5.66%**

Notes:

a The incremental land area is based on the increase in renewable electricity, biofuels, and afforestation under the Blueprint compared with the Reference case. The total land area is based on both existing and new renewable electricity, biofuels, and afforestation in 2030 under the Blueprint. See Appendix D online for assumptions and sources.

b The wind footprint includes the land used by the wind tower base, access roads, and supporting infrastructure. The total for wind includes the footprint as well as the area between the turbines that can be used for other productive uses, such as farming.

c Distributed photovoltaics are installed on residential and commercial buildings, and therefore would not require any new land.

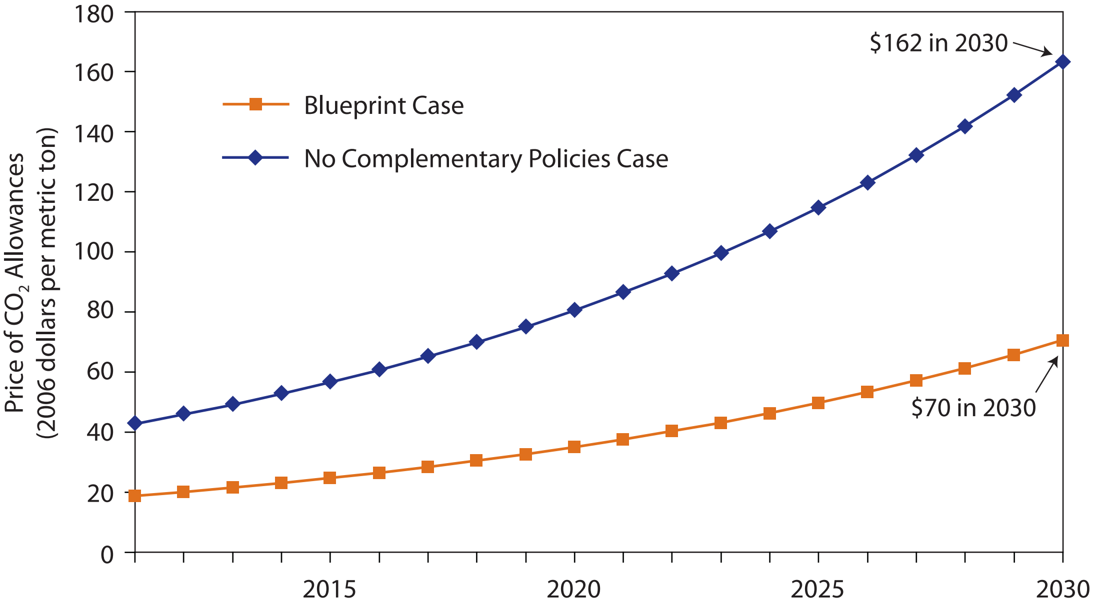
d The low end of the range includes only the wind footprint and does not include distributed PV, while the high end of the range includes the total areas for wind and distributed PV.

e These figures are based on an estimate of the amount of energy crops (switchgrass) used for producing biofuels. The incremental land area is zero under the Blueprint because no additional cellulosic biofuels are produced above the Reference case. We assumed that the use of agricultural, forest, urban, and mill residues would not require any new land, as these residues come from existing operations.

f Land use for corn ethanol reaches a maximum of 31 million acres, or 40 percent of the total corn crop, in 2017, and then declines to 8.4 million acres, or 11 percent of the total corn crop, by 2030, as lower-cost cellulosic biofuels replace corn ethanol.

g The land for afforestation offsets is based on the assumption that 50 percent of the total offsets in the Blueprint cap-and-trade program come from afforestation, and assumes carbon storage of 2.2 million to 9.4 million tons of CO_2eq per acre per year for up to 120 years.

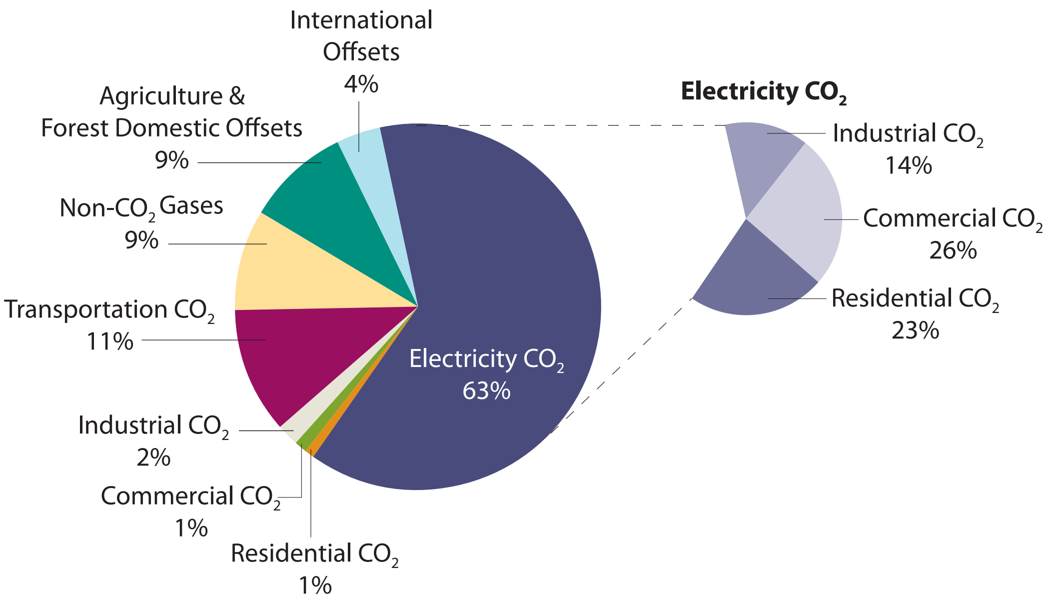
FIGURE 7.18. Prices of Carbon Allowances



The prices of carbon allowances are at least twice as high in the No Complementary Policies case as in the Blueprint case.

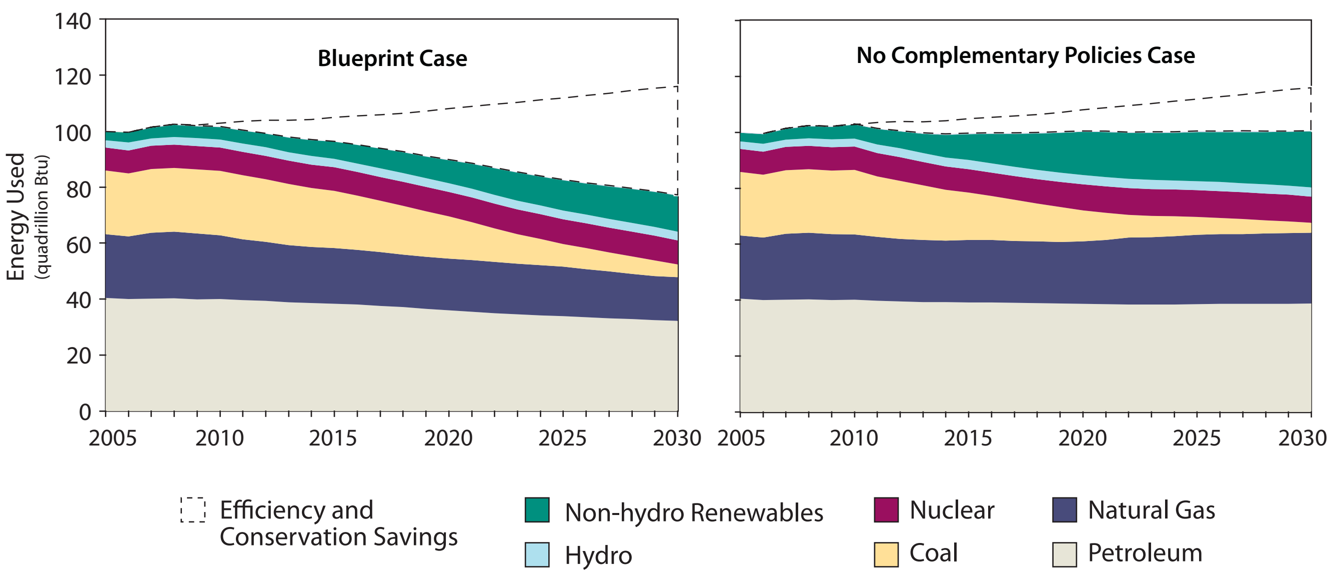
Blueprint policies that promote energy efficiency and cleaner technologies will significantly increase the prevalence of "green" buildings in the United States. The LEED Gold-certified City Hall in Austin, TX, employs daylighting, occupancy-controlled lighting sensors, and efficient appliances to reduce electricity demand; a high-efficiency natural gas boiler for hot water and heating; and a district cooling system that saves energy during peak daytime hours.

FIGURE 7.19. The Source of Cuts in Global Warming Emissions in 2030
(No Complementary Policies case vs. Reference case)



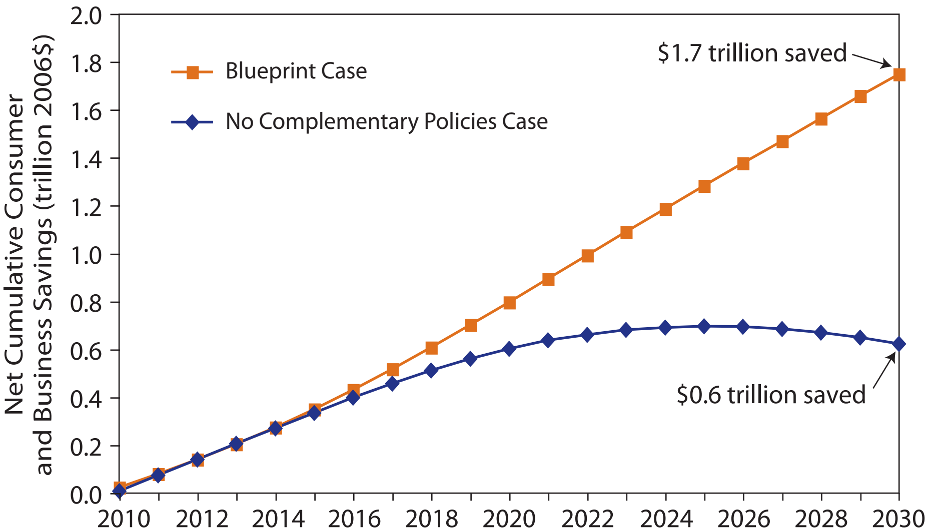
The electricity sector leads the way in cutting emissions, playing an even larger role than under the Blueprint case. Offsets follow, and also play a larger role than in the Blueprint case. Transportation is third, playing a smaller role than under the Blueprint. Emission cuts in the electricity sector include reductions in demand from energy efficiency in the residential, commercial, and industrial sectors.

FIGURE 7.20. U.S. Energy Use
(Blueprint case vs. No Complementary Policies case)



In the No Complementary Policies case, energy efficiency and conservation play a much smaller role in reducing U.S. energy use, while renewable energy, natural gas, carbon capture and storage, and nuclear power play a larger role in the electricity sector. Oil use is also greater without the cleaner cars and trucks and better transportation choices delivered by the Blueprint's complementary policies.

FIGURE 7.21. Net Cumulative Savings (2010–2030)



Note: Net present value using a 7% real discount rate.

The 2010–2030 net cumulative savings to consumers and businesses are $1.7 trillion under the Blueprint case. Under the No Complementary Policies case, which strips out all the energy and transportation policies, these savings are $0.6 trillion.

The complementary policies significantly increase the use of energy-efficient technologies in the building, commercial, and industrial sectors. These policies also expand the use of cleaner cars and trucks, and lower demand for travel, more than the carbon price signal alone.

The complementary policies have the added benefit of moving important technologies into the marketplace early, advancing them up the learning curve, bringing down their costs, and continuing to provide benefits beyond 2030. Funding for research and development will also help bring new breakthrough technologies to the market more quickly. Wide-scale deployment of all these low-carbon technologies cannot happen overnight, so any significant delays could eliminate the nation's chances of cutting carbon emissions 80 percent by 2050.

Many of the complementary policies in the Climate 2030 Blueprint aim to help increase the use of energy-efficient technologies in our homes, offices, and factories. Energy efficiency is one of the most cost-effective sources of emissions reductions in the Blueprint.

7.8.2. No Complementary Policies Case: Impact on Cuts in Carbon Emissions

Excluding the complementary policies also shifts reductions in emissions from the transportation, buildings, and industry sectors to the electricity sector (see Figure 7.19). Cuts in emissions from the electricity sector in 2030 grow from 57 percent under the Blueprint case to 63 percent in the No Complementary Policies case.

Carbon offsets play a slightly larger role in 2030, accounting for 13 percent of total cuts in emissions versus 11 percent under the Blueprint. On the other hand, cuts in emissions from the transportation sector drop to 11 percent of the total, versus 16 percent under the Blueprint. Reductions in non-CO_2 gases contribute 9 percent of the cuts.

7.8.3. No Complementary Policies Case: Impact on Total Energy Use

Our sensitivity results show that, without the help of complementary policies, the most important lowest-cost solutions—energy efficiency and conservation—play a much smaller role (see Figure 7.20). That is because a carbon price signal alone cannot overcome significant market barriers to investments in energy efficiency and conservation.

Strong climate policies that help the nation transition to a more efficient, cleaner, low-carbon economy will help us avert some of the worst consequences of global warming.

The result is that renewable energy, natural gas, carbon capture and storage, and nuclear power play a larger role in the electricity sector. The renewable energy mix also includes more higher-cost choices such as offshore wind, dedicated biomass plants, advanced geothermal, and solar, which all become more competitive than other low-carbon options at higher prices for carbon allowances. Oil use is also greater without cleaner cars and trucks and reduced travel in the transportation sector.

7.8.4. No Complementary Policies Case: Impact on Consumer Savings

With the complementary policies stripped out, cumulative net consumer and business savings are lower than in the Blueprint case. In the sensitivity analysis, cumulative consumer and business savings reach $0.6 trillion in 2030, compared with $1.7 trillion with the complementary policies in place (in 2006 dollars with a 7 percent discount rate) (see Figure 7.21). These comparisons assume that government recycles revenues from the auction of carbon allowances back into the economy, but does not target those revenues to specific uses such as energy efficiency and low-carbon technologies.

Our results show that putting a price tag on carbon emissions is insufficient to overcome market barriers that hinder the growth of the most important and least expensive climate solution: energy efficiency. Targeted policies encourage up-front investments in energy-saving technologies such as those found at the West Grove, PA, headquarters of Dansko Inc., a shoe manufacturer. Rooftop storm water collection (for use in the building's toilets), insulated windows, solar hot water heating, a green roof, and solar shades earned Dansko LEED Gold certification.

Climate 2030 Blueprint policies will benefit the U.S. economy by spurring investments in clean energy technologies and saving consumers and businesses money—in every region of the country.

The Climate 2030 Blueprint will jump-start a clean energy transition that will stabilize energy prices and put money in consumers' pocketbooks.

7.9. Economic, Energy, Health, and Global Benefits of Strong U.S. Climate Policies

Strong climate policies that help the nation transition to a more efficient, cleaner, low-carbon economy will not only help us avert some of the worst consequences of global warming. Such policies will also provide a host of other benefits, including opportunities for economic growth, more stable sources of energy, reductions in other pollutants, improvements in public health, and opportunities for cooperation and development worldwide.

Economic benefits. Climate policies will give a boost to our economy by providing new jobs in the clean technology sector, spurring technological innovation, creating opportunities to export those technologies, and stabilizing energy prices. Several recent studies show that this "green transition" will create millions of well-paying jobs (Apollo Alliance 2008; Pollin et al. 2008).

A recent UCS analysis of a 25 percent national renewable electricity standard by 2025 showed that this policy alone would create 297,000 new jobs in 2025—or more than three times as many jobs created by producing an equivalent amount of electricity from fossil fuels (UCS 2009). Renewable energy creates more jobs than fossil-fuel-based energy because it is typically more labor-intensive.

Energy benefits. Volatile energy prices and uncertainty about future sources of energy play havoc with our economic well-being. By taking advantage of the huge potential of energy efficiency, and by transitioning our energy supply to clean, reliable, renewable sources, we can help stabilize energy prices and improve the long-term health of our economy.

Reductions in other pollutants and improvements in public health. Production and consumption of goods and services often result in other forms of pollution besides carbon emissions. For example, burning fossil fuels releases sulfur emissions, mercury emissions, and particulate matter, among other harmful co-pollutants. Mining, drilling, transportation, and waste disposal related to coal, oil, natural gas, and nuclear power also pose serious health and environmental hazards. By implementing policies that cut our carbon emissions, we can also reduce these other pollutants (see Box 7.3).

Global cooperation. Climate change is a global problem, and all nations will need to take serious action to address it. However, the United States has a unique responsibility to play a leadership role in curbing global warming because of the outsized volume of our past and current heat-trapping emissions, and the wealth we built on those emissions.[95]

95 At the 1992 Earth Summit in Rio de Janeiro, 177 countries including the United States signed the U.N. Framework Convention on Climate Change. That framework clearly recognizes "common but differentiated responsibilities" among the signatory nations, and assigns the lead responsibility to developed countries.

Reducing carbon emissions also reduces harmful pollution that causes asthma, lung disease, and other respiratory ailments, improving our quality of life and leaving our children a cooler climate.

Aggressive U.S. action to reduce carbon emissions will send a strong signal to the rest of the world that we must work together to tackle this global problem.

The most important step we can take is to make a strong commitment to reducing our carbon emissions. As our analysis shows, our nation will reap tremendous benefits from doing so. We cannot solve global warming on our own, but our leadership will set the stage for other countries to take critical steps to reduce their emissions as well.

7.10. Limitations, Uncertainties, and Opportunities for Future Research

Projections of long-term changes in the supply, use, and prices of energy are subject to a great deal of uncertainty. Modeling the impacts of climate and energy policies that will require significant changes in the way we produce and use energy only adds to those uncertainties.

One limitation of our analysis is that we analyzed only two potential scenarios for meeting our targets for reducing global warming emissions. Other scenarios with different policy, economic, and technology assumptions could achieve these or more stringent targets, with different effects.

The most important types of assumptions we made concerned:

- energy demand and prices;
- the cost and performance of technologies;
- trajectories for emissions set by the cap, levels of offsets, and a zero terminal balance in the allowance bank;
- levels of development and policies for energy efficiency, conservation, and renewable energy;
- the availability and cost of carbon capture and storage, advanced nuclear power plants, and emerging renewable energy and transportation technologies; and
- the amounts of biomass available to provide electricity and fuels.

We were also unable to address a variety of limitations of NEMS, despite incorporating information from other analyses and modifying the model. Examples are described below.

Limitations of macroeconomic modeling. NEMS has significant limitations in how it quantifies the macroeconomic impacts of climate and energy policies. For example, it cannot fully account for the positive effects on GDP and employment of investments in energy efficiency, renewable energy, and other low-carbon technologies, and of savings on consumers' energy bills.

Indeed, NEMS predicts roughly the same gain in economic productivity in the Reference case as in the Blueprint case. That result understates the nation's ability to shift savings from reduced energy use to more productive uses. Nor does NEMS value other productivity gains and non-energy benefits that would both accelerate adoption of more advanced technologies and improve economic performance (Worrell et al. 2003).

Recent research by both utility companies and government agencies suggests that wind power can contribute up to 25 percent of the U.S. electricity supply without requiring storage or compromising the reliability of the electricity grid.

The model also treats reductions in energy consumption and increases in energy prices as exerting a negative impact on the economy, even if overall energy bills are lower. And NEMS does not account for the loss of GDP that may result from unchecked climate change in the Reference case.

As noted, the model is also not designed to target allowance revenues to specific technologies and purposes in ways that could reduce carbon emissions and improve economic welfare. Although the model can recycle these revenues generally to households, businesses, and government, modifying the model to include a more extensive approach was beyond the scope of our study.

Modeling energy efficiency. The model does include specific technologies for boosting energy efficiency in vehicles, industry, and buildings. However, analyzing the impact of proposed efficiency policies in the residential, commercial, and industry sectors is difficult without significantly modifying the model and its assumptions.

The model does attempt to capture some reductions in energy use owing to higher prices. However, that approach is limited. The way NEMS shows consumers and businesses adopting technologies in response to changes in price depends on fixed elasticities, or payback times linked to specific discount rates. But those elasticities and payback periods can shift over time because of changes in household income or consumer preferences.

As preferences evolve and as consumers become more aware of choices, the resulting carbon price signal needed to drive those choices may be substantially lower than NEMS might indicate. Stated differently, changed behaviors may deliver greater efficiencies or reductions in emissions for the same price signal.

The effects of sources of electricity with variable power output. The model does not fully capture the impact of high levels of variable-output wind and solar on the electricity grid. NEMS does capture variations in the output of these technologies during nine different time periods throughout the year for 13 different U.S. regions. However, it does not capture all the fluctuations that can occur over much shorter time periods, and at the subregional level. Doing so would require additional ramping up and down of other sources of power.

Several studies by U.S. and European utilities and government agencies have found that wind can capture as much as 25 percent of the electricity market at a modest cost, and without adverse effects on the system's reliability or the need to store power (EERE 2008; Holttinen et al. 2007). Our results are below these levels, with wind and PV capturing about 20 percent of the U.S. electricity market by 2030.

Offshore carbon emissions. The NEMS model does not track changes in heat-trapping emissions in other countries from the production of energy and other goods imported into the United States.

This shortcoming is significant for the transportation sector, which is responsible for the majority of the 3.5-million-barrel-per-day cut in imported petroleum products in the Blueprint versus the Reference case. Given projections that the United States could import more than 6 million barrels a day of high-carbon resources such as tar sands and oil shale by 2035 (Task Force 2006), our results could overlook significant cuts in carbon emissions that could result from curbing reliance on those overseas resources.

For example, if the 3.5 million barrels per day came from tar sands, U.S. cuts in global warming emissions in 2030 would rise by 2 percent under the Blueprint.[96] If the 3.5 million barrels per day came from oil shale, projected cuts in emissions could rise by 15 percent.[97]

NEMS also does not include carbon emissions from indirect changes in land use, either domestically or abroad, that could occur from using food crops and certain agricultural land to produce biofuels. Some estimates show that such indirect effects from the use of corn as a biofuel feedstock could nearly double carbon emissions compared with gasoline (Searchinger et al. 2008). Our Blueprint findings may therefore underestimate the benefit of moving away from corn ethanol. We have tried to minimize displacement of U.S. agricultural crops (see Section 7.7) to prevent potential adverse effects abroad, such as the clearing of rainforests to produce crops formerly grown in the United States.

These limitations of our model, and the uncertainties around some of our key assumptions, present important opportunities for future research. Different combinations of technologies and policies could also be modeled. Another important extension could be to more fully examine the effects of Blueprint policies on employment and other aspects of the economy.

96 This assumes that global warming emissions from fuel from tar sands would be about 15 percent higher than those from today's gasoline, on a well-to-wheels basis.

97 This assumes that global warming emissions from fuel from oil shale would be about double those from today's gasoline, on a well-to-wheels basis.

Cultivating a Cooler Climate:
Solutions That Tap Our Forests and Farmland

How we manage U.S. forests and farmlands has a major impact on our net emissions of carbon dioxide and other heat-trapping gases. The United States has a rich diversity of forests, from the maple-beech-birch woodlands of New England to the lob-lolly pinelands of the Southeast to the coastal redwoods of northern California. Covering almost 750 million acres of public and private lands, our forests provide critical habitat for wildlife, as well as recreational opportunities, sources of fresh water and timber, and aesthetic benefits for millions of people.

These forests are also important storehouses of carbon, with some 245 million metric tons carbon dioxide equivalent ($MMTCO_2eq$) stored in living tissue, leaf litter, and forest soils (CCSP 2007). Through photosynthesis, trees and other vegetation take up—or sequester—carbon. A combination of natural disturbances and human activities, including timber harvests, fire, pest infestations, and deforestation also release carbon back into the atmosphere as carbon dioxide. Today U.S. forests are a net "sink" for carbon, drawing more CO_2 out of the atmosphere than they release.

The United States is also home to some 1,400 million acres of cropland and grazing lands. Agriculture is a complex, malleable enterprise with variable impacts on net global warming emissions. Major sources of CO_2 include soil disruption, such as through tillage for crops; the fossil-fuel-intensive production of herbicides, insecticides, and, especially, industrial fertilizers; and the use of fuel to run farm machinery. Besides CO_2, agricultural activities allow the release of two other potent heat-trapping gasses, methane and nitrous oxide, from livestock, manure, and nitrogen fertilizers applied to soils.

Land-management practices and policies exert a major impact on U.S. heat-trapping emissions. In 2000 the United States emitted more than 7,000 $MMTCO_2eq$. The great majority of those emissions stemmed from the burning of fossil fuels, including 50 $MMTCO_2eq$ from on-farm use. U.S. forests, in contrast, were a major net sink of carbon, absorbing almost 840 $MMTCO_2eq$, or about 12 percent of U.S. emissions in 2000.

We are heading in the wrong direction. Our forests and other vegetation absorb more than 10 percent of U.S. global warming emissions, but that capacity is at substantial risk. More than 50 million acres of undeveloped, privately held lands are projected to be converted to urban and developed uses over the next 50 years (USFS 2007).

A recent EPA study projected that, under business as usual, the U.S. forest carbon sink will decline to about 220 $MMTCO_2eq$ by 2020, and 145 $MMTCO_2eq$ by 2030, with emissions from farmlands projected to remain high (Murray et al. 2005). Together forests and farms in the continental United States will soon become a major net source of emissions, contributing a projected 280 $MMTCO_2eq$ to the atmosphere in 2020, and 320 $MMTCO_2eq$ in 2030, from non-fossil-fuel sources. Without a major course correction, our lands will amplify—rather than reduce—global warming emissions.

We can do better. The Congressional Budget Office estimates that U.S. forests and farmlands have the technical (biophysical) potential to sequester the equivalent of 13–20 percent of what the nation's CO_2 emissions were in 2005, through expansion of forests onto lands now under other uses, reduced deforestation, and better management of current forests and farmlands (CBO 2007). Barriers to realizing that potential include the costs of altering land-use practices, trade-offs between carbon mitigation and other social goals, and the potential for climate change to reduce carbon storage by increasing the frequency and severity of fire and pest infestations in some U.S. forests (van Mantgem et al. 2009).

Recent modeling studies show that privately held U.S. forests and farmlands have the potential to cost-effectively sequester substantial quantities of CO_2 over the next few decades (CBO 2007; Murray et al. 2005), particularly through accelerated planting of trees on non-forest lands in the Midwest and Southeast. Further research is needed to refine these projections, to account for competing land uses, and to ensure that any expansion of forests (and bio-fuels) onto lands now used for food crops does not

Although not modeled in the Climate 2030 Blueprint, our forests have an important role to play in reducing global warming. Carbon is captured by trees during photosynthesis and stored in living tissue, leaf litter, and forest soils. Government projections, however, suggest that our forests' capacity to absorb global warming emissions could decline rapidly in just two decades. This dangerous trend can be addressed by encouraging better forest management on public lands, providing tax incentives for owners of private forests, and implementing land-use plans that enhance the capacity of lands to store carbon.

increase the price of agricultural commodities or raise emissions because of land-use changes in other countries (Searchinger et al. 2008). Research is also needed to develop robust estimates of the amount of carbon that the more than 40 percent of U.S. forestlands that are publicly owned could absorb (Smith and Heath 2004).

Smart Policies and Practices

Global warming solutions for U.S. forests. Most policy debates on how to boost carbon storage in forests have focused on carbon offsets under a cap-and-trade program. However, because large-scale reliance on offsets could enable capped companies to avoid cutting their emissions, leaders at the federal, state, and local levels need to develop a broader portfolio of policies designed to inventory and expand the amount of carbon forests store, and enhance the other critical benefits they provide.

The federal government, for example, could more fully integrate carbon storage into the management goals for 182 million acres of federally owned forests in the continental United States. The government could also require longer rotations for timber harvests, the use of reduced-impact harvesting techniques, and better management of fires and pests on public lands.

Federal and state governments can also provide tax incentives to owners of private forests who increase carbon storage on their lands, and offer challenge grants to communities to plant trees and pursue other programs that conserve carbon. Land-use plans, zoning ordinances, and laws protecting natural resources are all tools that local governments can use to encourage smart growth, protect open space, and maintain and enhance the capacity of lands to conserve carbon (Stein et al. 2008).

Global warming solutions for U.S. farmlands. Agriculture is such a complex and varied enterprise that its implications for global warming, like those of forestry, are best addressed through an integrated

More than half of the carbon dioxide humans put into the atmosphere each year is soaked up by trees, crops, soils, and oceans, helping to slow global warming. In addition to carbon storehouses, our forests are sources of fresh water and timber, homes for wildlife, and places of beauty and recreation.

set of policies and programs, some new and some already in place. The federal government, for example, could expand the Conservation Reserve Program to encourage farmers to sequester carbon, and maximize incentives under the Conservation Security Program for the use of cover crops, crop rotation, conservation tillage, and other carbon-conserving practices.

New programs to reduce methane emissions from cattle could include educational campaigns to discourage the consumption of beef and dairy products, and efforts to inform farmers about better feed mixes. The government could also investigate alternatives to anaerobic systems for storing manure, like hog lagoons, that produce methane. And it could provide incentives for the use of methane digesters to capture methane as a source of on-farm energy. Programs for promoting biofuels could emphasize the planting of deep-rooted grasses, which can enhance carbon sequestration as well as offset the use of fossil fuels.

Central to a climate-friendly policy agenda should be the promotion of agricultural systems that provide multiple climate as well as other environmental benefits. Organic-style cropping systems, for example, avoid the use of fossil-fuel-intensive insecticides, herbicides, and chemical fertilizers by employing multiyear rotations to suppress pests, and conservation tillage to suppress weeds (see Box 7.7). These systems also avoid the need for industrial nitrogen by relying on nitrogen-fixing cover crops to keep the soil fertile and promote the buildup of organic matter, maximizing the soil's potential as a carbon sink. The government can encourage the use of these systems through programs that provide transition and cost-share assistance to farmers.

This new policy agenda should rest on long-term, multidisciplinary research illuminating the connections between agricultural practices and heat-trapping emissions. Recent studies, for example, cast doubt on the efficacy of no-till—a kind of conservation tillage—in sequestering carbon (Blanco-Canqui and Lal 2008; Baker et al. 2007). Well-designed research will help reveal the inevitable trade-offs and new opportunities implicit in our choice of agricultural practices.

Important research also includes more detailed studies of the carbon-storing effects of conservation and no-till agriculture, differences between grain-based confinement livestock/poultry systems and pasture-based systems, better ways to replace chemical fertilizers with animal waste, and the factors that lead to the release of nitrous oxide from agricultural systems.

Through these and other smart policies and practices, the nation can fully realize the potential of our forests and farmlands to cultivate a cooler climate while providing other goods and services on which we depend.

BOX 7.7.

SUCCESS STORY

Farmers and Fungi: Climate Change Heroes at the Rodale Institute

Set amid the gently rolling hills of southeastern Pennsylvania, a little miracle unfolds every day. The miracle workers are microscopic fungi that live inside and around the roots of crops, holding the fabric of fertile soil particles together and simultaneously storing carbon.

Located on a 333-acre certified organic farm in Kutztown, PA, the Rodale Institute has been studying organic farming methods for more than six decades (Rodale 2009). Of particular interest, the institute has overseen a side-by-side comparison of organic and conventional farming practices since 1981. The longest-running experiment of its kind, this study shows that organic agricultural practices are regenerative—that is, they build the soil. Farmers practicing regenerative organic agriculture plant cover crops; rotate crops; avoid herbicides, insecticides, and industrial fertilizers; and fertilize with composted manure. Done in a smart way, these practices rebuild poor soils, use nitrogen efficiently, and remove carbon from the air and store it in the soil, where it accumulates year after year.

This roller-crimper tractor attachment is designed for organic no-till farming. Here, it is crushing a cover crop called hairy vetch into mulch, with little soil disturbance. This practice keeps most carbon in the ground, while the compressed crop suppresses weeds, contributes nitrogen and moisture to the soil, and creates habitat for insects beneficial to the corn that is simultaneously being planted.

There are several techniques for building up carbon in the soil. The first, and most commonly known, is preventing carbon from escaping the ground as it is tilled. Each time a plow turns over an acre of land, it releases an astounding 45 pounds of carbon. Organic farmers use a number of tillage systems to prevent carbon loss, including not tilling at all.

But the Rodale research has shown the viability of a second, and surprising, technique. Avoiding synthetic fertilizers and herbicides and keeping the soil covered with live plants builds the soil's organic content, which in turn captures carbon dioxide from the atmosphere and stores it underground.

Enter those amazing fungi. Allowed to flourish, mycorrhizal fungi perform two important functions: they help slow the decay of organic matter, and they help the soil retain carbon. Chemical fertilizers and weed killers essentially poison these fungi, hampering their carbon-storing ability.

In a world rapidly running out of time to reduce heat-trapping emissions, the promise of organic-style agriculture is welcome news. Implementing regenerative strategies for sequestering carbon requires no new technology or specialized knowledge. This suggests U.S. farmers, spurred by the right policies, could rapidly make the transition.

For more information, see *www.rodaleinstitute.org*.