# Chapter 1

# INTEGRATED ANALYSIS AND CONCLUSIONS[1]

This report presents results of a study of the potential for efficient and clean energy technologies to address a number of energy-related challenges facing the United States. These challenges include global climate change, air pollution, oil supply vulnerability, energy price volatility, and inefficiencies in energy production and end-use systems. Some of these concerns are visible today and are clear public priorities; others are emerging as issues or are possible outcomes of an uncertain future. How the nation responds to them will affect the prosperity and well-being of future generations.

The stimulus for this study derives from the recognition that any national effort to address these challenges must consider ways of increasing the productivity of the nation's energy system, while decreasing its carbon and pollution content. Conducted by researchers from five U.S. Department of Energy national laboratories[2], this study makes a strong case for the value of energy technology research, development, demonstration, and deployment as an effective public response. The study identifies specific public policies and government efforts that could foster solutions with positive economic impact.

## *1.1 STUDY OBJECTIVES*

The principal goal of this study is to produce well-documented scenarios that assess how public policies and programs can foster efficient and clean energy technologies to meet the nation's energy-related challenges. The energy-related challenges addressed in this study include:

- the threat of global warming and the possibility that human activities are contributing significantly to long-term climate change with potentially large economic and social costs;
- the possibility of increased acid rain, urban ozone, and other air pollution problems resulting from the continued growth in coal and petroleum use forecast for the next two decades;
- the vulnerability of U.S. oil supply and price volatility associated with the continued concentration of oil supplies in politically unstable parts of the world; and
- the existence of inefficiencies in energy production and end-use systems[3].

While cognizant of all of the above challenges, *Scenarios for a Clean Energy Future* (aka, the CEF study) concentrates primarily upon the challenge of global climate change – this is the principal focus of the supporting policies. In this context, the term "clean energy technologies" refers to technologies that result in fewer carbon emissions per energy service delivered (e.g., lighting, heating, refrigeration, mobility, and industrial processes). Using the framework of the 11-Lab study (DOE National Laboratory Directors, 1998), these technologies include:

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[2] The five national laboratories are: Argonne National Laboratory (ANL), Lawrence Berkeley National Laboratory (LBNL), National Renewable Energy Laboratory (NREL), Oak Ridge National Laboratory (ORNL), and Pacific Northwest National Laboratory (PNNL). This study has benefited greatly from reviews by representatives of the business, government, university, and nonprofit segments of the scientific community who provided important advice and feedback. Their assistance does not imply endorsement. The final responsibility for the content of this report lies solely with the authors.

[3] These challenges, and their relationship to DOE's energy R&D portfolio and its Comprehensive National Energy Strategy are described in DOE (1998 and 1999).

- measures that reduce the energy intensity of the economy (e.g., more efficient lighting, cars, and industrial processes),
- measures that reduce the carbon intensity of the energy used (e.g., renewable energy resources, nuclear power, natural gas, and more efficient fossil-fueled electricity plants), and
- measures that integrate carbon sequestration into the energy production and delivery system (e.g., integrated gasification combined cycle plants with carbon separation and storage).

Other energy-related challenges (i.e., air pollution, oil supply vulnerability, and inefficiencies in energy production and end use) are addressed both as co-benefits of climate change mitigation and as the target of policies specifically designed to tackle them.

## Overview of the Report

Chapter 2 provides introductory and background material, including an overview of recent energy and $CO_2$ emission trends, an explanation of the energy efficiency paradox, an explanation for the government role, and an overview of several past energy policy and program successes. Chapter 3 describes the analysis methodology employed in this study.

Chapters 4 through 7 address each of the major energy sectors: buildings (Chapter 4), industry (Chapter 5), transportation (Chapter 6), and electricity (Chapter 7). The following topics are covered in each of these chapters:

- the sector's current energy technology and fuel characteristics;
- the business-as-usual forecast for the years 2010 and 2020, including the amounts and types of forecast energy requirements and production;
- barriers to accelerated use of clean energy systems;
- public policies and programs that could address these barriers;
- the methodology employed to analyze these policies;
- the analysis results, including a description of key technologies, policies, end-uses, and energy resources; and
- remaining analysis needs.

Chapter 8 looks beyond 2020 at the longer-term, global context. This broader scope ensures that our near- to mid-term scenarios are responsive to anticipated, long-term energy needs, technology developments, and market opportunities, while also reflecting the increase in uncertainty that characterizes 50-year planning.

Additional details on the study can be found in the appendices. Appendix A itemizes the alterations made to the Energy Information Administration's National Energy Modeling System (NEMS) to create the CEF-NEMS. Appendix B provides details on the policy implementation pathways, including timing and magnitudes, how the policy was modeled, an explanation of key assumptions, and citations to key references justifying the assumptions, modeling approach, and inputs. Appendix C presents key technology assumptions used in the modeling, and Appendix D presents detailed results. Appendix E describes several ancillary analyses. These appendices are available at: http://www.ornl.gov/ORNL/Energy_Eff/CEF.htm

This study builds upon the results of a previous report, *Scenarios of U.S. Carbon Reductions* – also known as the “Five-Lab study” (Interlaboratory Working Group, 1997). This earlier report quantified one potential path for energy-efficient and low-carbon technologies to reduce carbon emissions in the United States to their 1990 levels by the year 2010. Key sectors of the economy were examined independently: buildings, transportation, industry, and electric generators. Specifically, the report identified one set of technologies with the potential to restrain the growth in U.S. energy consumption and carbon emissions so that levels in 2010 could be close to those in 1997 (for energy) and 1990 (for carbon). The report concluded that if feasible ways could be found to implement this technology set, the resulting reduction in energy costs would be roughly equal to or exceed the direct costs of implementing the technologies[4].

Unlike the Five-Lab study, the current study identifies specific policies and programs needed to motivate consumers and businesses to purchase the technologies that make up its scenario. Specifically, it examines the potential impacts of different packages of public policies and programs in an effort to identify feasible, low-cost policy pathways to a cleaner energy future. As such, the CEF study responds to a recommendation by the President’s Committee of Advisers on Science and Technology (PCAST), Panel on Energy Research and Development (1997), that the nation identify and adopt a commercialization strategy to complement its national energy R&D portfolio.

The Five-Lab study also did not conduct an integrating analysis and was therefore unable to assess the full range of effects of its technology scenarios on the U.S. economy[5]. The need for an integrating analysis was recognized by the authors and was addressed in a subsequent peer-reviewed report sponsored by the U.S. Environmental Protection Agency (Koomey, et al., 1998). An integrating analytical framework is also used in the CEF study. In particular, a variant of the Energy Information Administration’s (EIA’s) National Energy Modeling System (NEMS) – called the Clean Energy Future-NEMS (CEF-NEMS) – provides integrated results across individual sectors[6]. The integration step allows the effects of changes in energy use in each sector to be taken into account in the energy use patterns of the other sectors. For example, if electric generators should shift significantly to natural gas while at the same time energy consumption in buildings and industry grows, natural gas prices would rise, and some switching to other fuels would result. Through the integration process, such interactions are assessed.

Although this study builds on the Five-Lab study, it stands on its own. Its purpose, scope, and methodology are different, and as a result its findings, while complementary, are distinct. In addition to the differences noted above, the CEF scenarios extend beyond the Five-Lab study’s horizon – by looking quantitatively to 2020 and qualitatively to 2050 – and they address an array of multiple challenges, not just global climate change. By documenting the benefits that efficient and clean energy technologies can deliver in the short term and by characterizing the potential of emerging technologies, the CEF report informs a broad range of readers about policy-driven, technology-based approaches to reducing greenhouse gas emissions and addressing other energy-related challenges.

## *1.2 STUDY METHODOLOGY*

The methodology developed for this study is driven largely by the objective of assessing national policies to address the multiple energy and environmental challenges facing the United States. This objective requires that the methodology be scenario-based, integrated across sectors, and flexible (yet consistent) in

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[4] Direct costs include the increased technology cost plus an approximate estimate of the costs of program and policy implementation.

[5] This limitation and the lack of specific policies and programs were noted in a General Accounting Office review of the Five-Lab study (GAO, 1998, pp. 5–6).

[6] Koomey, et al. (1998) was based on many of the technology assumptions of the Five-Lab study. It used the NEMS integration module but changed the characterization of consumer behavior, the technology characteristics, and many assumptions of the end-use models. It found that the results were not significantly altered by the integration step.

handling a variety of policy options, market sectors, and technologies. The methodology developed here meets these requirements by employing a combination of tools and analytical approaches.

### 1.2.1 CEF Scenarios

A scenario-based approach is used to allow examination of a range of public policies that address energy-related challenges. Scenarios are stories of how the future might unfold; they are not predictions. They are useful for organizing scientific insight, gauging emerging trends, and considering alternative possibilities. A range of assessment methods, analytic tools, and expert judgement is used to analyze the impacts of individual policies. The CEF-NEMS model is then employed to integrate the impacts of each scenario's set of policies. Macroeconomic impacts and feedback are assessed through an analysis of previous modeling results.

The study employs three scenarios – Business-as-Usual (BAU), Moderate, and Advanced. The BAU forecast assumes a continuation of current energy policies and a steady pace of technological progress. In contrast, the Moderate and Advanced scenarios are defined by policies that are consistent with increasing levels of public commitment and political resolve to solving the nation's energy-related challenges. Some of the public policies and programs that define the scenarios are cross-cutting; others are designed individually for each sector (buildings, industry, transportation, and electric generators) and assessed for impacts out to 2020. Numerous policies are examined, including fiscal incentives, voluntary programs, regulations, and research and development.

The CEF scenarios are quantitatively assessed as a package in terms of both benefits and costs projected out to 2020. The benefits include lower greenhouse gas emissions, reduced local air pollution, reduced oil imports, and energy savings from more efficient energy production and use. The costs include the necessary private-sector investment in efficiency and low-carbon technologies, the cost of implementing federal programs designed to encourage such technologies, and the indirect costs of shifts in energy supply that will lead to changes in employment and economic activity.

The CEF scenarios address U.S. energy and environmental issues for the next 20 years. They are not long-term, global, integrated assessments. This 20-year domestic focus is not meant to minimize the importance of longer-term global energy issues such as:

- air pollution problems in many countries around the world,
- access to electricity for the third of the world's population that is currently unserved, and
- long-term fossil fuel resource limitations and distribution.

To place the CEF scenarios within this expanded context, an array of additional technology options are qualitatively described. With successful research, these options could provide additional pathways to address global energy-related challenges through 2050. These include carbon sequestration, novel nuclear reactor designs, advanced gas and chemical separation technologies, fuel cell/turbine hybrids, and a host of efficient and renewable energy technologies. However, the scope of our quantitative analysis is limited to near-term domestic issues to illuminate specific technology and policy opportunities for the U.S. today and in the near-term.

### 1.2.2 Treatment of Uncertainties

The use of scenarios in this study addresses one key uncertainty – the public response to the nation's energy-related challenges. However, additional uncertainties are associated with any study that estimates future impacts of technology and policy. Principal among these is the assumed cost and performance of technologies that are under development. Uncertainties also arise from imprecision in modeling consumer behavior and policy impacts on that behavior. Consumer preferences for new technologies are unreliable and subject to change. And certainly, the connection between public policy and such consumer preferences is even more tenuous.

Based on the scenario definitions and modeling approach used in this study, the CEF scenarios do not portray sudden shifts in policies, technologies, or market preferences. Rather, the scenarios are more incremental and continuous, based on an accumulation of policies impacting numerous technologies, sectors, and markets. To the extent we have failed to anticipate revolutionary technology- and market-driven developments, the CEF characterization of policy impacts over the next 20 years may be off target. However, given the time required for breakthrough technologies to penetrate the market – partly due to the longevity of equipment and infrastructure already in place – it is unlikely that yet-to-be-discovered technologies could have a major impact on the U.S. energy system during the 20-year modeling period.

All scenario-building exercises run the risk of unanticipated breakthroughs. History has experienced numerous transformations that were unanticipated by qualified planners. For instance, energy analysts in the 1970s failed to predict America's massive shift to sports utility vehicles in the 1990s – a shift that interrupted the post-oil embargo’s decade of steady gains in automobile efficiency. Similarly, electricity analysts in the 1970s failed to foresee the extraordinary consequences of the gas turbine technologies developed for the defense industry, which became the “technology of choice” in the 1990s – a shift that transformed the electricity industry.

We may also have failed to fully reflect transformational trends that are already under way. The scenarios do not, for instance, take into account the exploding growth of e-commerce and the Internet economy, which could fundamentally reshape the nation’s demand for energy services. On the one hand, Romm (1999, p. 9) argues that e-commerce could lead to significant reductions in the demand for energy services: “The Internet has the ability to turn retail buildings into Web sites and to turn warehouses into better supply chain software, to dematerialize paper and CDs into electrons, and to turn trucks into fiber optic cables.” Others argue that the explosion of Internet usage and e-commerce could increase demand for energy services.

Despite such potential omissions, the CEF study undertakes a diverse array of sensitivity cases to examine a number of key “what if’s.” These range from analysis of:

- energy prices: e.g., what if natural gas or petroleum prices rise substantially over the next two decades?
- technology breakthroughs: e.g., what if international markets could significantly drive down the price of new nuclear plants in the U.S.?
- technology failures: e.g., what if research is unable to produce a clean diesel engine for automobiles?
- policy preferences: e.g., what if the only acceptable new policy is a domestic carbon trading system?

These sensitivity cases allow the reader to examine numerous possible future scenarios and to determine the degree to which the “core” ones (i.e., the Moderate and Advanced scenarios) are robust over a multitude of circumstances. The overall conclusion of these sensitivities is that the existence of a wide array of policy and technology options provides many low-cost pathways to a cleaner energy future.

In the end, we take advantage of the data available, use our best judgment tempered by external expert review, and employ scenarios and sensitivity analysis to bound the uncertainties. For example, in addition to our three scenarios, we include high-level sensitivities in which we consider only demand-side policies or only supply-side policies (i.e., policies that impact electricity supplies). We also have examined the sensitivity to a limited number of specific major policies such as the renewable portfolio standard and tougher corporate average fleet efficiency standards.

In spite of our scenarios, sensitivities, caveats, and protests to the contrary, it is tempting to use point estimates provided by the individual scenarios as “the estimate.” In hindsight, we might have devoted more of our limited resources to developing a range of estimates for each scenario. For now, the reader is cautioned to consider the values shown as simply representative of a range of possible outcomes.

One remaining question is whether this range of possible outcomes might be large enough to reverse some of the principal findings of the study. In the end, each reader must weigh the data, methods, results, and sensitivities to answer this question. However, the size of the net “direct” benefits of the Advanced scenario, the robustness of the findings with respect to the sensitivities conducted, and the market’s inherent ability to innovate beyond that which can be anticipated by any study all lend credence, in our opinions, to the conclusions drawn. While the authors of this report have a range of views about the results, they believe that with sufficient commitment, the United States could achieve a substantial portion of the future portrayed by the Advanced Scenario.

## *1.3 POLICY IMPLEMENTATION PATHWAYS*

This study does not make policy recommendations. Rather, the purpose of the study is to better understand the costs and benefits of alternative sets of policies to accelerate clean energy technology solutions. Some of these policies are not the policies of the current Administration. In addition, the policies do not address the complete range of policy options. For example, the scenarios do not include international emissions trading which could be important to meeting possible carbon emission targets.

As noted, the analysis focuses on three scenarios: BAU, Moderate, and Advanced. The BAU forecast describes a future in which policies and the implementation of energy efficiency and low-carbon technology are not greatly different from today. It is based on the Reference case developed by the Energy Information Administration (EIA) and published in the *Annual Energy Outlook 1999* (EIA, 1998a). To follow a path that leads to the Moderate and Advanced Scenarios, new or strengthened policies and programs will be needed.

Tables 1.1 through 1.4 illustrate the types of policies and programs that define the Moderate and Advanced scenarios for buildings, industry, transportation, and electricity supply, respectively. The lists simply summarize each policy; a complete description of the policies can be found in each of the sector chapters that follow.

Many of the policies were selected on the basis of their potential to reduce carbon emissions. Others were designed specifically for air quality (e.g., reducing $SO_2$ emissions in the electric sector), oil security (e.g., alternative fuels R&D), and economic efficiency (e.g., restructuring of the electric sector). Regardless of the driving force behind them, almost all reduce carbon emissions and improve air quality. Policies are generally stronger in the Advanced than the Moderate Scenarios, with larger expenditures on public-private R&D partnerships, stricter standards, higher tax incentives, and greater government investment in programs that promote efficient and clean technologies. Two key differences for all of the sectors is the addition of a domestic carbon trading system to the Advanced scenario and increased R&D resources in both the Moderate and Advanced scenarios.

- **Domestic carbon trading system.** Emissions trading programs work by allocating allowances that permit the release of limited quantities of emissions during a specified period (e.g., annually). They allow sources to comply with the cap by reducing emissions or purchasing permits from other sources that can reduce emissions at lower cost. A firm's response will depend on its costs of control compared with the market price of carbon permits.

We assume that the domestic carbon trading program is announced in 2002 and is implemented in 2005[7]. Each year, beginning in 2005, permits are sold in a competitive auction run by the federal government. The carbon emissions limit is set so that the permit price equilibrates at $50/tC (in 1997$) throughout the study period[8]. (A $25/tC case is also analyzed.) The federal government collects the carbon permit revenues and transfers them back to the public. The idea of the carbon permit rebate is to leave people's "incomes" intact while changing the relative price of carbon-based fuels.

- **Increased R&D resources.** The Moderate scenario assumes a 50% increase in federal government appropriations for cost-shared research, development, and demonstration (RD&D) in efficient and clean-energy technologies. The increase is based on an assumed baseline of $1.4 billion in current federal energy R&D. This baseline, and the assumed increase includes research on energy-efficient end-use technologies as well as power generation technologies using renewable resources, natural gas, coal, and nuclear energy[9]. Since these resources are spent in public/private RD&D partnerships, they are matched by private-sector funds. The increase is assumed to be implemented gradually between 2000 and 2005, and to continue through 2020.

  The Advanced scenario assumes that the federal government doubles its appropriations for cost-shared RD&D, resulting in an increase of $2.8 billion per year (half as federal appropriations and half as private-sector cost share). Both scenarios assume a careful targeting of funds to critical research areas and a gradual, 5-year ramp-up of funds to allow for careful planning, assembly of research teams, and expansion of existing teams and facilities.

A set of guidelines was developed for selecting policies for each sector and scenario. These are described in Chapter 3. More than 50 policies are modeled; therefore, it is not possible to estimate the impacts of each policy in isolation. As a result, we focus on scenarios that involve collections of policies, tailored to meet the needs of each sector.

For buildings, the policies and programs include additional appliance efficiency standards; expansion of voluntary programs such as Energy Star, Building America, and Rebuild America; increased efforts on building codes; and expanded R&D. They also include tax credits consistent with the Clinton Administration's 1999 Climate Change Technology Initiative (CCTI); continuation of market transformation programs such as Rebuild America and Energy Star labeling; and related public benefits programs financed by electricity line charges.

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[7] To model the effect of announcing a carbon trading system in 2002, we assume that the market operates as though there were a gradually increasing increment to the cost of carbon-based fuels. The increase is based on the addition of $12/tC beginning in 2002, rising to $25/tC in 2003, $37/tC in 2004, and $50/tC in 2005. This modeling approach is equivalent to assuming that a domestic carbon trading program is implemented in 2002 with a carbon emissions limit that is increasingly constraining over the four-year period, causing carbon permit values to rise to $50/tC in 2005.

[8] $50 per tonne of carbon corresponds to 12.5 cents per gallon of gasoline or 0.5 cents per kWh for electricity produced from natural gas at 53% efficiency (or 1.3 cents per kWh for coal at 34% efficiency). $25/tC corresponds to half these incremental costs.

[9] The estimate of current federal energy R&D is based on a 1997 report by the President's Committee of Advisors on Science and Technology (PCAST, 1997), entitled "Federal Energy Research and Development for the Challenges of the Twenty-First Century." This PCAST report recommended that the United States double its federal energy R&D expenditures by the year 2003. EPRI (1999) recommends a 150% increase (i.e., more than doubling) of U.S. electricity-related R&D in order to resolve the energy–carbon conflict and achieve other energy-related goals.

### Table 1.1 Illustrative Buildings Sector Policies, By Scenario

| Moderate Scenario | Advanced Scenario |
|---|---|
| ➢ Expand voluntary labeling and deployment programs such as Energy Star, Building America, and Rebuild America to increase the penetration of efficient technologies in the market | ➢ Enhanced programs, more end-uses covered, and more penetration |
| ➢ Implement new efficiency standards for equipment, beyond those already planned | ➢ More end-uses covered by standards; another round of standards for some products |
| ➢ Increase enforcement and adoption of current building codes (Model Energy Code and ASHRAE 90.1R) | ➢ More stringent residential building code in 2009 that is gradually adopted by states |
| ➢ Implement tax credits as proposed by the Clinton Administration in the Climate Change Technology Initiative (CCTI) (e.g., $1,000 tax credit for new homes that are at least 30% more energy efficient than the International Energy Conservation Code, through 2004) | ➢ Same credits but with longer time periods before phase-out; size of tax credit increased for heat pump water heaters as well |
| ➢ Expand cost-shared, federal R&D expenditures by 50% | ➢ Double cost-shared, federal R&D expenditures, leading to greater cost reductions, more advanced technologies, more penetration associated with R&D |
| ➢ “Public benefits” (lines) charges for states implementing electricity restructuring (full national restructuring in 2008) | ➢ Higher line charges |
| ➢ Government procurement assumed to increase in scope over current efforts; increase Federal Energy Management Program (FEMP) efficiency goals by executive order; adopt renewable power purchase requirement for federal facilities[a] | ➢ More rapid implementation of FEMP efficiency goals and faster expansion of Energy Star purchasing to state and local governments as well as large corporations; more stringent renewable power purchase requirement for federal facilities. |
|  | ➢ Domestic carbon trading system with assumed permit price of $50 per metric ton of carbon, announced in 2002 and implemented in 2005 |

[a] Unlike other policies enumerated here, we do not explicitly model government procurement policy in this analysis. However, we recognize it here as an important and strategic enabling policy that is essential for the voluntary programs to achieve their estimated penetration levels.

For industry, the pathways include voluntary agreements with industry groups to achieve defined energy efficiency and emissions goals, combined with a variety of government programs that strongly support such agreements. These programs, detailed in Table 1.2, include expansion of existing information programs, financial incentives, greater cost-shared R&D investments, and strengthening of energy efficiency standards on motors systems. Measures are taken to encourage the diffusion and improve the implementation of combined heat and power (CHP) in the industrial sector.

**Table 1.2 Illustrative Industrial Sector Policies, by Scenario**

| Moderate Scenario | Advanced Scenario |
|---|---|
| ➢ Build upon existing voluntary sector agreements with associations and companies to achieve an energy efficiency improvement of 0.5% per year over the BAU scenario | ➢ Build upon existing voluntary sector agreements with associations and companies to achieve an energy efficiency improvement of 1.0% per year over the BAU scenario |
| ➢ Voluntary programs: increase motor, compressed air, steam, and combined heat and power (CHP) challenge programs; expand floorspace covered by Energy Star Building program by 50% | ➢ Voluntary programs: extend challenge programs to smaller companies and other activities; increase floorspace covered by Energy Star Building program by 100%; expand number of pollution prevention program partners grows to 1,600 by 2020 (from 700 in 1997) |
| ➢ Information and technical assistance: expand audit programs (Industrial Assessment Centers–IACs) and labeling programs | ➢ Information and technical assistance: expand audit programs (IAC) and labeling programs |
| ➢ Regulation: Mandate upgrades of all motors to EPACT standards by 2020 | ➢ Regulation: Mandate upgrade of all motors to Consortium for Energy Efficiency standards by 2020 |
| ➢ Investment enabling: expand Clean Air Partnership and line charges to 30 states, provide tax rebates of 50% of the salary of 5,000 energy managers by 2020 | ➢ Investment enabling: Extend Clean Air Partnership and expand line charges to 50 states, provide tax rebates of 50% of the salary of 10,000 energy managers by 2020 |
| ➢ CHP Policies: CCTI tax credits, expedited siting and permitting, interconnection standard in 2002 | ➢ CHP Policies: Extend tax credits beyond 2003, increase state grants through Clean Air Partnership Fund, further reduce expense associated with interconnection |
| ➢ Expand cost-shared federal R&D expenditures by 50%: increase industries-of-the-future effort and cross-cutting industrial efficiency R&D programs | ➢ Double cost-shared federal R&D expenditures: include new industries-of-the-future effort and further expand cross-cutting industrial efficiency R&D programs |
| | ➢ Domestic carbon trading system with assumed permit price of $50 per metric ton of carbon, announced in 2002 and implemented in 2005. |

For transportation, the scenarios result from a combination of financial incentives for efficient automobiles (“golden carrots”), strengthened R&D, several government programs, and voluntary energy efficiency targets for light-duty vehicles. The pay-at-the-pump automobile insurance program involves paying for a portion of automobile insurance by means of an added fee to gasoline, thereby “variabilizing” the cost of insurance to reflect miles traveled. Thus, the increase in the price of gasoline is somewhat offset by lower insurance premiums (depending on how much one travels).

**Table 1.3 Illustrative Transportation Sector Policies, by Scenario***

| Moderate Scenario | Advanced Scenario |
|---|---|
| ➢ Expand cost-shared, federal R&D expenditures by 50% (e.g., achieving 7.4 mpg for heavy trucks in 2020) | ➢ Double cost-shared, federal R&D expenditures (e.g., achieving 7.9 mpg for heavy trucks in 2020) |
| ➢ Implement vehicle purchase tax credits as proposed in the CCTI (e.g., $2,000 credit for vehicle that is two-thirds more fuel efficient than a comparable vehicle, for purchases in 2003 through 2006) | ➢ Tax credits are extended |
| ➢ Accelerate air traffic management improvements to reduce the time spent waiting "on line" on the ground and circling airports | ➢ Same |
| ➢ Program to promote investment in cellulosic ethanol production | ➢ Same |
| ➢ Invigorated government fleet program promoting alternative fuels and efficiency | ➢ Same, with more rigorous requirements |
|  | ➢ Voluntary agreements to improve fuel economy for light-duty vehicles (40 mpg autos, 30 mpg light trucks in 2010; 50 mpg autos, 35 mpg light trucks in 2020)[a] |
|  | ➢ "Pay-at-the-pump" automobile insurance (paid for by adding 34¢ per gallon of gasoline in 2010 and 51¢ per gallon in 2020) |
|  | ➢ Intelligent traffic systems controls, including intelligent roadway signing, staggered freeway entry and electronic toll collection |
|  | ➢ Domestic carbon trading system with assumed permit price of $50 per metric ton of carbon, announced in 2002 and implemented in 2005 |

*A side analysis examines the potential reduction in vehicle miles of travel from policies that affect the evolution of land use patterns and investments in highway infrastructure.

[a] These voluntary agreements, because they are met in the Advanced scenario, would have the same effect as a CAFE standard of the same level.

For electricity, the policies include extending the production tax credit of 1.5¢/kWh over more years and extending it to additional renewable technologies, setting stricter standards, enhancing RD&D, and facilitating the deployment of wind energy. The scenarios also include net metering capped at 1% in the Moderate scenario and 5% in the Advanced scenario. This policy allows on-site generation that exceeds site loads to be sold back to the grid at retail electricity prices. Net metering creates incentives for distributed generation that can have environmental and reliability benefits through higher efficiencies and reduced transmission and distribution requirements.

**Table 1.4 Illustrative Electricity Sector Policies, by Scenario**

| Moderate Scenario | Advanced Scenario |
|---|---|
| ➢ Wind deployment facilitation (e.g., facilitate siting on Federal land, design operator protocols to accommodate wind intermittency) | ➢ Same |
| ➢ 1.5¢/kWh production tax credit (PTC) for the first 10 years of operation for wind and biomass power installed through 2004 | ➢ Same, for all non-hydro renewable electricity options |
| ➢ 1¢/kWh credit for biomass cofiring during the years 2000-2004 | ➢ 1¢/kWh credit for biomass cofiring during the years 2000-2014 |
| | ➢ Renewable portfolio standard – represented by 1.5¢/kWh PTC in 2005-2008 to signify cap in Clinton Administration proposal |
| ➢ Enhanced R&D – represented by the electric technology cost and performance of the AEO99 high renewables and high fossil cases | ➢ Limited additional technology advances beyond those of the Moderate scenario; includes carbon sequestration option |
| ➢ Up to 1% net metering | ➢ Up to 5% net metering |
| ➢ Full national restructuring of the electricity industry in 2008 resulting in marginal cost pricing, lower reserve margins, etc. | ➢ Same |
| | ➢ $SO_2$ ceiling reduced in steps by 50% between 2010 and 2020 to represent tighter particulate matter standards |
| | ➢ Domestic carbon trading system with assumed permit price of $50 per metric ton of carbon, announced in 2002 and implemented in 2005 |

The policy set examined here is not exhaustive. Some potentially complementary policies are not included because of modeling difficulties (e.g., in the case of policies that target the improved performance of roofs, wall, windows, and foundations in existing buildings). In other cases, policies included in the CEF study are less stringent than the policies modeled in other studies (e.g., Geller, Bernow, and Dougherty, 1999; Tellus Institute, 1998). Examples include the higher levels of efficiency for appliances and the larger annual reductions in energy intensity for industrial plants specified by Geller, et al. (1999). Policies aimed at reducing vehicle miles of travel (vmt) were not included, because the BAU forecast already includes a vmt growth rate that our reviews indicated are unrealistically low (Appendix E-2). Finally, numerous policies examined in other studies are omitted, because they were considered to exceed the levels of action or cost that were used as guidelines to define the Moderate and Advanced scenarios. Examples of policies **not** included are:

- **Buildings:** mandate the demand-side management programs run by electric utility companies in the 1980s and first half of the 1990s, which were responsible for a substantial fraction of the energy efficiency improvements already realized in the buildings sector.

- **Industry:** establish tax incentives for new capital investments in energy equipment to accelerate the rate at which technological innovation diffuses into industries, thereby more quickly retiring outmoded and inefficient production equipment and facilities.
- **Transportation:** enact greenhouse gas standards for motor fuels that would be specified as a limit on the average greenhouse gas emissions factor of all motor fuels.
- **Electricity:** require all coal-fired power plants to meet the same emissions standards as new plants under the Clean Air Act, thereby removing the “grandfathering” clause that has allowed higher polluting, older coal-fired plants to continue to operate unabated.

Clearly, inclusion of such policies would result in accelerated progress toward meeting the nation’s energy and environmental goals. Thus, if the nation requires acceleration, these other studies could be consulted to identify stronger actions.

## *1.4 POLICY SCENARIO RESULTS*

This section begins with a discussion of the BAU forecast, since it provides the baseline for assessing the impacts of alternative policy scenarios.

### 1.4.1 The Business-as-Usual Forecast

The BAU scenario was developed from EIA’s AEO99 Reference case (EIA, 1998a). Like the EIA Reference case, it is based on federal, state, and local laws and regulations in effect on July 1, 1998, and does not reflect the potential impacts of pending or proposed legislation. However, the BAU forecast does incorporate the impacts of scheduled administrative actions, such as the issuance of scheduled standards which the EIA estimates do not. In addition, BAU is based on the assumption that federal funding of energy R&D continues at current levels. This ongoing investment, in combination with other private- and public-sector actions, is presumed to result in a steady pace of technological progress. For instance,

- New residential building shell efficiencies are assumed to improve by approximately 25% by 2020 relative to the 1993 average, due to advanced insulation methods and windows.
- In industry, total energy intensities are forecast to decrease by 1.1% annually, of which a reduction of 0.3% annually is through efficiency improvements.
- Switching to low rolling resistance tires is assumed to reduce fuel consumption by 1 trillion Btu (or 125,000 gallons of gasoline) in 2010, and purchases of alternative-fuel vehicles by state governments are assumed to increase to 75% of state fleet purchases in 2001 (EIA, 1998a, pp. 220-223).

The BAU scenario forecasts that U.S. energy consumption will increase 1.2% annually from 94 quads in 1997 to 110 quads in 2010 (Table 1.5). During the subsequent decade, the annual growth rate will drop to 0.8%, bringing total U.S. consumption to 119 quads in 2020. While there is necessarily great uncertainty associated with any specific forecast, all indications are that, without change, the United States is on a path toward increasing energy consumption well into the foreseeable future.

**Table 1.5 Primary Energy and Carbon Emissions, by Sector:**
**Reference Case vs. Business-as-Usual Forecasts**

| | Primary Energy (quadrillion Btu) | | | | Carbon Emissions (MtC) | | | |
|---|---|---|---|---|---|---|---|---|
| | 2010 | | 2020 | | 2010 | | 2020 | |
| | AEO99 Reference Case | BAU Scenario | AEO99 Reference Case | BAU Scenario | AEO99 Reference Case | BAU Scenario | AEO99 Reference Case | BAU Scenario |
| Residential | 21.1 | 21.2 | 22.9 | 23.1 | 333 | 330 | 375 | 363 |
| Commercial | 17.2 | 17.3 | 18.1 | 18.3 | 282 | 280 | 308 | 300 |
| Industrial | 39.4 | 38.7 | 42.1 | 41.1 | 549 | 534 | 595 | 563 |
| Transportation | 33.1 | 33.1 | 36.9 | 36.8 | 626 | 626 | 697 | 696 |
| Total | 110.8 | 110.2 | 119.9 | 119.4 | 1790 | 1769 | 1975 | 1922 |
| Electric Generators[a] | 39.2 | 39.2 | 42.1 | 41.9 | 655 | 645 | 746 | 718 |

Notes: BAU = Business-As-Usual scenario. Source for AEO99 Reference case forecast: Table A2, EIA, 1998a.

[a] The primary energy consumed by electric generators, and their carbon emissions, are distributed across consumption sectors and therefore are fully included in the row labeled "Total."

The CEF study's BAU scenario varies only slightly from the EIA Reference case. The differences reflect three changes. First, the BAU forecast assumes lower nuclear power relicensing costs than the EIA Reference case (these lower costs are believed to be more realistic). Second, the BAU forecast modified base year values as well as retirement rates in three industries – cement, iron and steel, and pulp and paper – based on detailed studies of these industries. Finally, it uses higher retirement rates for all industrial sectors and lower lifetimes of equipment to reflect actual lifetimes of installed equipment, based on detailed assessments of the same three industries. The input variations that distinguish these two cases are documented in Appendix A.

BAU forecasts that U.S. carbon emissions from fossil fuel consumption will increase 1.4% annually from 1,480 MtC in 1997 to 1,769 MtC in 2010 (Table 1.5). During the subsequent decade, the annual growth rate is forecast to be 0.6%, increasing emissions to 1,922 MtC in 2020. The carbon emissions forecasts of the BAU scenario and the EIA Reference case vary somewhat more than their energy forecasts. This is because in addition to assuming slower growth in energy consumption, BAU extends the operation of some nuclear plant capacity assumed to be shut down in the AEO99 Reference case, resulting in a slower rate of growth in the $CO_2$ emitted per kWh. Carbon emissions in the BAU scenario are almost 1% less in 2010 and are 3% less in 2020 than in the EIA Reference case.

The latest information on energy consumption and greenhouse gas emissions in the U.S. (EIA, 1999a, Tables A2 and A19, EIA, 1999b) indicates that in 1998, the nation's energy consumption grew by only 0.5%, and carbon emissions grew by only 0.4%, relative to 1997 levels. During the same year, the economy exhibited continuous growth, with approximately a 4% increase in Gross Domestic Product (GDP). Unlike buildings and transportation, the industrial sector's emissions actually dropped in 1998. This decline was likely affected by a warmer than normal winter season and structural shifts in U.S. manufacturing away from energy-intensive industries and toward information-intensive businesses. If this slowdown in energy demand and carbon emission growth rates reflects long-term structural shifts, then both the BAU and AEO00 forecasts for carbon and energy may be too high.

Notwithstanding these 1998 estimates, both BAU and the Reference case anticipate that each sector (buildings, industry, transportation, and electric generators) will increase its carbon emissions over the next 20 years. Emissions from the transportation sector are expected to grow most quickly and emissions from industry, least quickly. Without strong policy intervention and/or significant energy price increases, it appears unlikely that carbon emissions in the United States will stabilize or decline.

Results of the two policy scenarios are described in the following sections, in terms of energy savings, carbon reductions, key policies and technologies, and costs and benefits. In each case, the policy scenarios are compared with the BAU forecast to assess the magnitude and nature of their impacts.

### 1.4.2 Energy Savings of the Policy Scenarios

Table 1.6 and Fig. 1.1 present the energy use trajectories produced by the Moderate and Advanced policy scenarios and the BAU forecast. The presentation of values with three or more significant figures in this table and throughout the report is not intended to imply high precision, but rather is designed to facilitate comparison among the scenarios and to allow the reader to better track the results. An uncertainty range for each value would be preferred to our single-point estimates, but the analysis required to prepare such ranges was not possible given our resources and the CEF-NEMS methodology described earlier.

In the Moderate scenario, energy consumption grows at an annual rate of 1.0% between 1997 and 2010. Instead of reaching 110 quads in 2010, energy use increases to 107 quads. Overall, the Moderate scenario for 2010 shows an increase of 13% above the 94 quads consumed in 1997 (26% above the 84 quads used in 1990). During the second decade, energy consumption grows at an annual rate of 0.3%. Instead of reaching 120 quads in 2020, it increases to 110. The two quads saved in this scenario in the residential sector in 2020 is enough to meet the current annual home energy needs of 11 million households. The 2.7 quads of energy saved in the transportation sector in 2020 is equivalent to the energy needed to fuel 44 million of today's cars for a year.

Despite these energy savings, the Moderate scenario for 2020 shows an increase of 17% above the 94 quads consumed in 1997 (31% above the 84 quads used in 1990). Transportation energy use grows considerably faster than energy use in the other sectors.

In the Advanced scenario, with its more aggressive policies, energy consumption grows at an annual rate of only 0.4% between 1997 and 2010, approximately half the growth rate of the Moderate scenario. In the second decade, the accelerated penetration of efficient technologies in each end-use sector reverses the growth trend. Energy use between 2010 and 2020 decreases at a rate of 0.3% annually. The Advanced scenario projects an overall increase in energy use to 100 quads in 2010, just 6% higher than in 1997. Energy use in 2020 decreases to 97 quads, just 3% above 1997 levels and 15% above the 84 quads consumed in 1990. This energy savings of 23 quads in 2020 is enough to meet the current energy needs of all the citizens, businesses, and industries located in the top three energy consuming states (Texas, California, and Ohio) or the combined current energy needs of the 30 lowest consuming states.

An off-line analysis of combined heat and power in industry suggests that policies tackling barriers to this technology could increase energy savings by an additional 5 to 10%. Specifically, energy consumption is estimated to decrease by a further 0.3 quads in the Moderate scenario in 2010 and by an additional 0.5 quads in 2020. In the Advanced case, the potential additional reduction from CHP policies is estimated to be considerably larger: 1.1 quads in 2010 and 2.4 quads in 2020.

## Table 1.6 Primary Energy by Sector (quadrillion Btu)*

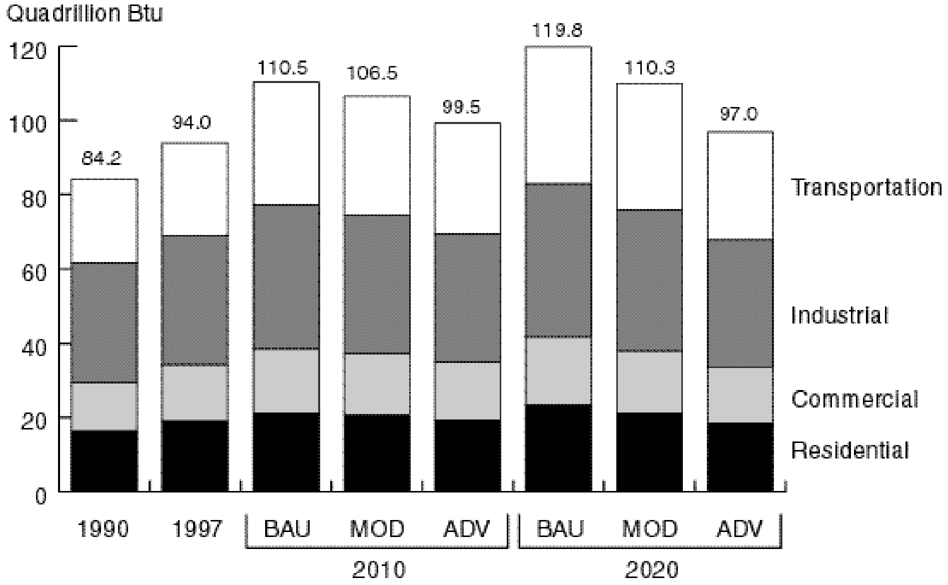
| | | | 2010 | | | 2020 | | |
|---|---|---|---|---|---|---|---|---|
| | 1990 | 1997 | BAU | Mod. | Adv. | BAU | Mod. | Adv. |
| Residential | 16.3 | 19.0 | 21.2 | 20.4<br>(-4%) | 19.3<br>(-9%) | 23.2 | 21.1<br>(-9%) | 18.3<br>(-20%) |
| Commercial | 13.1 | 15.2 | 17.3 | 16.7<br>(-3%) | 15.9<br>(-9%) | 18.5 | 17.0<br>(-9%) | 15.4<br>(-18%) |
| Industrial | 32.2 | 34.8 | 38.8 | 37.2<br>(-4%) | 34.7<br>(-11%) | 41.2 | 38.0<br>(-8%) | 34.3<br>(-17%) |
| Transportation | 22.6 | 25.0 | 33.1 | 32.2<br>(-3%) | 29.8<br>(-10%) | 36.8 | 34.1<br>(-7%) | 28.9<br>(-21%) |
| Total | 84.2 | 94.0 | 110.3 | 106.5<br>(-4%) | 99.5<br>(-10%) | 119.8 | 110.3<br>(-8%) | 97.0<br>(-19%) |
| Electric Generators[a] | 30.1 | 34.2 | 39.3 | 37.5<br>(-5%) | 34.6<br>(-12%) | 42.9 | 38.4<br>(-10%) | 32.6<br>(-24%) |

Notes: BAU = Business-As-Usual; Mod. = Moderate; Adv. = Advanced. Numbers in parentheses represent the percentage change compared with BAU. Source for 1990 electric generators data: Energy Information Administration (1990), Table A2, p. 44. Source for other 1990 data and 1997 data: Energy Information Administration (1998a), Table B2, p. 141.

*A number of key technologies were not modeled within the CEF-NEMS framework and are therefore not reflected in these numbers, including combined heat and power (CHP), solar domestic hot water heaters, and fossil fueled on-site generation in buildings. An off-line analysis suggests that policies tackling barriers to CHP in industry could reduce energy consumption by an additional 0.3 quads in the Moderate scenario in 2010 and by an additional 0.5 quads in 2020. The energy saved by new CHP systems in the Advanced case are estimated to be considerably larger: 1.1 quads in 2010 and 2.4 quads in 2020.

[a] The primary energy consumed by electric generators is distributed across consumption sectors and therefore is fully included in the row labeled “Total.”

## Fig. 1.1 Primary Energy by Sector (quadrillion Btu)



Note: BAU = Business-As-Usual; MOD = Moderate Scenario; ADV = Advanced Scenario. See Table 1.6 for the values associated with this graph.

Table 1.7 and Fig. 1.2 show the energy consumption by fuel type for the BAU, Moderate, and Advanced scenarios. This table includes several notable observations.

### Table 1.7 Energy Consumption by Source (quadrillion Btu)*

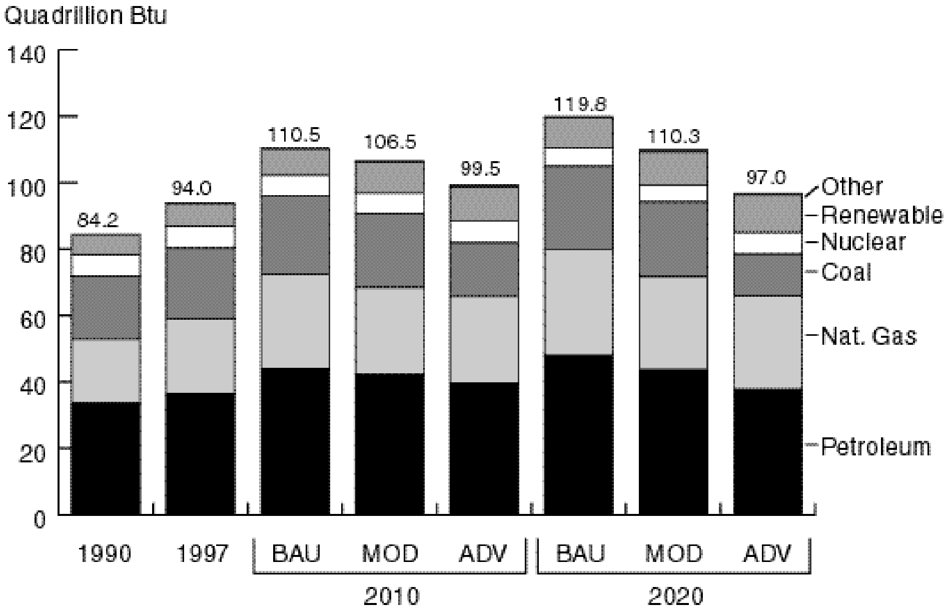
| | | | 2010 | | | 2020 | | |
|---|---|---|---|---|---|---|---|---|
| | 1990 | 1997 | BAU | Mod. | Adv. | BAU | Mod. | Adv. |
| Petroleum | 33.6 | 36.5 | 44.1 | 42.5<br>(-4%) | 39.7<br>(-10%) | 47.9 | 43.7<br>(-9%) | 37.8<br>(-21%) |
| Natural Gas | 19.3 | 22.6 | 28.3 | 26.1<br>(-8%) | 26.2<br>(-7%) | 32.1 | 28.1<br>(-12%) | 28.2<br>(-12%) |
| Coal | 19.1 | 21.1 | 23.7 | 22.6<br>(-5%) | 16.3<br>(-31%) | 25.0 | 23.0<br>(-8%) | 12.7<br>(-49%) |
| Nuclear Power | 6.2 | 6.7 | 6.2 | 6.2<br>(0%) | 6.7<br>(8%) | 5.6 | 4.9<br>(-13%) | 6.4<br>(14%) |
| Renewable Energy | 6.2 | 6.8 | 7.8 | 8.6<br>(10%) | 10.2<br>(31%) | 8.9 | 9.9<br>(11%) | 11.3<br>(27%) |
| Other[a] | 0.3 | 0.3 | 0.4 | 0.5<br>(25%) | 0.4<br>(0%) | 0.4 | 0.6<br>(50%) | 0.6<br>(50%) |
| Total | 84.1 | 94.0 | 110.5 | 106.5<br>(-4%) | 99.5<br>(-10%) | 119.8 | 110.3<br>(-8%) | 97.0<br>(-19%) |

Note: BAU = Business-As-Usual; Mod. = Moderate; Adv.= Advanced. Numbers in parentheses represent the percentage change compared with BAU.

*The off-line analysis of CHP policies suggests that increased CHP in industry would result in the following adjustments to the above Moderate and Advanced scenario results, both in 2010 and 2020. It would increase natural gas consumption, decrease petroleum-based industrial boiler fuels, decrease coal in both the electricity and industrial sectors, and slow the growth of wind and biopower, especially in the Advanced Scenario in 2020.

[a] Other sources include methanol and liquid hydrogen.

### Fig. 1.2 Energy Consumption by Source (quadrillion Btu)



Note: BAU = Business-As-Usual; MOD = Moderate; ADV = Advanced. See Table 1.7 for the values associated with this graph and for explanatory footnotes

First, fossil fuel consumption is reduced in both the Moderate and Advanced scenarios, compared with the BAU scenario, while a higher proportion of nuclear power is retained and renewable energy grows more rapidly. However, the magnitude and composition of these trends differ across the two policy scenarios. For example, coal consumption is impacted much less in the Moderate than in the Advanced scenario. In the Moderate scenario, coal consumption increases from 1997 levels in both 2010 and 2020. Relative to BAU, coal consumption declines by about the same magnitude as natural gas and petroleum in both 2010 and 2020 – on the order of 5 to 8% from 1997 levels. However, in the Advanced scenario with a $50/tonne carbon permit price, coal use declines to 77% of 1997 consumption in 2010 and 60% of 1997 consumption in 2020.

Even with the significant decline in coal consumption in the Advanced scenario, the growth in demand for natural gas is lower than in the BAU scenario. This is because the increased energy savings from efficiency investments, increased use of renewable energy, and maintained use of nuclear power in the Advanced scenario are greater in magnitude than the decline in coal use.

The use of renewable energy sources increases above BAU by 10% in the Moderate scenario and by 31% and 27% in the Advanced scenario for 2010 and 2020, respectively. In 2020, non-hydro renewables double from 2.3 quads in the BAU scenario to 4.6 quads in the Advanced scenario. Such contributions, consistent with cost projections for renewables in this time period, are especially notable for their longer term role. This analysis suggests that the 20-year CEF scenario horizon could see the beginning of a significant growth in renewables.

Another implication of the fuel use results is that growth in petroleum consumption slows in both the Moderate and Advanced scenarios (by 9% to 21% in 2020 compared with BAU). Nuclear power retirements continue in all cases, but at much lower rates in the Advanced scenario than in BAU (6.4 quads of nuclear power consumed in 2020, compared with 5.6 quads in BAU).

The off-line analysis of CHP policies suggests that increased CHP in industry would result in the following adjustments to the scenario results, both in 2010 and 2020. It would increase natural gas consumption, decrease petroleum-based industrial boiler fuels, decrease coal in both the electricity and industrial sectors, and slow the growth of wind and biopower, especially in the Advanced Scenario in 2020.

### 1.4.3 Carbon Emissions Reductions of the Policy Scenarios

Table 1.8 and Fig. 1.3 display the carbon emissions by sector for the three scenarios.

In the Moderate scenario, carbon reductions generally follow – but are somewhat greater than – the reductions in energy use for buildings, industry, and transportation. Between 1997 and 2010, carbon emissions grow at an annual rate of 1.0%. Instead of reaching 1,769 MtC in 2010 (BAU), they increase to 1,684 MtC. During the second decade, carbon emissions grow at an annual rate of only 0.3%, to 1,743 MtC instead of 1,922 MtC in 2020. Annual carbon emissions in 2010 are 85 MtC lower in the Moderate scenario than in BAU, and in 2020 they are 179 MtC lower. However, in both timeframes, carbon emissions are considerably higher than in 1990 or 1997.

In contrast, the Advanced scenario – with its more aggressive demand- and supply-side policies, and with a domestic carbon trading system – shows markedly greater percentage reductions in carbon emissions than in energy use. Between 1997 and 2010, carbon emissions do not grow at all; and during the second decade they decrease at an annual rate of 1.0%. Instead of growing to 1,922 MtC per year by 2020, carbon emissions are brought close to 1990 levels in 2020 (i.e., 1,357 MtC). Carbon emissions in 2010 are 302 MtC lower in the Advanced scenario than in BAU (a 17% reduction), and in 2020 they are 565 MtC lower than in the BAU scenario (a 29% reduction).

The most significant carbon emissions reductions in the end-use sectors occur in buildings and industry. These reductions result from two changes: increased energy efficiency and reduced carbon in the fuels used to generate electricity. An off-line analysis of combined heat and power in industry suggests that policies tackling barriers to this technology could reduce carbon dioxide emissions by an additional 5 to 8%. In the Moderate scenario they would reduce emissions by an additional 5 MtC in 2010 and 10 MtC in 2020; in the Advanced scenario they would reduce emissions by an additional 26 MtC in 2010 and 40 MtC in 2020.

**Table 1.8 Carbon Emissions from Fossil Energy Consumption, by Sector (MtC)***

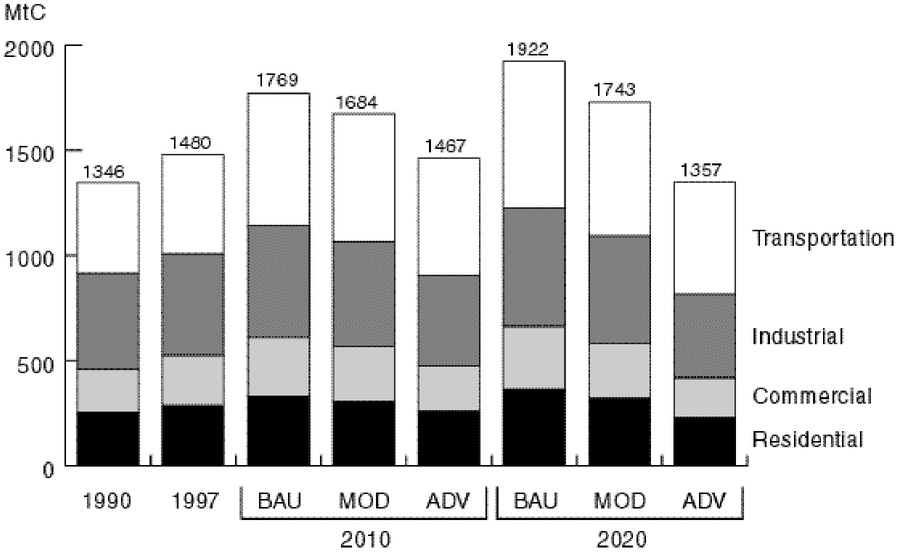
| | | | 2010 | | | 2020 | | |
|---|---|---|---|---|---|---|---|---|
| | 1990 | 1997 | BAU | Mod. | Adv. | BAU | Mod. | Adv. |
| Residential | 253 | 287 | 330 | 311<br>(-6%) | 260<br>(-21%) | 363 | 323<br>(-11%) | 230<br>(-37%) |
| Commercial | 207 | 237 | 280 | 263<br>(-6%) | 218<br>(-22%) | 300 | 271<br>(-10%) | 195<br>(-35%) |
| Industrial | 454 | 483 | 534 | 505<br>(-5%) | 429<br>(-20%) | 563 | 511<br>(-9%) | 399<br>(-29%) |
| Transportation | 432 | 473 | 626 | 606<br>(-3%) | 560<br>(-11%) | 696 | 638<br>(-8%) | 533<br>(-23%) |
| Total | 1346 | 1480 | 1769 | 1684<br>(-5%) | 1467<br>(-17%) | 1922 | 1743<br>(-9%) | 1357<br>(-29%) |
| Electric Generators[a] | 477 | 532 | 645 | 597<br>(-7%) | 460<br>(-29%) | 709 | 623<br>(-12%) | 382<br>(-46%) |

Note: BAU = Business-As-Usual; Mod. = Moderate; Adv. = Advanced. Numbers in parentheses represent the percentage change compared with BAU. Source for 1990 and 1997 data: Energy Information Administration (1998b), Table 7, p. 21.

*An off-line analysis of CHP in industry suggests that policies tackling barriers to this technology could decrease carbon emissions by an additional 6 to 9%.

[a] The carbon emissions from electric generators are distributed across consumption sectors and therefore are fully included in the row labeled “Total.”

**Fig. 1.3 Carbon Emissions by Sector (MtC)**



Note: BAU = Business-As-Usual; MOD = Moderate; ADV= Advanced. See Table 1.8 for the values associated with this graph.

The carbon intensity of the U.S. energy system is forecast to remain unchanged in the BAU scenario. Measured in terms of million metric tons of carbon emissions per quadrillion Btu of energy, the economy continues to produce 16.0 MtC per quad of energy consumed (Table 1.9). The electricity sector is forecast to undergo a slight trend toward decarbonization, reducing its carbon emissions by 7% from 172 gC/kWh in 1997 to 160 gC/kWh in 2020.

### Table 1.9 Changes in Carbon Intensity and Allocation of Carbon Reductions*

| | **2010** | | | **2020** | | |
|---|---|---|---|---|---|---|
| | BAU | Mod. | Adv. | BAU | Mod. | Adv. |
| **Carbon Intensity:** | | | | | | |
| **Primary Energy:** MtC/quad (Note: 1990=16.0; 1997=15.7) | 16.0 | 15.8<br>(-1%) | 14.7<br>(-8%) | 16.0 | 15.8<br>(-1%) | 14.0<br>(-13%) |
| **Electricity Only:** gC/kWh[a] (Note: 1990=167; 1997=172) | 164 | 159<br>(-3%) | 131<br>(-20%) | 160 | 161<br>(1%) | 109<br>(-32%) |
| Percent Reduction in Primary Energy Relative to BAU (A) | | 3.5 | 9.9 | | 7.9 | 19.0 |
| Percent Reduction in Carbon Emissions Relative to BAU (B) | | 4.8 | 17.1 | | 9.5 | 29.4 |
| Carbon Reductions due to End-Use Energy Reductions (in MtC)[b] | | 62 | 175 | | 152 | 366 |
| Carbon Reductions due to Lower Carbon Intensity (in MtC) | | 23 | 127 | | 27 | 199 |
| Total Carbon Reductions (in MtC) | | 85 | 302 | | 179 | 565 |

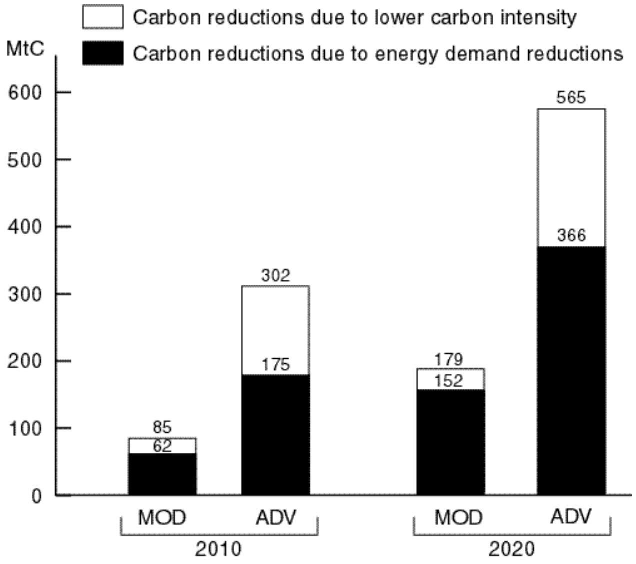
Note: BAU = Business-As-Usual; Mod. = Moderate; Adv. = Advanced. Numbers in parentheses represent the percentage change compared with BAU.

*A number of key technologies were not modeled within the CEF-NEMS framework and are therefore not reflected in these numbers. These omitted technologies include: combined heat and power (CHP), solar domestic hot water heaters, and fossil fueled on-site generation in buildings. An off-line analysis of CHP in industry suggests that policies tackling barriers to this technology would decrease carbon emissions in both scenarios. In the Moderate scenario they would reduce emissions by an additional 5 MtC in 2010 and 10 MtC in 2020, and in the Advanced scenario by an additional 26 MtC in 2010 and 40 MtCin 2020.

[a] Excludes electricity cogeneration.

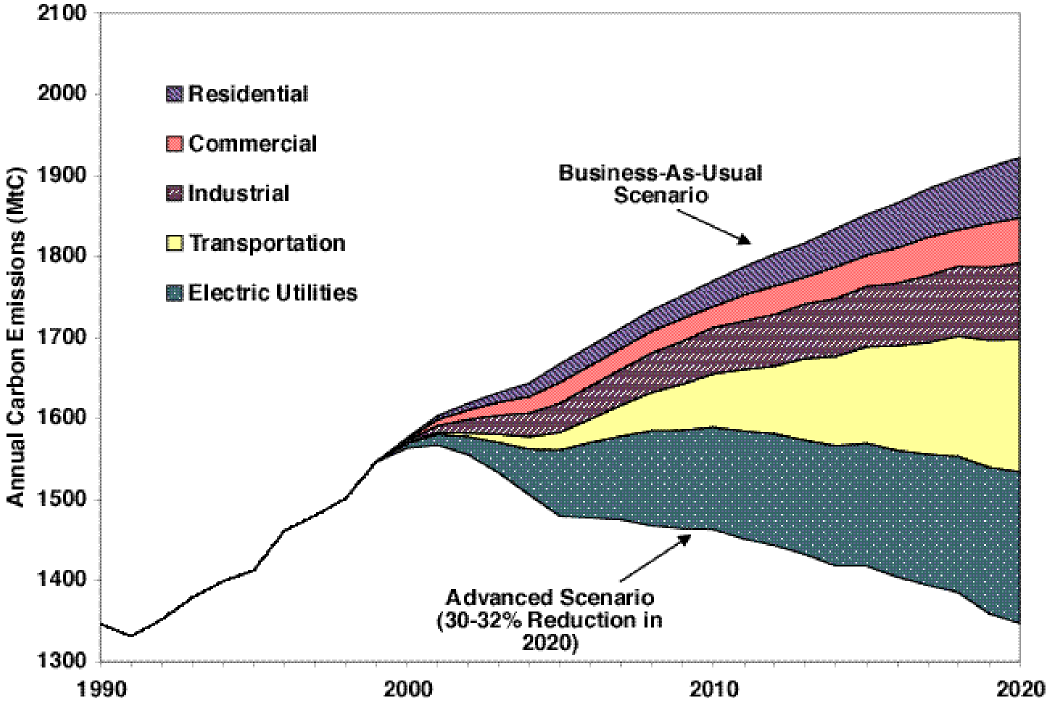
[b] Calculated as (A)/(B) times total carbon reductions.

### Fig. 1.4 Allocation of Carbon Reductions



The carbon intensity of the U.S. energy system also changes very little (only 1%) as a result of the Moderate scenario's policies, decreasing by only 1% throughout the two decades. The electricity sector tracks the BAU scenario with a 7% decrease from 1997 intensities to 161 gC/kWh in 2020. As a result, most carbon reductions from the Moderate scenario, in both 2010 and 2020, are due to reductions in energy demand in the end-use sectors. Estimates of these demand-driven reductions are provided in Table 1.9 and Fig. 1.4. The carbon reductions due to demand-driven reductions were estimated by (1) dividing the percent reduction in energy by the percent reduction in carbon, and then (2) multiplying that fraction by the total carbon reductions.

**Fig. 1.5 Carbon Emission Reductions by Sector, in the Advanced Scenario**



The carbon intensity of the U.S. energy system is reduced significantly by Advanced scenario policies, decreasing by 8% in the first decade and 13% in 2020 relative to essentially unchanged. The electricity sector undergoes even greater decarbonization in the Advanced scenario. It drops 20% in 2010 (from 164 gC/kWh in BAU to 131 gC/kWh in the Advanced scenario), and 32% in 2020 (from 160 gC/kWh in BAU to 109 gC/kWh in the Advanced scenario). As a result, more than one-third of the carbon reductions from the Advanced scenario, in both 2010 and 2020, are due to the lower carbon intensity of the energy system (labeled "electric generators" in Fig. 1.5).

Much of the difference in carbon emissions between the two scenarios is caused by the policies in the Advanced scenario, including carbon trading, that increase the use of low-carbon fuels for electricity generation. These policies result in greater switching from coal to natural gas, increased use of renewable electricity, and extended nuclear power plant operation in the Advanced scenario, relative to the Moderate scenario (Table 1.10 and Fig. 1.6).

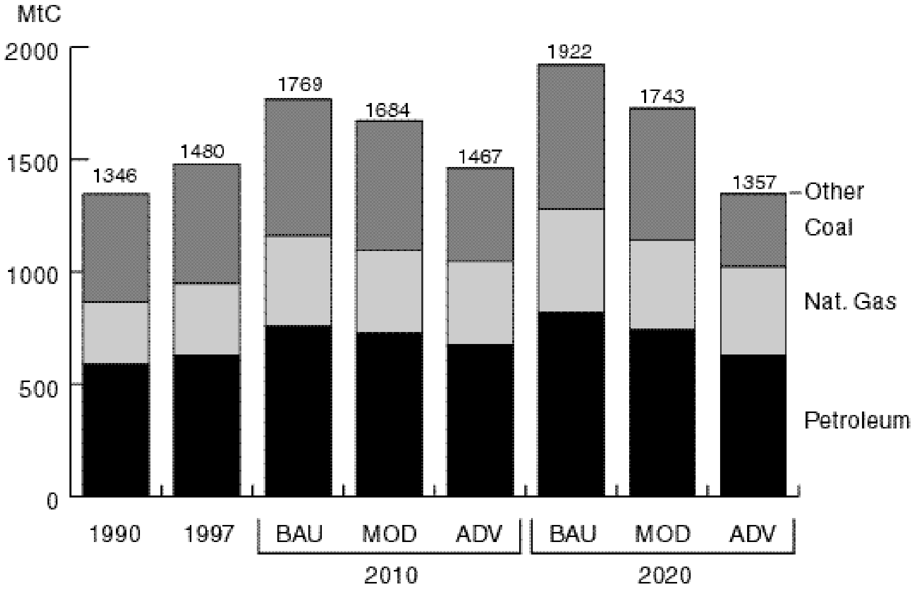
**Table 1.10 Carbon Emissions from Fossil Energy Consumption, by Source (MtC)**

| | | | **2010** | | | **2020** | | |
|---|---|---|---|---|---|---|---|---|
| | 1990 | 1997 | BAU | Mod. | Adv. | BAU | Mod. | Adv. |
| Petroleum | 591 | 628 | 755 | 727<br>(-4%) | 673<br>(-11%) | 818 | 742<br>(-9%) | 627<br>(-23%) |
| Natural Gas | 273 | 319 | 404 | 373<br>(-8%) | 375<br>(-7%) | 460 | 402<br>(-13%) | 398<br>(-14%) |
| Coal | 482 | 533 | 608 | 581<br>(-4%) | 418<br>(-32%) | 642 | 593<br>(-8%) | 328<br>(-50%) |
| Other[a] | 0 | 0 | 1 | 3<br>(200%) | 2<br>(100%) | 2 | 5<br>(150%) | 3<br>(50%) |
| Total | 1346 | 1480 | 1769 | 1684<br>(-5%) | 1467<br>(-17%) | 1922 | 1743<br>(-9%) | 1357<br>(-30%) |

Note: BAU = Business-As-Usual; Mod. = Moderate; Adv.= Advanced. Numbers in parentheses represent the percentage change compared with BAU. Source for 1990 and 1997 data: Energy Information Administration (1998b), Table 6, p. 21.

[a] Other sources include methanol and liquid hydrogen.

**Fig. 1.6 Carbon Emissions by Source (MtC)**



Note: BAU = Business-As-Usual; MOD = Moderate; ADV= Advanced. See Table 1.10 for the values associated with this graph.

### 1.4.4 Key Policies and Technologies

The success of different types of policies and programs varies by end-use sector, reflecting sector-specific market and organizational barriers and imperfections that inhibit the full implementation of cost-effective technologies. Two policies, however, are important to all of the sectors in the Advanced scenario: the domestic carbon trading system and the doubling of federal RD&D appropriations. The importance of the carbon trading system is documented in the sensitivity analysis described in Section 1.5. The importance of expanded R&D is illustrated in Table 1.11.

Table 1.11 Illustrative R&D Advances in the Advanced Scenario

| Buildings | Industry |
|---|---|
| **Heat Pump Water Heaters (HPWHs):**<br>R&D reduces the cost of HPWHs by 50% in 2005, relative to the BAU | **Iron and Steel Technologies:**<br>Development of near net shape casting technologies saves up to 4 MBtu/ton steel and reduces production costs between $20 and $40/ton<br>Smelt reduction starts to replace blast furnaces at the end of the scenario period, reducing energy use by 20-30% in ironmaking as well as emissions from coke ovens and ore agglomeration |
| **Small Metal Halide (Mini-HID) Lamps:**<br>R&D produces a 20-Watt mini-HID with an electronic ballast that has the same brightness as a 100-Watt incandescent lamp and an incremental cost of $7.50, available in 2005 | **Pulp and Paper Technologies:**<br>R&D produces an efficient black liquor gasifier integrated with a combined cycle making a kraft pulp mill a net electricity exporter; this results in primary energy savings of up to 5 MBtu/ton air-dried pulp<br>New drying processes (e.g., condebelt and impulse drying) in the paper machine is successfully developed and commercialized resulting in energy savings of up to 1.4 MBtu/ton paper |
| **Transportation** | **Electric Generators** |
| **Direct Injection Diesel Engines:**<br>R&D enables direct injection diesel engines to meet EPA's proposed Tier 2 $NO_x$ standards in 2004 | **Natural Gas Combined Cycle:**<br>R&D reduces capital costs from the BAU forecast of $405/kW to $348/kW for the 5th of a kind plant; carbon sequestration adds $4/MWh |
| **Hydrogen Fuel Cell Vehicles:**<br>R&D drives down the cost of a hydrogen fuel cell system from $4,400 more than a comparable gasoline vehicle in 2005 to an increment of only $1,540 in 2020 | **Wind:**<br>R&D reduces capital costs from $778/kW throughout the period in the BAU down to $611/kW in 2016; fixed O&M costs decline from $25.9/kW-yr throughout the period in the BAU down to $16.4/kW-yr in 2020 |

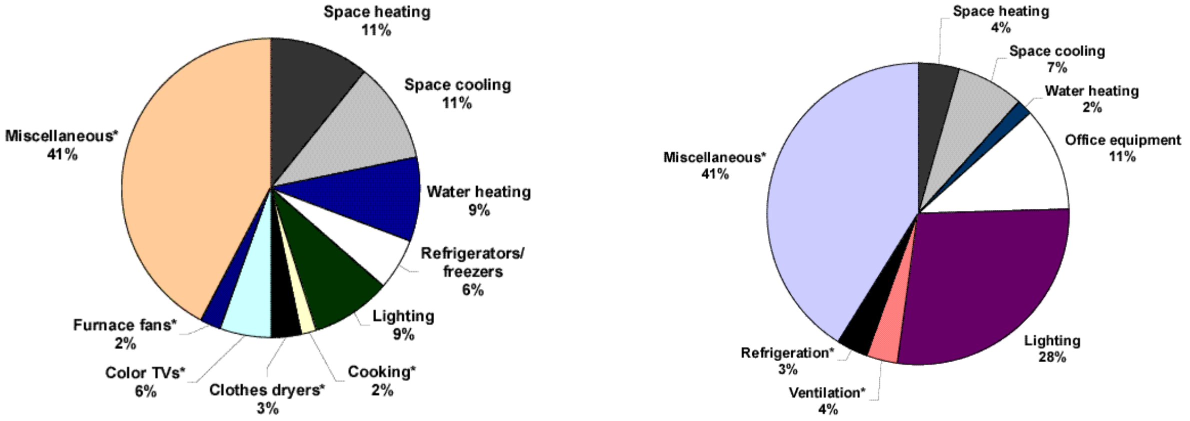
**Buildings.** The largest energy and carbon savings in residential buildings occur in the category "all other" uses (including cooking, clothes dryers, clothes washers, dishwashers, color TVs, and personal computers – see Fig. 1.7). A large fraction of these savings comes from movement toward a "one-watt" standby loss goal by 2010, based on the switch-mode power supplies that are now widely used in the best new equipment. Next in rank order are space cooling, space heating, water heating, and lighting.

In commercial buildings, lighting and "all other" end-uses dominate the energy and carbon savings. "All other" in the commercial sector includes a collection of small end-uses that are explicitly represented in CEF-NEMS, including ventilation, cooking, and refrigeration, as well as other unidentified uses.

Minimum equipment efficiency standards and voluntary programs are the two most important contributors to energy savings; building codes, tax credits, other incentive programs, and R&D generally play a supporting role. In residential heating and cooling end-uses, building codes take on a larger role.

For electronics end-uses, where rapid technological innovation and the proven success of voluntary efforts hold sway, the voluntary programs capture most of the savings.

**Fig. 1.7 Carbon Emission Reductions in the Advanced Scenario in 2020, by Buildings End Use**
(Reductions are Relative to the Business-as-Usual Forecast)



**Residential Buildings**

Constituents of the “All other” category shown in Tables 4.8 and 4.9 are marked with asterisks above. “Miscellaneous uses” include clothes washers, dishwashers, other home electronics, ceiling fans, pool pumps, and other unidentified end-uses.

**Commercial Buildings**

Constituents of the “All other” category shown in Tables 4.8 and 4.9 are marked with asterisks above. “Miscellaneous uses” include transformers, traffic lights, exit signs, cooking, district services, automated teller machines, telecommunications equipment, medical equipment, and other unidentified end-uses.

Note: Carbon savings from electrical end-uses include both demand-side efficiency and supply-side effects.

**Industry.** Energy is saved in all industrial subsectors under both the Moderate and Advanced scenarios. Continuing intra- and inter-sectoral shifts, as well as ongoing efforts to reduce environmental impacts and improve energy efficiency, contribute to the savings within the industrial sector. Decarbonization of the power sector contributes to savings, especially in electricity-intensive industrial subsectors (Fig. 1.8).

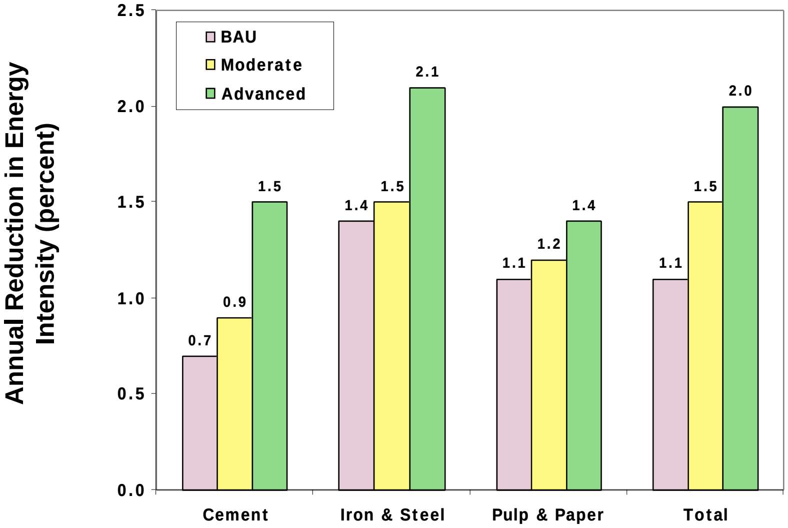
Voluntary agreements between government and industry are the key policy mechanism for achieving these savings. The following policies and programs support the voluntary agreements:

- information programs,
- technology demonstrations,
- energy efficiency audit programs,
- financial incentives, and
- funding for R&D.

The energy-efficiency improvements across scenarios are attributed to increased awareness among plant and company management of opportunities to cut energy costs, as well as strengthened programs to assist in implementing technologies and measures to reduce carbon emissions.

A number of cross-cutting technologies – such as combined heat and power, waste recycling, process control and management, steam distribution system upgrades, improved energy recovery, motor and drive system improvements, and preventive maintenance – contribute significantly to the savings in the policy scenarios. Much of the efficiency improvement results from replacing old process equipment with state-of-the-art equipment instead of new equipment of average efficiency as components and plants are retired. Energy savings in the steel, cement, and aluminum industry are also influenced by the increased use of waste materials. Large improvements in the generation, distribution, and use of steam contribute to savings in the food, paper, and chemical industries.

**Fig. 1.8 Annual Reductions in Energy Intensity in the Industrial Sector**



Based on off-line expert analysis, the CEF policy scenarios accelerate the development and implementation of these practices and technologies. This will increase energy efficiency beyond that assumed in the BAU scenario. In the steel industry, new technologies such as scrap preheating for electric arc furnaces are more efficient than the technologies used in existing plants, and new casting technologies reduce material and energy losses further. New advanced smelting reduction technologies lead to significant savings after 2010 in the Advanced scenario. In the pulp and paper industry, improved paper machines as well as reduced bleaching and increased wastepaper recycling impact energy use, and black liquor gasification substantially changes the energy profile of pulping in the long term. In cement making, the key technologies and measures are the introduction of blended cements and the gradual retirement of old wet-process clinker plants, which are replaced by modern pre-heater pre-calciner kilns. While some of these technologies are currently available or being developed, there is still a large potential for further development or deployment.

**Transportation.** The rate at which carbon emissions from transport can be reduced is limited by the lack of opportunities for retrofitting technologies, together with constraints on the quantities of low-carbon fuels, such as cellulosic ethanol, that can be supplied over the next 10 to 20 years. As a result, the impacts of policies and technologies in 2010 are far less than their impacts in 2020. Indeed, the maximum impacts of advanced technologies are yet to be realized even in 2020.

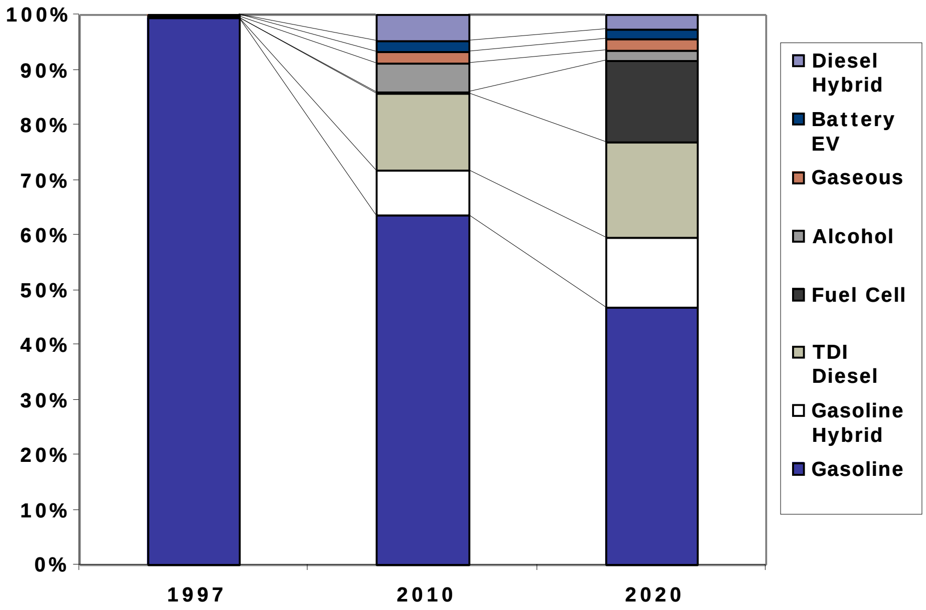
In the Moderate scenario, a combination of several conventional technologies and the turbo-charged direct injection (TDI) diesel have the greatest impact on passenger car and light-truck fuel economy. Even with incentives of up to $4,000 per vehicle, advanced alternative technologies appear to be unable to overcome the market barriers of higher initial cost (especially at low production volumes) and, in the case of alternative-fuel vehicles, limited fuel availability. Encouraged by continuing, though decreasing, tax subsidies, cellulosic ethanol is a key technology for reducing carbon emissions, because it can be readily integrated into existing fuel systems via blending with gasoline. Similarly, modest gains are achieved in non-highway modes of transport.

The key distinguishing features of the Advanced scenario are:

- the greater degree of technological success, attributed to a doubling of R&D investment;
- a voluntary commitment to improved efficiency by vehicle manufacturers that accelerates the introduction of technology and, for cars and light trucks, de-emphasizes vehicle weight and horsepower; and
- significant fuel price signals for highway vehicles in the form of pay-at-the-pump insurance fees and a modest carbon permit price.

The combined effect of these measures is an array of impressive new technologies in large numbers (Fig. 1.9). TDI diesels play a major role in the light-duty vehicle market, with sales exceeding 1 million after 2005 and standing at 2.6 million per year in 2020. In the same year, 2.2 million fuel cell vehicles are sold, representing 10% of the new light-duty vehicle market. Hydrogen fuel cell vehicles, which according to our assumptions are cheaper and more energy efficient, are the most successful, accounting for 1.0 million of the 2.2 million total sales in 2020. In 2020, 3.9 million hydrogen fuel cell vehicles are on the road consuming 0.1 quads of hydrogen annually. Advanced technologies also improve fuel economy significantly in non-highway transport.

**Fig. 1.9 Advanced Scenario New Light-Duty Vehicle Sales**



Energy efficiency is also improved by restraining the large forecasted growth in vehicle horsepower (hp). In 1998, the average hp of new passenger cars sold in the United States was 155. In the BAU case, passenger car hp increases to 251 by 2020. Light truck horsepower increases even more, from 189 in 1998 to 293 in 2020. The Advanced scenario foresees much more modest increases, to 174 hp for cars and 199 hp for light trucks. However, vehicle weight decreases in the Advanced scenario by about 12 percent for passenger cars, so that vehicle acceleration performance would still be about 25 percent faster than today's cars.

**Electric Generators.** The demand reductions due to policies described in the end-use sectors greatly limit the growth in electric generation, especially in the Advanced scenario. Within the electric sector, the key policy driving the changes is the domestic carbon trading system in the Advanced scenario. The resulting carbon permit price:

- makes the building of new coal plants cost-ineffective and increases the retirement of coal and other fossil steam plants between 1997 and 2020 – from 66 GW in the BAU scenario to 187 GW in the Advanced scenario,
- impacts the variable cost of production, causing the remaining carbon-intensive technologies to lower their capacity, and
- encourages extension of the life of existing nuclear plants and development of non-hydro renewables, especially wind and biomass.

Restructuring also plays a significant role. By removing incentives for regulated utilities to retain capital investments that are no longer cost-effective, deregulation encourages the retirement of inefficient plants when new plants represent a more cost-effective option. A somewhat contrary impact is that restructuring promotes real-time pricing and customer shifts in peak load requirements. This lowers the need for additional capacity as existing plants operate more fully, which in turn reduces the need to build new, cleaner plants that displace older plants. In the Advanced scenario, while generation drops 2% between 2010 and 2020, generation capacity declines by 4%.

A third major policy driving the changes in the electric sector is the production tax credit (PTC) for non-hydro renewable energy, especially wind. The Renewable Portfolio Standard (RPS) also creates strong incentives for renewable energy development. By creating growth in wind energy through 2004 or 2008, it encourages the development of a strong capacity base that leads to further growth, but at a slower pace after the PTC and RPS expire. In the Advanced scenario, wind generation grows from 7.1 TWh in 2000 to 129 TWh in 2008, as a result of the PTC and RPS incentives, with help from the carbon permit penalty on other technologies and advances in technology. This 18-fold increase would require an unprecedented growth in production capacity of suppliers of wind generation equipment. In the Moderate scenario, with its shorter schedule for the PTC and no RPS or carbon permit price, wind quadruples by the time the PTC expires (2005). Other renewables are helped as well, but to a lesser extent. Biomass cofiring tax credits increase the use of biomass up to 50% in the Moderate scenario before the PTC expires, and biomass replaces up to 1.2% of coal consumption in 2004. Even higher amounts of cofiring occur in the Advanced scenario as other policies influence its use.

Improvements in technologies through R&D expand opportunities for carbon reductions. They provide effective alternatives to reducing demand or requiring higher prices for the permits. Without technology improvements, low- and non-carbon supplies are more expensive and less likely to displace current inefficient and carbon-intensive sources. Technology advances alone are generally insufficient to impact the overall carbon intensity of the production, but they are powerful in conjunction with the carbon permit price. In the BAU scenario, the carbon intensity by 2020 is 160 gC/kWh. The Moderate scenario, with only modest improvements in fossil technology efficiencies and lower demand growth, actually has 2.3% higher carbon intensity; lower demand means fewer opportunities to build low-carbon systems. Also, with no carbon permit price, there is little incentive to reduce carbon emissions. The Advanced scenario has higher fossil efficiencies but lower demand still. When the Advanced scenario was modeled without a $50/tC permit price, carbon intensity declined by 3% from BAU. With the carbon permit price, the intensity dropped 32% to 109 g/kWh.

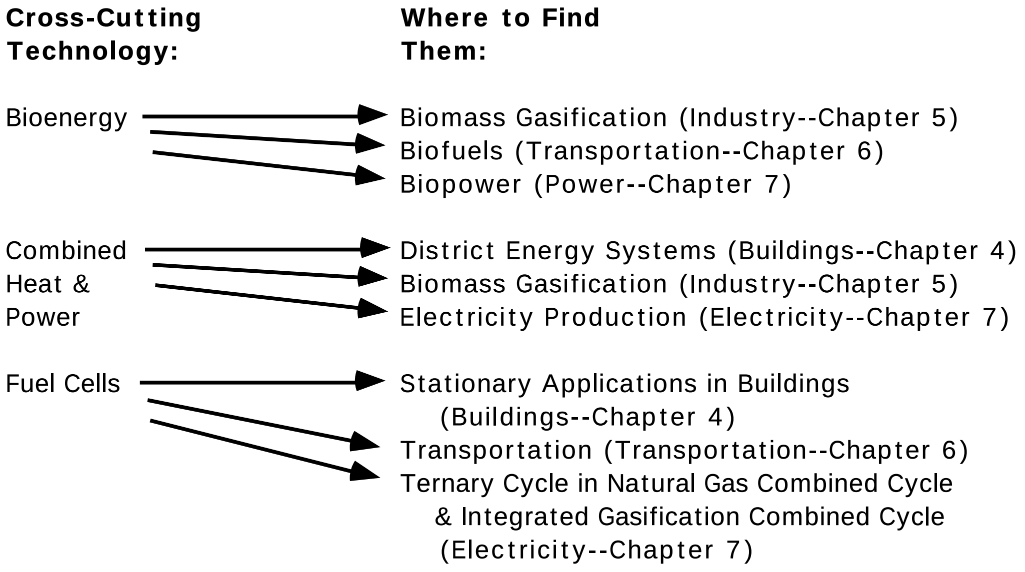
Advances in non-hydro renewable technologies help increase the penetration of new technologies into the market and help make them a viable long-term supply. Production of non-hydro renewable energy in the

Moderate scenario is 28% higher than in the BAU by 2020. But that figure represents only an increase from 3.7 to 5.4% of total production, so non-hydro renewable technology advances alone have a relatively small impact on carbon emission reductions. In the Advanced scenario, with other policies in place as well, non-hydro renewables double their production compared with BAU and represent almost 10% of production. Once again, the synergies of multiple policies contribute more than any one set of policies alone.

**Cross-Cutting Technologies.** Several technologies apply to multiple sectors. These include combined heat and power systems, bioenergy, and fuel cells. The use of CEF-NEMS as an integrating model, which considers all sectors simultaneously, simplifies the evaluation of these technologies. Special considerations in their treatment are discussed in Chapter 3. The following box shows where the reader can find information on these technologies.

**Where Did the Cross-Cutting Technologies Go?**

Several technologies apply to multiple sectors and are therefore discussed in more than one of the chapters in this report. The following “wiring diagram” shows where the reader can find information on three of these cross-cutting technologies.



### 1.4.5 Costs and Benefits of the Policy Scenarios

In this section, we report our estimates of the first-order economic impacts of the CEF scenarios. Specifically, five “direct” cost and benefit components are examined:

- policy implementation and administration costs incurred by the public sector;
- R&D costs incurred by both the public and private sectors;
- incremental technology investment costs;

- changes in the energy bill, including the cost of carbon permits; and
- return of the carbon permit revenues to the public.

In the CEF scenarios, these costs and benefits arise over time as follows.

As policies are enacted, the government begins to incur direct costs for their implementation and administration. Energy prices then change as the market reacts to these policies, including higher fossil fuel prices in response to the purchase of carbon permits and lower energy costs due to reduced demand. Consumers react to the policies directly and to the changing energy prices by modifying their demand for energy services and investing in more energy-efficient and low-carbon technologies. The nation's energy bill reflects the changing energy prices and demands. The investments made in more efficient end-use technologies, on the other hand, are not reflected in this bill and must be accounted for separately. With the annual auction of carbon permits, the government accrues revenues. These revenues are then distributed back to the public.

**Economic Climate Change Consensus**

"Economic studies have found that there are many potential policies to reduce greenhouse gas emissions for which the *total benefits outweigh the total costs*. For the United States in particular, sound economic analysis shows that there are policy options that would slow climate change without harming American living standards, and these measures may in fact *improve U.S. productivity in the longer run."*

— From a statement signed by ~2500 economists led by Nobel laureates Kenneth Arrow and Robert Solow, at a January 1997 meeting of the American Economics Association. *Italics added for emphasis.*

**Summary of Direct Costs and Benefits.** In both the Moderate and Advanced scenarios and in both timeframes (2010 and 2020), the estimated annual energy bill savings exceed the sum of the annualized policy implementation costs and the incremental technology investments. This finding is consistent with many economic-engineering studies (Section 1.6) and with the views of many economists (see box). The gap is wider in 2020 than in 2010, reflecting the greater energy reductions as more cost-effective, clean energy technologies are developed and deployed. These net benefits do not reflect the macroeconomic impacts of the scenarios.

Two externality benefits are quantified but are not monetized: improved air quality and energy security. Amenity costs that may result from the CEF scenarios are also not monetized. One of these, however, is discussed: the lower horsepower of light-duty vehicles purchased by consumers in the CEF scenarios relative to the BAU forecast. Long-run macroeconomic costs are discussed primarily in terms of estimates reported in other published studies. In addition, we describe some industries and regions likely to experience significant economic impacts, at least in the short run, if the nation transitions to the type of clean energy future characterized in the two policy scenarios.

**Policy Implementation and Administrative Costs**. Policy implementation costs include the costs of administering the public policies and programs that are modeled in each scenario, various fiscal incentives, and the incremental R&D costs. For the purposes of this project, ***administrative costs*** include the following costs to the public agencies implementing the policies and programs:

- program planning, design, analysis, and evaluation;
- activities designed to reach customers, bring them into the program, and deliver services such as marketing, audits, application processing, and bid reviews;

- inspections and quality control;
- staff recruitment, placement, compensation, development, training, and transportation;
- data collection, reporting, record-keeping, and accounting; and
- overhead costs such as office space and equipment, vehicles, and legal fees.

Preliminary cost increments were developed by estimating the administrative costs and energy savings associated with 12 policies and programs that have operated over the past decade or two. (Details on these 12 cases are provided in Appendix E-1.) Administrative costs associated with these 12 policies range from $0.052 to $2.49 per MBtu saved. The average value was rounded to $0.6 per MBtu, the increment used in the CEF study. It is added to the annualized incremental technology costs required to generate one MBtu of primary energy savings. This value is consistent with the findings of Berry (1991), who reviewed the cost of implementing demand-side management programs in the 1980s.

Based on these assumptions, the policy administration costs of the Moderate scenario are estimated to range from $3 to $7 billion per year in 2010 and 2020, respectively (Table 1.12). For the Advanced scenario, they range from $9 to $13 billion per year in 2010 and 2020.

**Table 1.12 Annualized Policy Implementation and Administration Costs of the Advanced Scenarios in 2010 and 2020 (in Billions 1997$ per Year)**

| | **Moderate Scenario** | | **Advanced Scenario** | |
|---|---|---|---|---|
| | 2010 | 2020 | 2010 | 2020 |
| Residential | 0.5 | 1.5 | 1.0 | 2.7 |
| Commercial | 0.5 | 1.1 | 0.8 | 1.6 |
| Industrial | 1.0 | 2.2 | 2.3 | 3.9 |
| Transportation | 0.5 | 1.6 | 1.9 | 4.6 |
| Electric Generators | 0.4 | 0 | 2.8 | 0 |
| Total | 2.9 | 6.4 | 8.8 | 12.9 |

In addition to these administrative costs, other policy implementation costs must be considered.

- The fiscal incentives include the production tax credit for renewable energy in the power sector. In 2010, these amount to $0.4 billion in the Moderate scenario and $0.6 billion in the Advanced. These values are part of the "electric generators" row in Table 1.12. These costs do not occur in 2020, because all costs to the government end before 2020. (Note: Fiscal incentives for energy efficiency measures such as the credit for efficient new homes and vehicles are taken into account as incremental technology investment costs. These are shown in Table 1.14.)

- When actually implemented, the cost of an RPS would be captured within the energy bills of consumers. However, in our CEF-NEMS modeling of the RPS, we employed a 1.5¢/kWh tax credit as a surrogate for the RPS with its 1.5¢/kWh allowance cap. Thus in CEF-NEMS, the cost of the RPS is not captured by the utility bill but must be accounted for separately. The annual cost between 2010 and 2015, when the RPS terminates, is $2.2 billion. This value is part of the "electric generators" row for the Advanced scenario in Table 1.12.

**RD&D Costs**. The Advanced scenario assumes that the federal government doubles its appropriations for cost-shared RD&D in efficient and clean-energy technologies; the Moderate scenario assumes a 50% increase (Table 1.13). Since these resources are spent in public/private RD&D partnerships, they are matched by private-sector funds. Altogether, the Advanced scenario assumes an increase of $2.8 billion per year by approximately 2005 (half as federal appropriations and half as private-sector cost share). This increment continues through 2020. The Moderate scenario assumes an additional $1.4 billion per year over the same period. Both scenarios assume a careful targeting of funds to critical research areas and a gradual, 5-year ramp-up of funds to allow for careful planning, assembly of research teams, and expansion of existing teams and facilities.

**Table 1.13 Research, Development, and Demonstration Costs in 2010 and 2020 (in Billions 1997$ per Year)**

| | Moderate Scenario | | Advanced Scenario | |
|---|---|---|---|---|
| | 2010 | 2020 | 2010 | 2020 |
| RD&D Costs | 1.4 | 1.4 | 2.8 | 2.8 |

**Incremental Technology Investment Costs.** Incremental technology costs refer to the additional investment in technology required by consumers and businesses to purchase more efficient equipment and energy services. Since we compute costs and benefits on an annual basis, we emphasize the annualized incremental technology costs for each year. The annualized cost for a particular year is the annualized cost of the total investment made to that time. We approximate the annualized cost by calculating an investment cost per unit of energy conserved and multiplying this cost of conserved energy (in $/kWh or $/MBtu) by the energy savings in that year.

For example, policies promoting more efficient residential refrigerators are projected to save 6 billion kWh in 2020 in the Advanced case. The cost of conserved energy for those savings is $0.034/kWh (every kWh saved costs 3.4¢). In addition, the program implementation cost for capturing those savings is $0.006/kWh. The annualized technology cost associated with these savings would be 6 billion kWh times $0.034/kWh, or about $0.2 billion per year. Including program costs, total annualized cost for capturing these savings would be 6 billion kWh times ($0.034 + $0.006), or $0.24 billion per year.

Between 2010 and 2020, the annual incremental technology investment costs – totaled across all technologies and sectors – increase from $11 billion to $30 billion in the Moderate scenario, and from $31 billion to $66 billion in the Advanced scenario (Table 1.14). The transportation sector accounts for approximately half of these costs in both years.

**Table 1.14 Annualized Incremental Technology Investment Costs in 2010 and 2020 (in Billions 1997$ per Year)**

| | Moderate Scenario | | Advanced Scenario | |
|---|---|---|---|---|
| | 2010 | 2020 | 2010 | 2020 |
| Residential | 1.9 | 5.8 | 3.8 | 9.1 |
| Commercial | 2.0 | 4.6 | 2.7 | 5.8 |
| Industrial | 3.1 | 6.7 | 6.9 | 11.8 |
| Transportation | 4.3 | 13.4 | 16.2 | 39.1 |
| Electric Generators[a] | 0 | 0 | 0 | 0 |
| Total | 11.4 | 30.5 | 29.6 | 65.9 |

[a] These investment costs are reflected in the price of electricity and hence in the bill savings calculation.

It is also useful to estimate the incremental capital outlays required each year to purchase the energy efficiency and clean energy technologies that are promoted by the CEF scenarios. These costs reflect the actual incremental expenditures needed for each scenario in each year. They can be calculated from the year-by-year annualized costs of these investments shown in summary in Table 1.14. The annualized cost calculations involve spreading the cost of capital across the operating lifetimes of new investments, while calculating the capital outlays requires removing that annualization and determining the change in actual capital investments from one year to the next. The actual capital outlays allow us to examine how the nation's investment capital would be affected by the CEF policies.

We are only able to estimate the incremental capital outlays for demand-side technologies and electricity supply-side technologies from the outputs of the CEF-NEMS model. It is not possible to estimate these same requirements for all parts of the supply-side investments that would come about in our policy scenarios. By limiting our estimates to the demand-side, we are likely overestimating the total net investment costs. Because the demand for electricity and fuels is reduced relative to the BAU forecast in both the Moderate and Advanced scenarios, investment capital required to build and operate new generation capacity, mines, and refineries will be avoided. The extent of these capital savings, however, cannot be estimated accurately. As a result, our estimates of incremental technology investments are based solely on the need to invest in improved demand-side technologies in the buildings, industry, and transportation sectors, with the recognition that these estimates are probably upper bounds to the net capital investments required in any given year.

The incremental capital outlays vary year-to-year in both the Moderate and Advanced scenarios. In the Moderate scenario they increase from several billion in 2000 to $17 billion in 2015, after which they decline gradually. In the Advanced scenario, incremental technology investments increase more rapidly from $4 billion in 2000 to $30 billion in 2005; after that they decrease to $17 billion in 2020. These energy-efficiency capital outlays are small relative to gross private domestic investments made in the United States on an annual basis, which totaled $1.7 trillion in 1999 (Bureau of Economic Analysis, 2000). By comparison, the AEO99 reference case projects Real Investment at annual rates of $2,011 billion in 2010 and $2,508 billion in 2020 (in 1997$).[10] Thus, the CEF capital outlays are no more than 2% of total capital investments in any year between 2000 and 2020.

**Changes in the Energy Bill.** The total change in energy bill is a function of changes in energy prices, as well as changes in amounts and types of energy used. Generally, both factors are at work and are described below. The energy bill is calculated as the sum over all fuels (including electricity) in all end-use sectors of the fuel price times the amount of fuel used minus the pay-at-the-pump fee[11]. Average energy prices to all users are shown, by type of energy and by scenario, in Table 1.15 and Fig. 1.10. Prices for fuels are shown in 1997$ per million Btu. Energy prices are given in more common units (e.g., gallons of gasoline and thousand cubic feet of natural gas) in Table 1.16. The Advanced scenario prices include the $50/tonne carbon permit charge that energy producers are assumed to add to energy prices as a result of the domestic carbon trading system. Scenarios can project energy price increases (as when carbon permit costs are added or in the case of more costly, but cleaner energy options) or decreases (as in the case of reduced energy use resulting from energy-efficient technologies).

The BAU scenario assumes that electricity prices will be 12% lower by 2010 than in 1997 and will decline another 8% by 2020 due to electricity restructuring in parts of the U.S. [Note: Following the lead of EIA's Reference case, the BAU assumes that five regions of the United States transition to competitive pricing with full consumer access and fully competitive prices beginning in 2008 (EIA, 1998a, p. 62).] The Moderate scenario results in even lower electricity prices in both 2010 and 2020, due largely to full national electricity restructuring and the decreased demand resulting from improved end-use energy

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[10] The 1992 dollars of the AEO99 reference case are converted to 1997 dollars using the 1997 chain-type price index for Fixed Gross Private Domestic Investment (AEO99, Table 20; Council of Economic Advisers 1999, Table B-7).

[11] An additional $44 billion is paid for motor gasoline in 2010 due to the pay-at-the-pump increment for automobile insurance, and an additional $56 billion is paid in 2020. These costs are actually transfer payments (they offset other payments for insurance elsewhere in the economy) and are therefore not treated as an addition to the nation's energy bill.

## Table 1.15 Average Energy Prices to All Users

| | | | 2010 | | | 2020 | | |
|---|---|---|---|---|---|---|---|---|
| Average Energy Prices (1997$ per Million Btu) | 1990 [a] | 1997 | BAU | Mod. | Adv. [b] | BAU | Mod. | Adv. [b] |
| Motor Gasoline | 9.96 | 9.70 | 10.40 | 10.16<br>(-2%) | 13.41<br>(29%) | 10.41 | 9.74<br>(-6%) | 13.54<br>(30%) |
| Other Petroleum | 6.72 | 6.17 | 6.38 | 6.27<br>(-2%) | 7.09<br>(11%) | 6.65 | 6.36<br>(-4%) | 7.01<br>(5%) |
| Natural Gas | 4.20 | 4.32 | 4.02 | 3.80<br>(-5%) | 4.55<br>(13%) | 3.90 | 3.56<br>(-9%) | 4.14<br>(6%) |
| Coal | 1.63 | 1.28 | 1.07 | 1.06<br>(-1%) | 2.35<br>(120%) | 0.94 | 0.93<br>(-1%) | 2.22<br>(136%) |
| Electricity | 21.08 | 20.26 | 17.85 | 16.44<br>(-8%) | 19.32<br>(8%) | 16.15 | 15.51<br>(-4%) | 17.92<br>(11%) |
| Energy Bill (billion 1997$) | 516 | 552 | 651 | 595<br>(-9%) | 634<br>(-3%) | 694 | 594<br>(-14%) | 572<br>(-18%) |

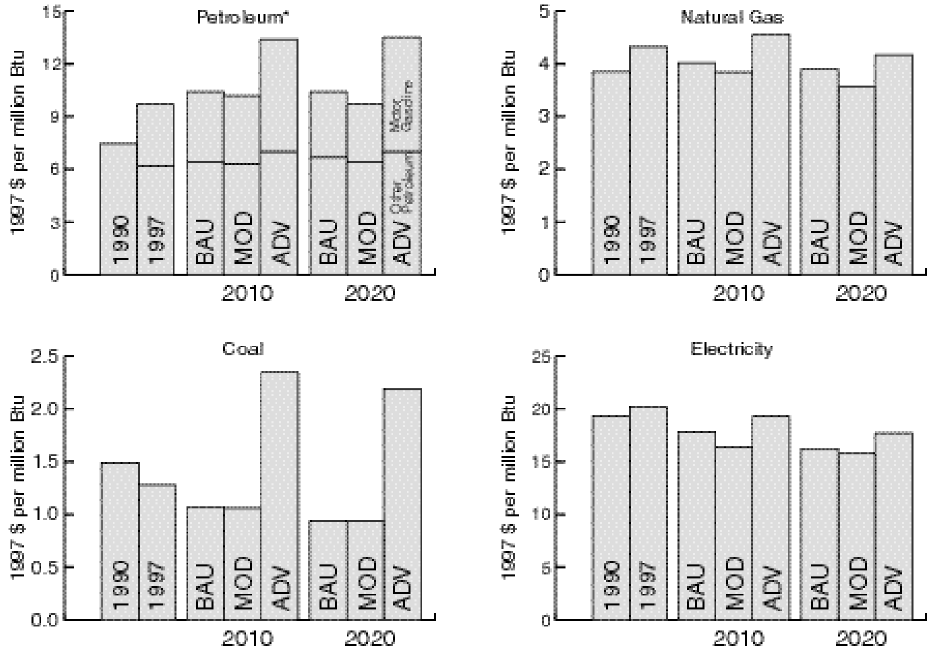
Note: BAU = Business-As-Usual; Mod. = Moderate; Adv. = Advanced. Numbers in parentheses represent the percentage change compared with BAU.

[a] Source: EIA (1998d), Tables 3.3 and 3.4, inflated to 1997$ using consumer price indexes for energy from Table B-58, Council of Economic Advisers (2000).

[b] The Advanced scenario prices include the $50/tonne carbon permit cost that energy producers are assumed to add to energy prices as a result of the domestic carbon trading system. Motor gasoline prices also include the pay-at-the-pump insurance charge of $2.72 per MBtu in 2010 and $4.08 per MBtu in 2020. The pay-at-the-pump insurance charge is not included in the energy bill shown in the last row of this table.

## Fig. 1.10 Average Energy Prices to All Users

(1997 $ per Million Btu)



*For petroleum, the top bars designate the price of motor gasoline including the pay-at-the pump insurance charge, while the lower bars designate the price of other petroleum products.

Table 1.16 Average Energy Prices in Common Units

| Average Energy Prices (1997 $ per Million Btu) | 1997 | 2010 BAU | 2010 Mod. | 2010 Adv. [a] | 2020 BAU | 2020 Mod. | 2020 Adv. [a] |
|---|---|---|---|---|---|---|---|
| Motor Gasoline<br>(1997 $ per gallon) | 1.21 | 1.30 | 1.27<br>(-2%) | 1.68<br>(29%) | 1.30 | 1.22<br>(-6%) | 1.69<br>(30%) |
| Natural Gas<br>(1997 $ per Mcf) | 4.44 | 4.13 | 3.90<br>(-6%) | 4.67<br>(13%) | 4.01 | 3.66<br>(-9%) | 4.25<br>(6%) |
| Coal<br>(1997 $ per ton) | 27.26 | 22.79 | 22.57<br>(-1%) | 50.04<br>(120%) | 20.02 | 19.80<br>(-1%) | 47.27<br>(136%) |
| Electricity<br>(1997 cents per kWh) | 6.91 | 6.09 | 5.61<br>(-8%) | 6.59<br>(8%) | 5.51 | 5.29<br>(-4%) | 6.11<br>(11%) |

Note: Mcf = thousand cubic feet; BAU = Business-As-Usual; Mod. = Moderate; Adv. = Advanced. Numbers in parentheses represent the percentage change compared with BAU.

[a] The Advanced scenario prices include the $50/tonne carbon permit cost that energy producers are assumed to add to energy prices as a result of the domestic carbon trading system. The gasoline prices also include the pay-at-the-pump insurance charge of 34¢ per gallon in 2010 and 51¢ per gallon in 2020.

efficiency. The Advanced scenario, on the other hand, produces electricity prices that are 9% higher than BAU in the two timeframes. This increase is due largely to the inclusion of the $50/tC carbon permit price[12]. It also is affected by the greater use of renewable resources in power production.

The end-use price trajectories for natural gas are similar to those for electricity. In the BAU scenario, end-use prices are forecast to decline by 7% between 1997 and 2010 and by another 3% over the subsequent decade. The Moderate scenario results in even lower natural gas end-use prices in both 2010 and 2020, due largely to decreased demand resulting from energy-efficiency improvements. The Advanced scenario, on the other hand, results in 13% higher gas prices in 2010 (relative to BAU), but the relative increase drops to 6% by 2020. As with electricity prices, the increased natural gas prices in the Advanced scenario are due primarily to the domestic carbon trading system. Improved energy-efficiency reduces demand for natural gas in industry and buildings, which prevents price escalation as the result of rising natural gas demand in the power sector.

The same price trends occur for coal, but the effects of the Advanced scenario are more pronounced. Coal prices are forecast to decrease in the BAU scenario, and they decrease 1% further in the Moderate scenario because of decreased demand for electricity and steam coal. In the Advanced scenario, coal prices increase 120% in 2010 and 136% in 2020 relative to BAU.

Trends in prices for motor gasoline and other petroleum products are considered separately, because the pay-at-the-pump insurance charge applies only to gasoline. In the BAU scenario, gasoline and other petroleum product prices are forecast to grow only modestly over the next two decades. In the Moderate scenario, petroleum prices – especially gasoline prices – grow even more slowly because of dampened growth in demand. By 2020, gasoline prices have returned to 1997 levels. In the Advanced scenario, with its carbon permits and pay-at-the-pump fees, motor gasoline prices are 30% higher than the BAU

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[12] The carbon allowance in the Advanced scenario adds 0.66¢ per kWh to the price of electricity in 2010. In 2020, it adds only 0.55¢ per kWh because of the lower carbon content of electricity in that year.

forecast, both in 2010 and 2020. Prices for other petroleum products in the Advanced scenario are 11% higher than the BAU forecast in 2010 and 5% higher than the BAU in 2020.

The magnitude of change in motor gasoline prices is perhaps best understood in terms of 1997$ per gallon of gasoline. In the Advanced scenario, a gallon of gasoline costs $1.68 in 2010 and $1.69 in 2020, compared to $1.30 in the BAU forecast for both time periods and lower prices in the Moderate scenario. In the Advanced scenario, 12¢ of the increase is a result of the carbon permit cost. The pay-at-the-pump increment is 34¢ in 2010 and 51¢ in 2020. The price of gasoline does not rise in full by the sum of these increments because the reduction in demand exerts downward pressure on prices.

While gasoline prices are higher in the Advanced scenario than in the BAU forecast, the cost of fuel per mile of travel is essentially unchanged. In 1997, gasoline prices averaged $1.21 per gallon and the average light-duty vehicle got 20.5 miles to the gallon – resulting in a fuel cost of 5.90¢ per mile. In the Advanced scenario in 2020, paying $1.69 per gallon of gasoline (including the pay-at-the-pump increment) results in a fuel cost of 5.98¢ per mile traveled. Thus, consumers pay essentially the same per mile of travel in the Advanced scenario in 2020 as they do today, while also paying for a portion of their insurance premiums through the cost of their fuel.

The combination of evolving prices and demand for energy results in energy bill trajectories that vary widely across the scenarios (Table 1.17). Under BAU conditions, the U.S. energy bill is forecast to increase 26%, from $552 billion in 1997 to $694 billion in 2020 (in 1997$). In both the Moderate and Advanced scenarios, the nation benefits from lower energy bills relative to the BAU increases. The energy bill is reduced in each of these scenarios, because the policies cause prompt efficiency increases and decreased energy use in the end-use sectors. In the Moderate scenario, U.S. energy cost savings are $55 billion in 2010 and increase to $100 billion in 2020.

In the Advanced scenario, efficiency increases in the end-use sectors are large enough to reduce the nation's energy bill even with increased energy prices. The energy bill savings in 2010 are $16 billion, which is much smaller than in the Moderate scenario because of the energy price increases and the time required to turn over the existing stock of equipment. The savings rise to nearly $122 billion in 2020 as a result of improvements in the performance of energy-efficient technologies and their greater penetration in buildings, industry, and transportation. The transportation sector accounts for a large portion of the energy bill savings in both 2010 and 2020.

**Table 1.17 Net Energy Bill Savings in 2010 and 2020**
**(in Billions 1997$ per Year)**

| | **Moderate Scenario** | | **Advanced Scenario**[a] | |
|---|---|---|---|---|
| | 2010 | 2020 | 2010 | 2020 |
| Residential | 12.6 | 19.3 | 2.8 | 20.1 |
| Commercial | 14.1 | 17.7 | 0.7 | 8.2 |
| Industrial | 13.5 | 19.3 | -5.4 | 8.0 |
| Transportation | 15.0 | 44.0 | 18.3 | 85.6 |
| Total | 55.3 | 100.3 | 16.4 | 121.9 |

[a] The energy prices used to calculate the energy bill savings in the Advanced scenario include the cost of the carbon permit charges. They do not include the pay-at-the-pump fees for motor gasoline.

**Return of Carbon Permit Revenues to the Public.** The Advanced scenario assumes that each year beginning in 2005, carbon emissions permits are auctioned at a permit price of $50/tC. The government collects the carbon permit revenues and returns them to the public, offsetting revenues paid by the public in increased energy costs caused by the carbon permit. The idea of the carbon permit rebate is to leave people's "incomes" intact while changing the relative price of carbon.

As a result, the domestic carbon trading system imposes minimal first-order changes in the total income of "the public." Distribution of income will change, with some winners and losers, but aggregate income will change very little. This is a fairly gross system, but more refined rebate and allocation options are emerging (Bovenberg and Goulder, 2000; Center for Clean Air Policy, 1999; Weyant and Hill, 1999; Fischer, Kerr, and Toman, 1998a, b). The value of the transfer payments is shown in Table 1.18.

As with a tax, the carbon permit payments to the government reduce both consumer and producer surplus. Consumers pay a higher price and demand less fossil-fuel-derived energy, while producers see a lower demand, and, after subtracting the carbon payment to the government, a lower marginal price of supply. These price and quantity changes are reflected in the nation's energy bill. A small portion ($1.8B to $2.5B per year) of lost consumer and producer surplus is not captured in the energy bill calculation of the Advanced scenario. It is part of the macroeconomic costs that are discussed later in this section.

**Table 1.18 Net Transfers to the Public of the Carbon Permit Revenues in 2010 and 2020 (in Billions 1997$ per Year)**

| | Moderate Scenario | | Advanced Scenario | |
|---|---|---|---|---|
| | 2010 | 2020 | 2010 | 2020 |
| Total | 0[a] | 0[a] | 72.9 | 67.4 |

[a]The domestic carbon trading system operates only in the Advanced scenario.

The method used to transfer carbon permit revenues back to the public will not affect the direct costs and benefits of the Advanced scenario, but it could affect the magnitude and nature of second-order impacts. Two fiscal policy approaches were analyzed in the Energy Information Administration's assessment of the Kyoto Protocol (EIA, 1998c):

- Returning collected revenues to consumers through personal income tax rebates, and
- Lowering the social security tax rate as it applies to both employers and employees.

Both of these fiscal policies would ameliorate the short-term impacts of higher energy prices on the economy by bolstering disposable income.

**Net Direct Savings.** Table 1.19 shows the "net direct savings" of the two policy scenarios. The total savings are the difference between the direct benefits shown in Tables 1.17 and 1.18 (i.e., net energy bill savings and carbon permit revenue transfers to the public) and the direct costs shown in Tables 1.12 through 1.14 (i.e., annualized program implementation and administration costs, RD&D costs, and annualized incremental technology investment costs). The direct costs for both scenarios rise over time at a nearly linear pace. The energy bill savings of the Moderate scenario also rise at an essentially linear rate, as does the sum of the net energy bill savings (which includes the cost of carbon permits) and the carbon permit revenue transfers in the Advanced scenario. The net energy bill savings are negative in 2005, but by 2010 and in subsequent years, consumers experience positive net energy bill savings.

In 2010, net energy bill savings and carbon permit transfer payments exceed direct costs by $39 billion in the Moderate scenario and by $48 billion in the Advanced scenario. By 2020, the gap has widened to an estimated $62 billion of direct savings in the Moderate scenario and $108 billion in the Advanced case.

Figures 1.11 and 1.12 compare the annual gross energy savings with the two measures of incremental technology investment costs: the annualized costs and the annual capital outlays. These figures show that the investments spurred by the CEF policies quickly pay back in terms of reduced energy costs. This is true in both the Moderate and Advanced scenario.

**Table 1.19 Net Direct Savings of the Clean Energy Future Scenarios in 2010 and 2020 (in Billions 1997$ per Year)***

| | **Moderate Scenario** | | **Advanced Scenario** | |
|---|---|---|---|---|
| | **2010** | **2020** | **2010** | **2020** |
| **Policy Implementation and Investment Costs:** | | | | |
| ▪ Annualized policy implementation and administration costs | -3.2 | -6.7 | -9.1 | -13.0 |
| ▪ RD&D costs | -1.4 | -1.4 | -2.8 | -2.8 |
| ▪ Annualized incremental technology investments | -11.4 | -30.5 | -29.6 | -65.9 |
| **Total Investment Costs** | **-16.0** | **-38.6** | **-41.5** | **-81.7** |
| **Net Energy Bill Savings:** | | | | |
| ▪ Gross energy bill savings | 55.3 | 100.3 | 89.2[a] | 189.3[a] |
| ▪ Carbon permit costs | 0 | 0 | -72.9 | -67.4 |
| **Net Energy Bill Savings** | **55.3** | **100.3** | **16.4** | **121.9** |
| **Carbon Permit Revenue Transfers to the Public** | **0** | **0** | **72.9** | **67.4** |
| **Total** | **39.3** | **61.7** | **47.7** | **107.6** |

*These net direct savings do not account for the macroeconomic impacts of the scenarios. For example, the savings in the Advanced scenario are decreased by a small loss in consumer and producer surplus due to the domestic carbon trading system. These are estimated to be $2.5 billion in 2010 and $1.8 billion in 2020. Other macroeconomic costs are discussed later in this chapter and in Appendix E-4.

[a] The gross energy bill savings do not include pay-at-the-pump fees for automotive gasoline. These fees, which are part of the Advanced scenario policy portfolio, are treated as transfer payments and are therefore omitted from this table.

**Externality Costs and Benefits.** A variety of externality costs and benefits would also accompany the CEF scenarios. The environmental externality benefits, for example, could be substantial. They include the possibility of reduced damages from global climate change and avoided costs of adapting to changing climates, such as stronger physical infrastructures, more effective emergency preparedness programs, and increased investments in air conditioning.

More certain environmental externality benefits include cleaner air and water, which can produce significant public health benefits (Romm and Ervin, 1996). The “clean air story” is described in the following box. The CEF policy scenarios also result in energy security externality effects. Oil security, for instance would be enhanced. (This is one of the aspects of the “oil story.”)

A variety of ancillary or collateral costs and benefits would accompany the CEF policy scenarios. On the cost side are:

- amenity losses (e.g., from cars with lower horsepower) and

- opportunity losses (e.g., from investing in energy efficiency retrofits to manufacturing plants when more profitable investments such as creating a new product line may be available).

These costs are not captured in the analysis of direct costs and benefits, but could be considerable. On the benefits side are:

- the productivity and product quality gains that have accompanied many investments in industrial efficiency improvements (Romm, 1994; Romm, 1999) and
- the growth in export markets for energy technologies.

**Fig. 1.11 Annual Gross Energy Bill Savings and Incremental Technology Investments of the Moderate Scenario: 2000 through 2020**

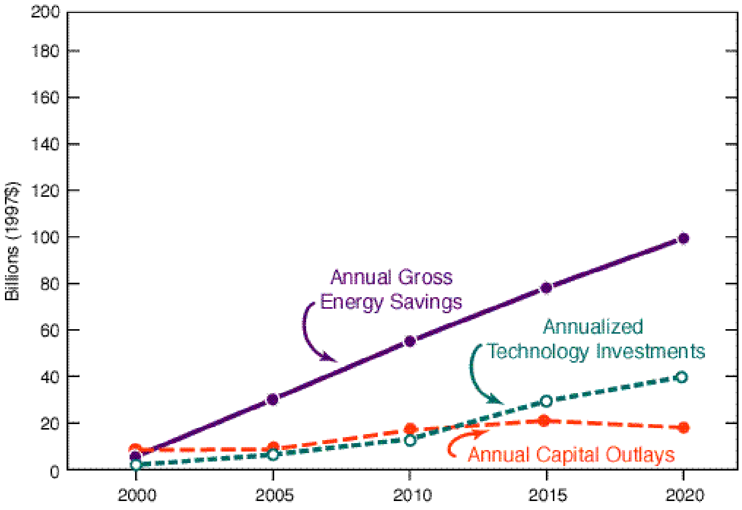
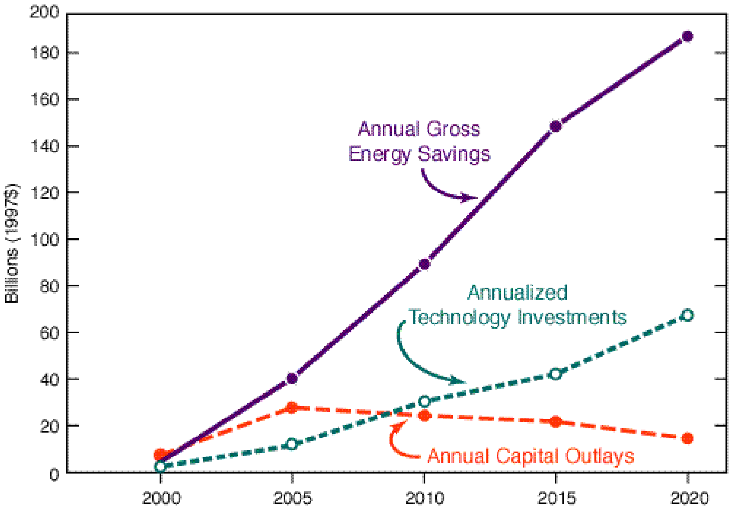


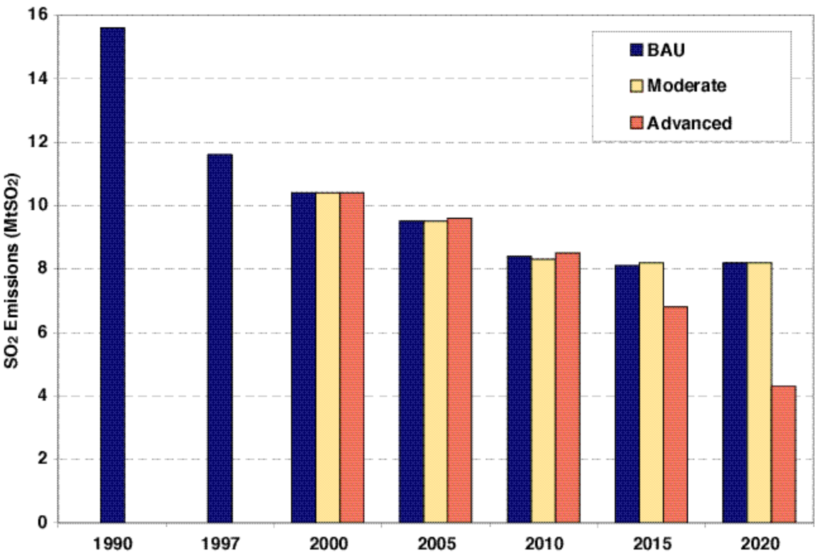
**Fig. 1.12 Annual Gross Energy Bill Savings and Incremental Technology Investments of the Advanced Scenario: 2000 through 2020**



## The Clean Air Story

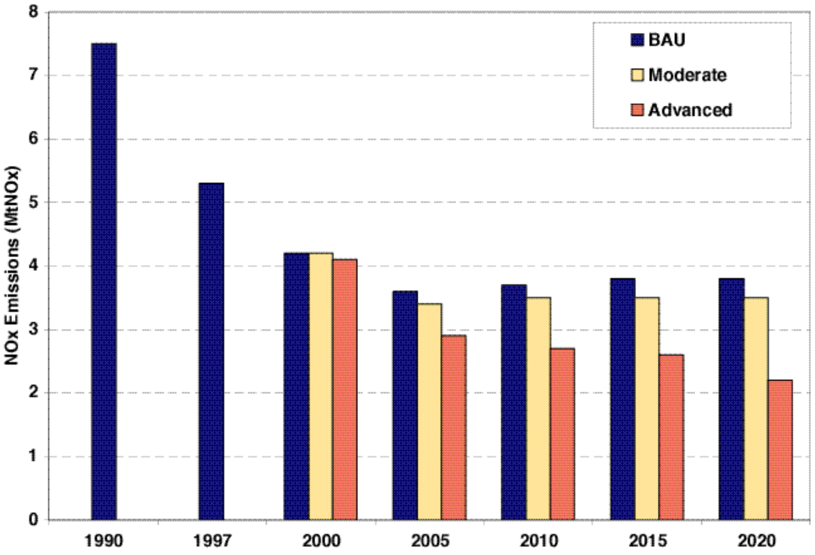
In both the Moderate and Advanced scenarios, emissions of local air pollutants are substantially reduced. These reductions are an added benefit of the cuts in fossil fuel combustion that occur largely as a result of policies directed at increasing energy efficiency and reducing carbon emissions.

**$SO_2$ Emission Reductions in the Electric Sector**



In the Moderate scenario, $SO_2$ emissions from the electric sector in 2010 remain at the limits set by the Clean Air Act Amendments of 1990. However, the allowance price needed for $SO_2$ to keep emissions at that level drops to $96/ton in 2020 (a 16% decrease relative to the BAU forecasted allowance price of $114/ton). With lower demand and improved new technologies, it is easier to meet the limits. $NO_x$ and mercury emissions also decline in the Moderate scenario.

**$NO_x$ Emission Reductions in the Electric Sector**



In the Advanced scenario, a policy is modeled that calls for $SO_2$ emissions to be reduced in steps between 2010 and 2020, so that by 2020 they have declined to half the Phase II limits set by the Clean Air Act Amendments of 1990. This policy is designed to represent tighter particulate matter standards. As a result, the cost of sulfur allowances in the Advanced scenario in 2020 rises to $161/ton in 2020. Simultaneously, $NO_x$ emissions by 2020 fall to less than half of the current $NO_x$ emissions from the electric sector, and mercury emissions decline significantly.

While the monetary value associated with clean air is difficult to estimate, the benefits of the Clean Energy Future scenarios are clearly positive in terms of improved human and ecological health.

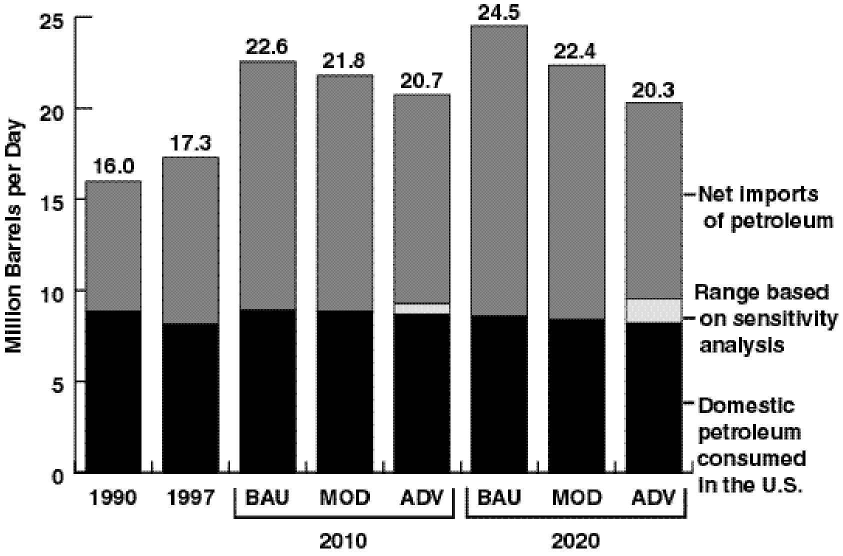
## The Oil Story

What is the possible fate of oil in twenty-first century America? The Advanced scenario shows that it is possible for the United States to significantly decrease its use of oil in the coming decades, while growing the economy. It illustrates a future in which oil is a smaller percentage of the fuels used to run the economy, which translates into a more secure energy future.

In 1997 the U.S. consumed approximately 17 million barrels per day (mmbd) of crude oil and petroleum products.[13] Consumption of these fuels is forecast to rise to approximately 23 mmbd by 2020. The aggressive policies in the Advanced scenario bring petroleum consumption in 2020 down to 1997 levels, resulting in a savings of approximately 5 mmbd in 2020, when compared to the BAU forecast[14]. Over the same two decades, the population is expected to grow by 20%. Thus, the oil-to-GDP ratio in the Advanced scenario is much lower in the Advanced scenario in 2020 than the ratio today.

The Advanced scenario also brings about a reduction in the nation's expected reliance on imported oil. This translates into a significant improvement in the nation's balance of payments.

**U.S. Consumption of Domestic and Imported Crude Oil and Petroleum Products**



The reduced oil consumption is brought about by the improved performance and deployment of energy-efficient technologies in cars, trucks, and home heating equipment, motivated by an array of policy changes. Technology such as the turbo-charged diesel injection engine, cellulosic ethanol, hydrogen fuel cell vehicles, and lightweight materials will enable the transportation sector, the main consumer of oil, to use petroleum more efficiently and to increase its reliance on alternative fuels.

While gasoline prices are higher in the Advanced scenario than in the BAU forecast, the cost of fuel per mile of travel is essentially unchanged because of fuel efficiency gains. In 1997, gasoline prices averaged $1.21 per gallon and the average light-duty vehicle got 20.5 miles to the gallon – resulting in a fuel cost of 5.90¢ per mile. In the Advanced scenario, gasoline prices increase to $1.69 in 2020, and fuel efficiency of the existing fleet of light-duty vehicles increases to 28.3 mpg. This results in a fuel cost of 5.98¢ per mile. Thus, consumers pay essentially the same per mile of travel in the Advanced scenario in 2020 as they do today, while also paying for a portion of their insurance premiums through the cost of their fuel.

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[13] One million barrels per day of petroleum use is equivalent to an annual energy consumption of 2.1 quadrillion Btu.

[14] The numbers given here assume the same world oil prices in both scenarios. As a result, they overestimate the reduction of oil imports and underestimate the economic benefits resulting from lower oil prices A sensitivity analysis testing alternative assumptions about OPEC behavior and world oil prices is described Chapter 6 (Section 6.5.5.)

Neither of these benefits is included in the analysis of direct costs and benefits, yet they could be considerable. Results reported in Elliott et al. (1997) and Laitner (1999) indicate that the total benefits –including both energy and non-energy savings – that accrue from so-called "energy-saving" projects can be much greater than the energy savings alone. In fact, based on numerous case studies, the authors conclude that the average total benefits received from "energy-saving" projects in industry are typically two to four times the value of the energy savings alone.

**Macroeconomic Effects.** The CEF study does not model the macroeconomic impacts of its two policy scenarios because of the difficulty of estimating transition and long-term macroeconomic effects on costs and investments that average less than 1% of national GDP over the study period. Instead, we commissioned the preparation of a short discussion paper, which appears in Appendix E-4. The purpose of this appendix is to review the issue of second-order or macroeconomic effects that might occur as a result of the energy price changes that could result from the permit trading option included in the Advanced scenario. The conclusions of this paper are summarized here.

A key premise of the CEF study is that large-scale market and organizational failures, in addition to potentially substantial transaction costs, prevent consumers and firms from obtaining energy services at the least cost. The essential conclusion of the study's scenarios is that this problem can, to a considerable extent, be overcome through policies that correct these market failures and reduce the transaction cost barriers to the diffusion of energy-efficient technologies. This conclusion is supported by numerous past energy policy and program successes, as described in Chapter 2.

The authors conclude, based on information presented in Chapter 2, that the economy is not currently operating in an optimal fashion with respect to the provision of energy services (i.e., it is not operating on its aggregate production-possibilities frontier). As a consequence, Pareto improvements are available through policy interventions. Thus, whatever shifts or adjustments in markets occur as a result of such policies, *the aggregate result is a gain in economic efficiency*. In the case of the domestic carbon trading policy, however, the question arises of the possibility of substitution between GDP and carbon reductions. That possibility motivated the analysis of the $50/tonne carbon permit price in Appendix E-4.

Appendix E-4 assesses the macroeconomic costs of a $50/tonne carbon permit price by examining the Energy Modeling Forum's recent compilation of results from simulations using seven of the leading energy/economic models (Weyant and Hill, 1999). These seven models provide alternative estimates of what it might cost to achieve carbon emissions at 1990 levels from energy use and generation. The scenarios varied according to how much (and among which countries) international trading was allowed to occur. Four trading scenarios were run: (1) no trading of international emissions rights; (2) full Annex I (or Annex B)[15] trading of emissions rights; (3) the "double bubble," which considers separate European Union and "rest of Annex I" trading blocs; and (4) full global trading of emissions rights.

To estimate the GDP loss associated with a $50/tonne carbon permit price, the authors of Appendix E-4 calculated a "GDP response curve" for each model indicating the expected response of GDP to various carbon permit prices. Each curve was determined by a quadratic extrapolation using the Annex I trading and global trading scenarios as reported by the Energy Modeling Forum (EMF-16), in Weyant and Hill (1999). (These are the scenarios with carbon permit prices that bracket or are close to the $50/tonne level.) For each model, the origin and the two estimates of implicit carbon permit price and GDP loss determine a unique quadratic response curve.

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[15] The Annex I (of the 1992 Framework Convention on Climate Change) countries include the U.S., OECD-Europe, Japan, CANZ (Canada/Australia/New Zealand), and the EEFSU (East Europe and Former Soviet Union) countries. The Annex B (of the Kyoto Protocol) list varies slightly from the Annex I list (Weyant and Hill, 1999).

The estimated 2010 GDP losses (in 1997$) associated with $50/tonne carbon permit price range from $4 billion for the MERGE3 model to $66 billion for the CETA model. These are the same order of magnitude as the $48 billion in net direct benefits estimated for the Advanced scenario in 2010.

Appendix E-4 also explores the transitional macroeconomic adjustment costs of the carbon permit price caused by the economy's reacting to higher energy prices in the CEF scenarios. This is accomplished by examining two EIA analyses that use the DRI model to examine the effects of introducing carbon permit prices into the U.S. economy (EIA, 1998c and 1999c). When carbon trading is phased in beginning in 2000 (EIA, 1999c), achieving the CEF Advanced scenario levels of reduction requires a $63/tonne carbon permit price, which results in a GDP loss (including both transitional and long-term macroeconomic costs) of $39 billion. This is equal to the median of the range predicted by the seven models described in EMF-16 (Weyant and Hill, 1999). Based on the EIA study (1998c) that models carbon trading beginning in 2005, the CEF Advanced scenario levels of reduction would require a $66/tonne carbon permit price. This results in a GDP loss (including both transitional and long-term macroeconomic costs) ranging from $47 billion to $74 billion (in 1997$). The lower estimate occurs when revenues are recycled using payroll tax reductions, and the higher estimate occurs with revenue recycling through personal tax rebates, which do not correct pre-existing distortions in taxes.

As with the long-term macroeconomic costs described in the previous paragraphs, these findings show that even in the transition period, potential GDP losses can be mitigated – and indeed potential GDP gains may result – when revenue recycling is used to stimulate investment. In 2010, the net direct savings are of the same order of magnitude as the macroeconomic (transitional plus long-term) costs. Over the following decade, the net direct savings grow as energy-efficient technologies gain market shares, while the long-term macroeconomic impacts remain steady and the transitional costs decline.

**Macroeconomic Indicators.** A range of macroeconomic indicators associated with the two policy scenarios is provided in Table 1.20. For simplicity, these assume that GDP grows in the Moderate and Advanced scenarios at the same pace as in the BAU forecast.

**Table 1.20 Macroeconomic Indicators**

| | | | 2010 | | | 2020 | | |
|---|---|---|---|---|---|---|---|---|
| | 1990 | 1997 | BAU | Mod. | Adv. | BAU | Mod. | Adv. |
| GDP (billion 1997$) | 6136<br>(1992$) | 8171 | 11,123 | 11,123<br>(0%) | 11,123 [a]<br>(0%) | 13,128 | 13,128<br>(0%) | 13,128 [a]<br>(0%) |
| Energy/GDP Ratio (kBtu/1997$) | 13.7<br>(1992$) | 11.5 | 9.9 | 9.6<br>(–4%) | 8.9<br>(–10%) | 9.1 | 8.4<br>(–7%) | 7.4<br>(–20%) |
| Carbon/GDP Ratio (gC/1997$) | 219<br>(1992$) | 181 | 159 | 151<br>(–6%) | 132<br>(–17%) | 147 | 133<br>(–10%) | 103<br>(–29%) |

Note: BAU = Business-As-Usual; Mod. = Moderate; Adv. = Advanced. Numbers in parentheses represent the percentage change compared with BAU.

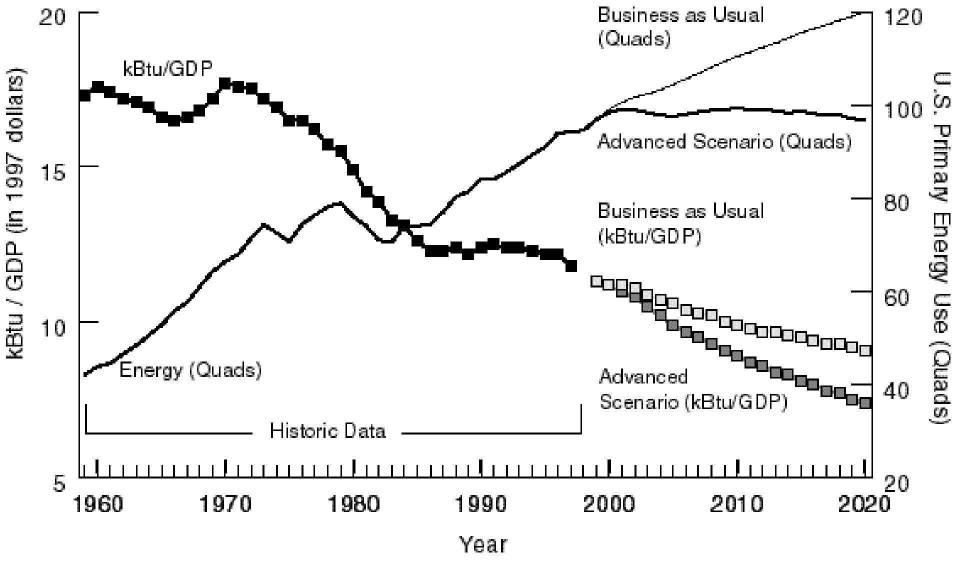
[a] As noted in the section on "Macroeconomic Effects," there is great uncertainty regarding the GDP levels that would result from Advanced scenario policies (ranging from an increase of $14 billion to a decrease of $44 billion, relative to the BAU). For the purposes of this table, we have assumed the same GDP levels as in the BAU forecast.

One of the macroeconomic indicators reflects the energy productivity of the U.S. economy: the energy/GDP ratio. An expanded portrayal of this indicator is provided in Fig. 1.13 in terms of U.S. energy use in kBtu/GDP in 1997$. This figure shows the historic reduction in energy intensity of the U.S. economy from 1973–74 (the OPEC oil embargo) through 1986 (when energy prices began a period of decline that has continued to today). The EIA AEO99 Reference case calls for a continuing improvement in this indicator as the result of a GDP growth rate that outpaces the increase in energy use. The Advanced scenario projects even larger energy productivity gains, especially in the second decade of the twenty-first century. This is a result of the leveling off of U.S. energy consumption at 97 quads in 2020 in the Advanced scenario, compared with the Reference case forecast of 119 quads in 2020.

**Sectoral and Regional Impacts.** Many sectors of the economy and regions of the United States would benefit from a transition to the type of clean energy future characterized in this study's two policy scenarios. For example, the growth of strong domestic wind and bioenergy industries could bring new employment opportunities to many regions and could lead to a revitalization of the economies of rural America. A wide range of other business opportunities would thrive under the Advanced scenario. Specific sectors likely to see positive impacts on output include:

- energy service companies, contractors, and consultants,
- light-weight materials and fuel cell manufacturing,
- nuclear energy services industry,
- wind turbine manufacturers and biomass producers and processors, and
- electronic sensors and controls and advanced battery manufacturers.

**Fig. 1.13 Energy/GDP Ratios**



Financial institution business should expand along with the growth in third-party energy service companies, since many manufacturing companies or building owners may prefer to lower their debt-equity ratios through third-party investors when undertaking energy efficiency measures.

The enhanced energy-technology innovation envisioned from the doubling of RD&D budgets in the Advanced scenario could lead to a stronger domestic economy through international cooperation. The development of advanced energy technologies could help expand the market share of U.S. companies in the vast global market for efficient and clean energy technologies. It could also enhance long-term markets for other U.S. exports by building the energy basis for sustainable prosperity in developing and transitional economies. Both of these goals are highlighted in the recent report from the PCAST Panel on

International Cooperation in Energy Research, Development, Demonstration, and Deployment (PCAST, 1999).

The reduction of coal consumption in the Advanced scenario by 30% in 2010 and by nearly 50% in 2020 (relative to BAU) would have major negative consequences for the coal industry. Stricter policies to reduce $SO_2$ are anticipated to have a smaller negative impact on coal production in western states because of its lower sulfur content and its increasingly lower mining costs (EPA, 1999). Policies to reduce $CO_2$, on the other hand, are anticipated to have a smaller negative impact on coal production in Northern Appalachia and the Midwest because these mines are closer to coal markets and do not require long-haul, carbon-intensive transportation (EIA, 1998c).

Unequal regional impacts of $CO_2$ policies on the electricity industry are also anticipated because of regional differences in the resources used to generate electricity. In particular, interior states would suffer greater economic hardship than coastal regions based on the interior region's greater dependence on coal for electricity. Coastal regions have more readily available nuclear and hydroelectric power (Resourcedata International, Inc., 1999).

The reduced demand for coal would also adversely affect the transportation sectors (i.e., rail and barge) that draw sizeable fractions of their business from hauling coal. The viability of some rail links and barge routes would be weakened by the reduced freight.

Similarly, the 10 to 20% reduction in petroleum consumption in the Advanced scenario would dampen demand for petroleum products from the domestic refining industry. This could further challenge the U.S. oil industry's ability to compete in world markets and to expand its production quickly in the event of oil supply shocks.

At a broader scale, cost-effective energy-efficiency measures free up real resources that otherwise would be needed for energy production. Because the energy-efficiency measures are cost-effective, a net surplus output remains for increased consumer and business investment spending. The increased consumer and business investment spending are the sources of general benefits to most sectors in the economy (Hanson and Laitner, 2000).

## *1.5 SENSITIVITY ANALYSIS*

This section analyzes a range of alternative policies to systematically assess the opportunities and consequences of a variety of futures other than the BAU, Moderate, and Advanced scenarios described in the rest of the report. These alternative scenarios are important for several reasons. First, they reflect the highly unpredictable nature of political and consumer views and they highlight the diversity of policy alternatives. Second, they characterize the impact of uncertainties in parameter values and model assumptions.

Many types of uncertainties influence the CEF scenarios. Some of these uncertainties can be captured through quantitative sensitivity analyses, in which one or more key input assumptions are varied and the results studied. Other uncertainties are more difficult to capture – e.g., uncertainties in the specification of basic data and underlying assumptions, in the realism of the models and related forecasting approaches, and in the assessment of impacts of policies. Recognizing that sensitivity analysis captures only a portion of the uncertainty, we have carried out a range of sensitivities on a number of important variables. These are described in detail in subsequent chapters. To illustrate the approach, the following box summarizes a selection of sensitivity cases, including (1) higher natural gas prices, (2) shorter duration of the renewable

## Results of Selected Sensitivity Cases

***High Natural Gas Prices***

By assuming limited technological progress in gas drilling, exploration, and recovery, natural gas prices in the electric sector were increased by 12% above the BAU scenario for 2020. The major impact is a reduction in natural gas consumption for electricity generation of about 12%. About three-quarters of the natural gas is replaced by coal in both the BAU and Advanced scenarios. The result is an increase in carbon emissions by between 6 and 10 MtC in the two cases, respectively. By also assuming that demand reduction policies were not implemented, natural gas prices were increased further to 26% over the BAU forecast for 2020. Coal increases make up two-thirds of the gas reduction. Biomass, geothermal, and wind make up 8%, 5%, and 4% of the lost gas generation, respectively.

***High Natural Gas and Petroleum Prices***

The EIA's "High World Oil Prices" (EIA, 1998a) were added to the high natural gas price sensitivity (described above) to model a future in which both natural gas and petroleum prices rise significantly. In this sensitivity, world oil prices increase from $19 per barrel in 1997 to $27 in 2010 and $29 in 2020. When this energy price trajectory is added to the standard Advanced scenario, light-duty vehicle miles of travel drop by 2% (by 2005) and the efficiency of the light-duty fleet increases by 2 to 3% compared to the standard Advanced scenario. The result is a significant decrease in carbon emissions from transportation. This is offset slightly by an increase in carbon emissions in the electric sector caused by a shift from natural gas to coal generation resulting from the higher natural gas prices and fuel switching from oil to electricity in buildings and industry.

***Renewable Energy Policy and Cost Sensitivities***

In this sensitivity, the renewable portfolio standard (RPS) was terminated in the Advanced scenario in 2004, four years ahead of schedule. This causes wind generation in the Advanced scenario to fall from 159 to 97 TWh in 2020. (It is 9 TWh in the BAU in 2020.) This results in an increase in carbon emissions in the Advanced scenario of 20 MtC in 2020. An increase in the projected capital costs for wind and biomass of 20 to 25% in 2020 has the same effect as early termination of the RPS.

***No Diesel Penetration in Light-Duty Vehicles***

The Advanced scenario has a penetration of 2.2 million high-efficiency diesels in 2010 and 3.1 million in 2020. We simulated a case in which there is no diesel penetration in light-duty vehicles. The effect was to reduce fuel economy for new light-duty vehicles from 41.9 to 40.5 mpg in the Advanced case in 2020. (This compares with a projected fuel economy of 30.5 mpg in the BAU in 2020.) The net effect is an increase in energy use of 0.5 quads in the Advanced scenario in 2020, or about 10 MtC. The absence of diesels has such a small effect on energy and carbon emissions because other efficient technologies (e.g., fuel cells) are assumed to be available to replace the diesels.

***Higher Cost of Advanced Fossil Fuel Technology***

Sensitivity analyses were conducted to examine a less optimistic future for the cost and performance of natural gas and integrated gasification combined cycle plants. (For example, capital costs for natural gas combined cycle plants were assumed to be 17 to 30% higher, depending on the scenario.) The results show a decline in carbon emissions (6 MtC for the Moderate and 3 MtC for the Advanced scenarios), resulting from replacement of the fossil energy generation by renewable and nuclear power. With higher cost advanced technologies, the market price for $SO_2$ credits increases slightly, as do electricity prices (by 1 to 2 mills per kWh). Because of the availability of advanced technologies for renewables and combustion turbines and the continued availability of relicensed nuclear plants as backstops, less R&D success for combined cycle technologies does not have a major impact on the overall results.

## Table 1.21 Summary of Sensitivity Cases

| | **Domestic Carbon Trading System** | **Moderate Demand and Supply-Side Policies** | **Advanced Demand-Side Policies**[a] | **Advanced Supply-Side Policies**[b] | **Advanced Demand and Supply-Side Policies** |
|---|---|---|---|---|---|
| **2010:** | | | | | |
| **No Carbon Trading** | **BAU Scenario:** | **Moderate Scenario:** | | | |
| Primary Energy (Quads) | 110.3 | 106.5 | 102.9 | 109.0 | 103.3 |
| Carbon Emissions (MtC) | 1769 | 1684 | 1634 | 1714 | 1619 |
| Carbon Emissions (MtC) from Electric Generators | 645 | 597 | 589 | 604 | 575 |
| **$25/tC** | | | | | |
| Primary Energy (Quads) | 109.1 | 104.9 | 100.7 | 107.5 | 101.0 |
| Carbon Emissions (MtC) | 1720 | 1625 | 1556 | 1652 | 1539 |
| Carbon Emissions (MtC) from Electric Generators | 608 | 555 | 534 | 557 | 515 |
| **$50/tC** | | | | | **Advanced Scenario:** |
| Primary Energy (Quads) | 107.5 | 103.2 | 99.1 | 106.0 | 99.3 |
| Carbon Emissions (MtC) | 1663 | 1548 | 1504 | 1579 | 1463 |
| Carbon Emissions (MtC) from Electric Generators | 562 | 491 | 493 | 496 | 456 |
| **2020:** | | | | | |
| **No Carbon Trading** | **BAU Scenario:** | **Moderate Scenario:** | | | |
| Primary Energy (Quads) | 119.8 | 110.1 | 101.9 | 112.6 | 100.9 |
| Carbon Emissions (MtC) | 1922 | 1740 | 1602 | 1748 | 1568 |
| Carbon Emissions (MtC) from Electric Generators | 709 | 623 | 584 | 593 | 550 |
| **$25/tC** | 118.5 | 108.8 | 99.8 | 112.1 | 98.8 |
| Primary Energy (Quads) | 1842 | 1651 | 1490 | 1684 | 1472 |
| Carbon Emissions (MtC) | 645 | 551 | 500 | 547 | 482 |
| Carbon Emissions (MtC) from Electric Generators | | | | | |
| **$50/tC** | | | | | **Advanced Scenario:** |
| Primary Energy (Quads) | 116.5 | 107.6 | 98.3 | 110.8 | 96.8 |
| Carbon Emissions (MtC) | 1755 | 1546 | 1426 | 1562 | 1347 |
| Carbon Emissions (MtC) from Electric Generators | 571 | 461 | 443 | 440 | 374 |

[a] The advanced demand-side policies are those policies that are defined for the end-use sectors in the Advanced scenario (excluding the domestic cap and trade system).

[b] The advanced supply-side policies are those policies that are defined for the electricity sector in the Advanced scenario (excluding the domestic cap and trade system).

portfolio standard or higher cost of renewable energy technology, (3) no penetration of light-duty diesel engines, and (4) higher cost of advanced fossil fuel technologies.

Overall, the results show impacts on the order of 3 to 20 MtC in 2020 for each of the sensitivities. These results are to be compared with the reduction in carbon emissions in 2020 of approximately 180 MtC in going from BAU to the Moderate scenario, and a reduction of 565 MtC in going to the Advanced scenario. In short, each of the particular sensitivities analyzed has an impact on carbon emissions that is less than 4% of the reduction achieved in moving from BAU to the Advanced scenario.

In the following section, the results of system-wide variations in policies are presented – comparing and contrasting demand-side versus supply-side policies and examining cases that rely strictly on domestic carbon trading. The demand-side policies are those defined for the three end-use sectors in the Advanced scenario (excluding the domestic carbon trading system). The supply-side policies are those defined for the electricity sector in the Advanced scenario (excluding the domestic carbon trading system). Two values of the carbon permit price were assessed: $25/tC and $50/tC. Twelve sensitivity cases were defined by combining various of these categories of policies, as shown in Table 1.21. The Advanced scenario is the combination of all three categories of policies, with the $50/tC carbon permit price, and the BAU scenario is the absence of any of these policies. Results are summarized for both 2010 and 2020 in Table 1.21. Additional tables in Appendix D-5 provide more detailed results for each of these sensitivities.

### 1.5.1 Demand-Side Policies

Efforts to promote energy efficiency have been a cornerstone of U.S. energy policy since the OPEC oil embargo of 1973–74. These efforts have been viewed favorably by a majority of the public (Bonneville Power Administration, 1999; Sustainable Energy Coalition, 1999) and have produced well-documented, positive impacts (Chapter 2). Thus it is plausible to imagine a future in which politicians and the public support a vigorous push to improve energy efficiency. This scenario could result, for instance from an increased awareness of the link between energy use and a range of negative environmental consequences. Or it could be precipitated by a rise in energy prices. Our analysis indicates that a push on energy efficiency, by itself, could produce significant reductions in energy use and proportionate cuts in carbon emissions.

When the demand-side policies from the Advanced scenario are modeled separately (i.e., without supply-side policies and without a domestic carbon trading system), energy use in 2010 grows to only 103.1 quads, a 7% decrease relative to BAU. During the second decade of demand-side policies, accelerated strides in the performance and deployment of efficient technologies cause the historic energy use to “turn the bend” and decline, dropping to 102.2 quads by 2020. This is a 15% decrease from the BAU forecast and is 77% of the Advanced scenario’s energy reductions.

The drop in carbon emissions from the demand-side scenario is comparable to the drop in energy use. When demand-side policies are modeled separately, carbon emissions in 2010 grow to only 1641 MtC, 7% lower than the BAU forecast of 1,771 MtC. During the second decade of demand-side policies, further efficiency investments cause carbon emissions to decline slightly (as with energy use), decreasing to 1609 MtC by 2020. This reduction is 16% of the BAU and is 55% of the Advanced scenario’s carbon emission reductions.

Almost no further energy reductions – and only a modest decrease in carbon emissions – result from adding supply-side policies to the demand-side scenario, in either 2010 or 2020. This finding is not surprising since the supply-side policies focus on encouraging the production and use of clean energy options. Also, it highlights how the success of demand-side policies can make it more difficult for low-carbon energy options to penetrate the market, partly because reduced demand restricts the need for new capacity.

In contrast, adding carbon trading to the demand-side scenario significantly reduces both energy consumption and carbon emissions. In both 2010 and 2020, energy use decreases by an additional 2 quads with a \$25/t carbon permit price and by an additional 4 quads with a \$50/t carbon permit price. Coupling these two types of policies brings the energy and carbon reductions to within 90% of the reductions produced by the Advanced scenario.

### 1.5.2 Supply-Side Policies

One can imagine a future in which the United States implements an energy policy that focuses primarily on the production of cleaner energy through a variety of supply-side policies. This might result, for instance, from the rise in popularity of green power programs. Or it could result from a political preference for dealing with the smaller number of energy producers rather than expanding programs dealing with the large number of energy end-users.

To model this type of scenario, we look at the impacts of the Advanced scenario's supply-side policies in the absence of demand-side interventions and without a domestic carbon trading system. When these supply-side policies are modeled, the impacts on energy use are minimal, ranging from a 1% decrease from BAU in 2010 to a 6% decrease in 2020. Carbon reductions are somewhat more significant, ranging from a 3% decrease from BAU in 2010 to a 9% decrease in 2020. Both of these impacts are much smaller than for the demand-side scenario.

Looking specifically at carbon emissions from electric generators, a more noteworthy carbon impact is indicated. A decrease of only 2% in electricity demand in 2010 relative to the BAU forecast – presumably due to slightly higher electricity prices, yields a 6% decrease in carbon emissions from electric generators. Similarly, electricity demand decreases by just 9% in 2020 relative to the BAU, but carbon emissions from electric generators decrease by 16%. Thus the reduced demand is not the principal driver; the more significant effect is from switching to low-carbon sources of electricity. Comparable decreases are achieved in the demand-side scenario, but the cause is the significant decline in electricity consumption.

Adding demand-side policies to the supply-side scenario produces a substantial drop in overall energy use and carbon emissions. The impact on carbon emissions from electric generators, however, is relatively small since the supply-side policies have already significantly reduced these by shifting electricity generation to cleaner fuels.

Adding a domestic carbon trading to the supply-side scenario results in only a modest decrease in energy use, but it has a significant dampening impact on carbon emissions. The \$25/t carbon permit price on its own cuts carbon emissions to 7% and 12% below the BAU forecast in 2010 and 2020, respectively. For electric generators, carbon emissions drop even more significantly, to 14% and 23% below the BAU in 2010 and 2020. At \$50/tC, the carbon permit price has an even more dramatic effect on carbon emissions from electric generators, achieving 80% of the reduction in the electric sector in the Advanced scenario (without any additional demand-side policies).

### 1.5.3 Carbon Trading Policy

Many analysts have argued for the merits of tackling the global climate change challenge by creating a domestic carbon trading program, as was done to reduce $SO_2$ emissions from electric generators. Trading programs could motivate innovative and low-cost actions to reduce $CO_2$ emissions, as well as the emissions of other greenhouse gases such as $CH_4$, $N_2O$, HFC, PFC, and $SF_6$. Thus it is plausible to imagine a future in which the nation implements a domestic carbon trading policy as its primary approach to carbon mitigation.

Compared with the demand- and supply-side cases, a trading case alone where carbon acquires a value of $25/t has the least impact on energy use and carbon emissions. At a value of $50/tC, the carbon trading case still reduces energy use and carbon emissions less than the demand-side scenario. Energy use drops by only 2% in both 2010 and 2020 relative to BAU (to 107.5 and 116.5 quads in 2020 compared with BAU forecasts of 110.3 and 119.8 quads). Carbon emissions decrease by only 6% to 9% relative to BAU (to 1663 and 1755 MtC in 2020 compared with BAU forecasts of 1769 and 1022 MtC).

Compared with the supply-side case, the carbon trading case with a value of $50/tC is more effective at reducing energy use and carbon emissions in the first decade, but it is less effective in the second decade. The carbon trading system is assumed to be announced in 2002 and operational beginning in 2005. From then on, energy prices take on a proportionately higher value. The supply-side policies are more gradual. The RPS, for instance, is not fully in effect until 2010. Also, restrictions on particulate emissions (modeled as an $SO_2$ ceiling) are not implemented until 2010 and then are enacted over the following decade in incremental steps.

The further reductions from adding demand-side policies to the carbon trading case are much greater than the incremental reductions from adding supply-side policies. In fact, of the various combinations shown in Table 1.21, coupling demand-side policies with carbon trading at $50/tC comes the closest to achieving the energy and carbon reductions of the Advanced scenario.

### 1.5.4 Summary

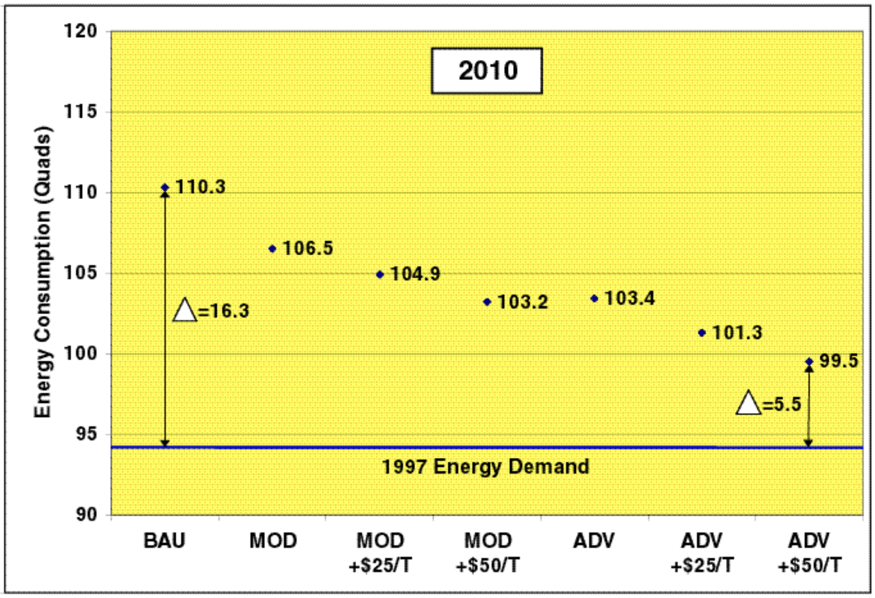
Among the three categories of policies, the demand-side policies produce the greatest energy and carbon reductions (Fig. 1.14 and 1.15). They dampen energy use and carbon emissions in approximately equal proportions. Supply-side policies and the domestic carbon trading policy, on the other hand, principally reduce carbon emissions in the electricity sector. However, neither of these sets of policies is able to stabilize (or reduce) carbon emissions during the 20-year period. Adding a domestic carbon trading system to the demand-side policies gets to within 90% of the Advanced scenario's energy and carbon reductions. This is the most effective combination of two policy categories, bringing energy use and carbon emissions in 2020 down to below 1997 levels. In sum, the opportunities and consequences of each of these sets of policies varies considerably, and the value of each depends intimately upon the specific goals of the policy intervention – for example, short-term vs. long-term impacts and energy vs. carbon reductions.

Because our scenarios extend only to 2020, it is not possible to estimate the longer term benefits of different policy clusters. For instance, what is the full cost of a policy scenario limited to demand-side options if it means delaying the development of environmentally attractive supply-side options? Would future U.S. export markets for supply-side technologies be diminished? Would the U.S. be less prepared to add clean power if, a compelling need were to unexpectedly emerge? Such longer term considerations suggest that a diversified portfolio of demand- and supply-side policies is advantageous.

## *1.6 COMPARISONS ACROSS STUDIES*

This section compares the results of the CEF analysis with those of other major carbon mitigation scenarios that employ engineering-economic (i.e., "bottoms up") methodologies. The goal of these comparisons is to explain the divergence of modeling results by comparing the assumptions and methodologies of each study. The policy pathways that are modeled, the base and target years, and the baseline assumptions about economic growth and future energy prices can all affect results, including estimates of future energy consumption and carbon emission levels, rates of market penetration of key technologies, and the estimated costs associated with these scenarios.

**Fig. 1.14 Sensitivity Cases for the Year 2010**



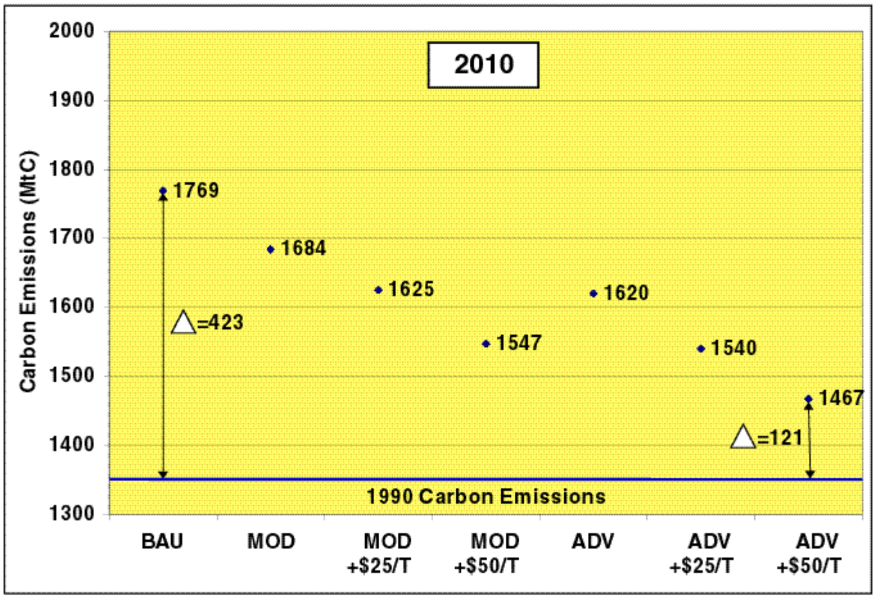
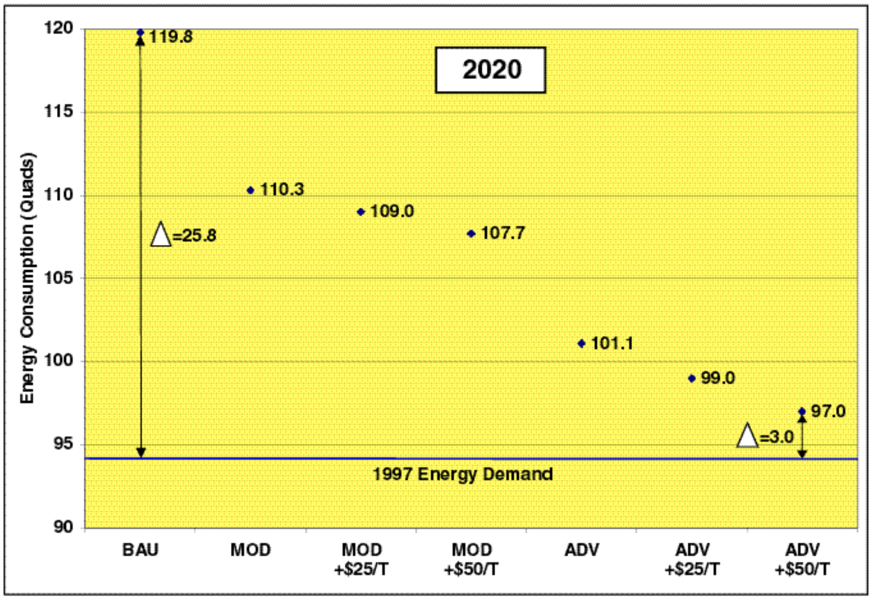
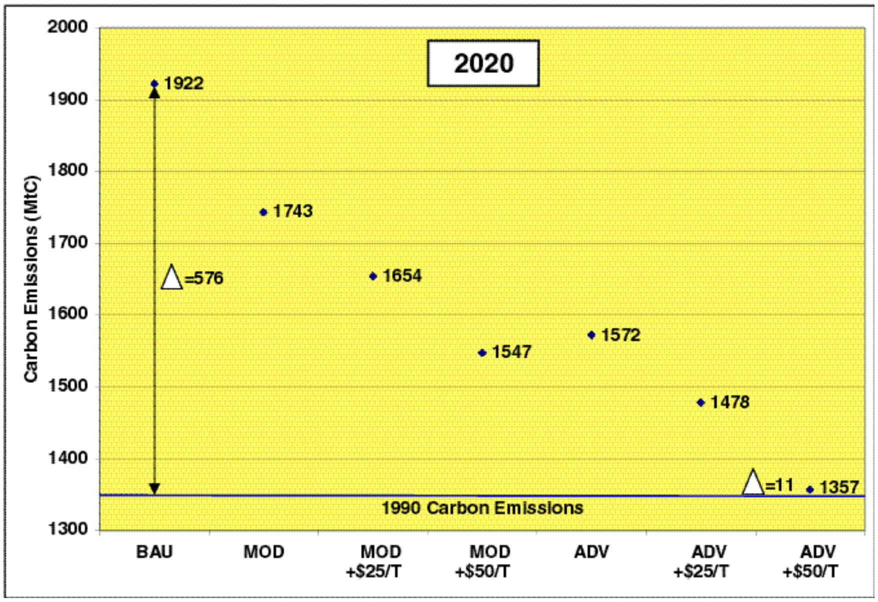


**Fig. 1.15 Sensitivity Cases for the Year 2020**





Additional studies have used general equilibrium, “top-down” modeling to estimate the costs of achieving various levels of carbon reduction in the United States. These include studies by WEFA (1998), analyses using the Pacific Northwest National Laboratory’s Second Generation Model (Edmonds et al., 1992), studies using MIT’s Emissions Prediction and Policy Analysis Model (Jacoby et al., 1997), analysis by Manne and Richels (1997) sponsored by the Electric Power Research Institute, and analysis by Standard and Poors DRI (1998). Detailed comparisons are not provided with these studies because of the differences in basic methodology. However, the reader can find a lucid comparison of their projections and cost estimates for achieving the Kyoto Protocol goals in EIA's *Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activit*y (1998c, chapter 7).

The following engineering-economic studies are examined in the following pages:

- *Changing by Degrees: Steps to Reduce Greenhouse Gases,* by the Office of Technology Assessment (OTA, 1991);
- *Policy Implications of Greenhouse Warming: Mitigation, Adaptation, and the Science Base* by the National Academy of Sciences (NAS, 1992);
- Interlaboratory Working Group. *Scenarios of U.S. Carbon Reductions: Potential Impacts of Energy-Efficient and Low-Carbon Technologies by 2010 and Beyond*–also known as "The Five-Lab Study" (1997);
- *Policies and Measures to Reduce $CO_2$ Emissions in the United States: An Analysis of Options for 2005 and 2010* by Tellus Institute (1998);
- Bernow, S., et al. (1999) *America's Global Warming Solutions*, by Tellus Institute and Stockholm Environment Institute[16];
- *Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity*, by the Energy Information Administration (EIA, 1998c); and
- *Analysis of the Impacts of an Early Start for Compliance with the Kyoto Protocol,* by the Energy Information Administration (EIA, 1999c).

Each of these studies describes at least one "low-cost" carbon reduction scenario. To keep the comparisons manageable, only one scenario from each study is described. The scenario chosen in each case is the one that produces the largest carbon reductions while maintaining low costs (i.e., annual costs generally less than $100 billion). These include the "tough" scenario from OTA (1991), the high-efficiency/low-carbon case from the Five-Lab study, the "climate protection" scenario from the 1998 and 1999 Tellus studies, and the EIA (1998c and 1999c) scenarios that reduce carbon emissions to 24% above 1990 levels. The variation in carbon reduction levels across these scenarios is shown in Fig. 1.16. To facilitate these cross-study comparisons, this figure portrays each scenario's carbon reductions relative to EIA's AEO99 Reference case (EIA, 1999a). Differences in the assumptions and methodologies used by these studies that help to explain variations across their findings are summarized study-by-study in the following paragraphs. For a more detailed, parameter-by-parameter comparison of many of these studies, see Brown et al. (1998).

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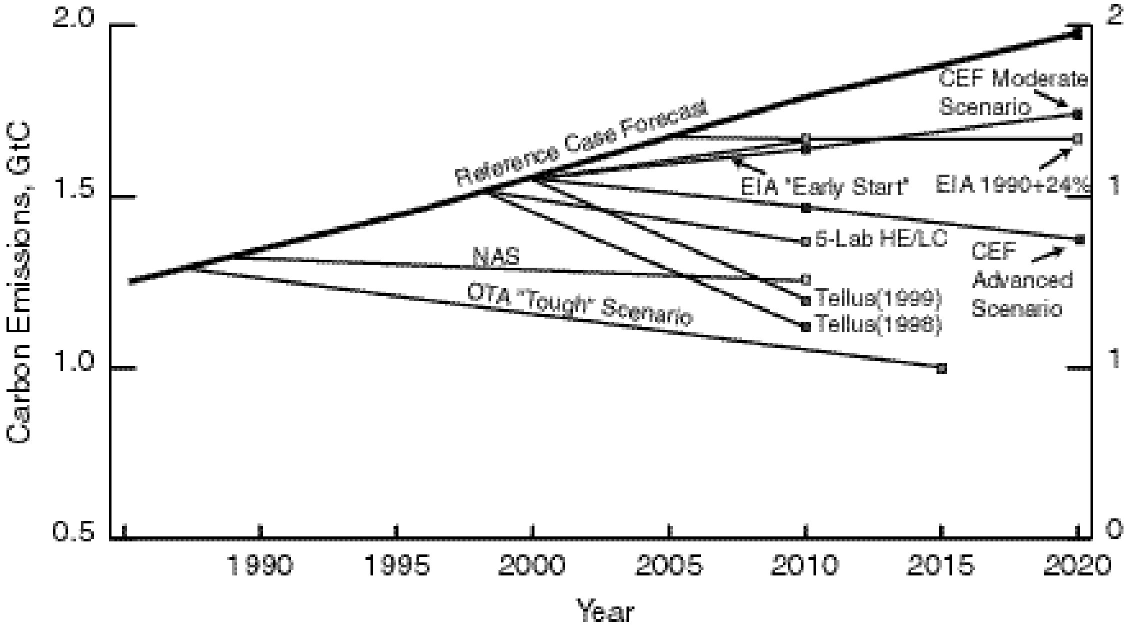
[16] The Tellus Institute reports reflect an effort among leading non-governmental energy organizations that was begun with *America's Energy Choices* in 1991. The series of reports includes *Energy Innovations: A Prosperous Path to a Clean Environment* by five national environmental organizations (Alliance to Save Energy, et al., 1997).

Fig. 1.16 A Selection of Low-Cost Engineering-Economic Scenarios



The 1991 report by the Office of Technology Assessment (OTA) titled *Changing by Degrees* (Office of Technology Assessment, U.S. Congress, 1991) analyzed the potential for energy efficiency to reduce carbon emissions by the year 2015, starting with the base year of 1987. Its **"tough" scenario** results in a 20% to 35% emissions reduction relative to 1987 levels, or emissions levels of 850 to 1,000 MtC/year in 2015. The CEF study's carbon reductions are considerably less than OTA's "tough" case. However, the annual rate of decrease in carbon emissions is similar, as can be seen by the parallel positioning of their trajectories in Fig. 1.16. The large difference between their endpoints is due partly to OTA's 13-year "jumpstart."

The tough scenario achieved its reductions at an estimated net annual cost ranging from -$28 billion to $212 billion (in 1997$). Residential building efficiency improvements are seen as the least-cost options and are estimated to generate net savings in both the pessimistic and optimistic cases. Energy-efficient technologies for commercial buildings and for transportation are seen as saving or costing money, depending on the assumptions. Altogether, these three end-use efficiency "stair-steps" in the supply curve account for more than 450 MtC of reductions in the year 2015. The savings from the first three steps are offset by the net costs represented by the two remaining steps – industrial efficiency and electric generators. These two options are estimated to deliver more than 400 MtC of reductions. This study differs from the CEF Study in its view that industrial efficiency technologies have net costs, even under the most optimistic assumptions.

The **NAS scenario** (National Academy of Sciences, 1992) included energy conservation technologies that had either a positive economic return or that had a cost of less than $2.85 (in 1997$) per tonne of carbon. Electric utility technology options play a negligible role. Altogether, NAS concluded that energy conservation technologies offered the potential to reduce carbon emissions by 463 MtC over a 20-year period, with more than half of these reductions arising from cost-effective investments in building energy efficiency. The CEF Advanced scenario describes bigger reductions overall (575 MtC over a 20-year period). However, only 369 MtC of these reductions come from energy efficiency improvements. A key reason that the NAS estimate is higher is that it did not use stock turnover periods to constrain the introduction of new technologies. Another reason is that it did not employ any type of "participation fraction" to limit the portion of purchases that actually buy optimum-efficiency equipment. Rather, the NAS study focused on the full technical potential of a suite of energy conservation technologies.

The NAS study estimated that it could realize this potential at a net benefit to the economy ranging from $14 billion to $116 billion per year (in 1989$). This net benefit results from adherence to the low-cost guidelines for including individual technologies. Power plant upgrades constitute the only supply-side technology option that does not exceed the NAS definition of a low-cost technology for reducing carbon emissions. These upgrades include 3% efficiency improvements to existing coal plants, 5% efficiency improvements to hydroelectric plants, and a 5% increase in the average capacity factor of existing nuclear power plants. In contrast, new electricity supply technologies that emit no carbon are estimated to require high implementation costs. They are therefore not part of the potential emission reduction estimated by the NAS study, thereby keeping costs low.

The pace of carbon reductions in the Five-Lab study's **"high-efficiency/low-carbon" scenario** is similar to the pace of reductions in the Advanced scenario, as documented by the parallel carbon reduction trajectories shown in Fig. 1.15. However, in 2010 both the carbon and energy reductions in the CEF study's Advanced scenario are less than those of the Five-Lab study's HE/LC case. This difference is largely due to the distinct timeframes of each study. The Five-Lab study's scenarios used a variation of the EIA AEO97 Reference case as its baseline and assumed that a national focus on efficient and clean energy technologies would begin in 1998. In contrast, the CEF study uses a variation of the AEO99 Reference case as its baseline and therefore is working against a 5% higher level of energy use and carbon emissions in 2010. In addition, it assumes that new policies begin in 2000, which allows only 10 years, instead of 12, to produce impacts by 2010. These two differences make it more difficult to devise low-cost strategies to bring down future energy use and carbon emissions to historic levels.

Sector-specific differences also exist in the energy savings modeled by the CEF and Five-Lab studies. Specifically, the CEF study shows lower savings for the transportation sector and higher savings for both buildings and industry. In the Advanced scenario, 20 years are required for the transportation sector to deliver energy reductions comparable to those achieved in the other two sectors. The Five-Lab study showed less of a lag partly because it had two more years in which to generate results.

Carbon emissions from electricity production in the HE/LC case are somewhat higher than in the Advanced scenario in 2010. This is due primarily to the greater use of wind energy and the relicensing of more nuclear plants in the Advanced scenario. These potential carbon reductions are somewhat offset by the Advanced scenario's smaller introduction of biomass cofiring, hydropower, and fossil plant efficiency improvements, compared with the HE/LC case. In contrast to the electricity sector, the end-use sectors in the HE/LC case generate greater carbon reductions than in the Advanced scenario. This is partly because the impacts of fuel cells in buildings and combined heat and power in industry are not included in the CEF bottom-line estimates, and ethanol displaces less gasoline in the Advanced scenario. In the Five-Lab study, savings from lower energy bills exceed the incremental technology investment costs and the cost of administering the programs and policies required to motivate these investments. The same is true for the CEF study, if the recycled revenues from the domestic carbon trading system are used to offset higher energy prices, as was implicitly assumed in the Five-Lab study.

The Tellus Institute's 1998 **"climate protection" scenario** modeled the carbon emission reductions from a vigorous set of RD&D and deployment policies. Compared to the policies modeled in the Advanced scenario, these policies are more aggressive. For instance they include stricter appliance and buildings standards, increased CAFE standards, a carbon content standard for transportation fuels, incentives for more rapid investment in new manufacturing equipment in industry, and a 10% "unconstrained" renewable portfolio standard in the electric utility sector. The result is an estimated decrease in carbon emissions of 593 MtC in 2010. This is approximately the same level of reduction that is achieved by the CEF Advanced scenario in 2020. The reductions are particularly strong in the transportation sector due to the aggressive policies of the climate protection scenario. It foresees the potential to reduce petroleum use by 2.2% per year. In contrast, the CEF study estimates growth in petroleum use through 2010, and reductions during the second decade only after sufficient R&D-generated improvements have materialized.

The **"climate protection" scenario** produced by the Tellus Institute in 1999 models many of the same policies as in its 1998 climate protection scenario. Again, these are generally more aggressive than the policies modeled in the CEF study's Advanced scenario and include:

- a cap and trade system to reduce the carbon intensity of the electric sector by 40% in 2010,
- incentives for biomass cofiring and district energy systems with cogeneration,
- stricter appliance and building standards,
- a carbon content standard for motor fuels to achieve a 10% reduction by 2010,
- a 10% unconstrained renewable portfolio standard, and
- facilitation of high-speed intercity rail development and intermodal freight movement.

The result is a rapid decline in carbon emissions to 1,150 MtC in 2010.

The 1998 climate protection scenario estimates net annual benefits of $87 per tonne of reduced carbon, for a total annual savings of $52 billion (in 1997$). The net annualized savings of the 1999 climate protection scenario is estimated to be $43 billion (in $1996) in 2010. A substantial portion of this scenario's carbon reductions comes from a 28% decrease in petroleum use, relative to the BAU scenario. This sizeable reduction reflects a set of policies to decrease vehicle miles traveled and to shift the nation toward more efficient transportation modes. Such policies are not considered in the Advanced scenario of the CEF study, although they are discussed in detail in Appendix E-2.

The **1990+24% scenario** described in *Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity* (EIA, 1998c), is driven by a single policy instrument: a domestic carbon trading system. In this scenario, emissions in 2010 are limited by a cap defined as 24% above 1990 levels. (EIA also models scenarios that reduce carbon emissions to +9%, -3%, and –7%. These other cases are not described here because their costs are significantly higher.) It is assumed that the domestic carbon trading system is phased in beginning in 2005. At the 1990+24% cap (i.e., a carbon reduction of 123 MtC in 2010), carbon permits are estimated to trade at $67 per tonne (in $1996) in 2010. The annual macroeconomic costs to the economy are estimated to be $56 to $88 billion ($1992) between 2008 and 2012. This range reflects two different revenue-recycling schemes (either a social security tax rebate or a personal income tax rebate).

The introduction of carbon prices in 2005 in the 1990+24% scenario lowers the demand for energy services due to both the direct effect of higher energy prices on energy markets and the indirect effect of higher energy prices on the economy. There is also greater adoption of more efficient equipment and increased use of low-carbon fuels. U.S. coal consumption is significantly lower, while petroleum consumption decreases by a modest 2%. Thus, the analysis suggests that a small increase in oil prices from the domestic carbon trading system would have a minimal impact on vehicle efficiencies.

Consumption of natural gas, nuclear power, and renewable energy is higher, primarily for electricity generation.

In EIA's **"Early Start" scenario** (EIA, 1999c), it is assumed that a domestic carbon trading program is phased in beginning in 2000. This earlier start date smooths the transition of the economy to carbon reduction targets in 2008-2012. Other assumptions of the analysis are the same as in the EIA study described above (EIA, 1998c). The earlier start date reduces the carbon prices in 2010 from $67 (1996$) to $62 per MtC in the 1990+24% case. With the early start, actual GDP begins to rebound back toward its level in the Reference case sooner, and the recovery is smoother than in the case with a 2005 start date. Thus, the early start case involves a tradeoff. Its peak impacts are less severe, but they occur earlier than with the 2005 start. Net present value calculations show that the cumulative discounted impacts are larger in the early start cases.

The primary differences between these two EIA analyses and the present study are that the 1990+24% scenarios achieve their carbon reductions through a domestic carbon trading system, that is modeled as a carbon tax. We have seen in our analysis that carbon permits are effective in producing fuel switching in the electric utility sector, from coal to natural gas, but have relatively little impact on energy demand. Because of the low demand elasticity in the end-use sectors, EIA has had to apply a high carbon tax to obtain demand reductions. In contrast, the CEF study (and most of the other studies examined here) has used policies – such as appliance standards and voluntary agreements – to achieve demand reductions, and thus has not needed such high carbon permit prices. The EIA study also did not assume increased RD&D programs, while the CEF study assumes significantly increased RD&D resources, with resulting technology improvements in all sectors of the economy, especially in the transportation.

## *1.7 STUDY LIMITATIONS AND REMAINING ANALYSIS NEEDS*

The objective of this CEF study is to develop scenarios that show how energy efficiency and clean energy technologies can address U.S. energy and environmental challenges while enabling continued economic growth. To meet this objective within our resources, we have restricted the scope of the CEF study. These limitations, and the need for further analysis, are described in the following paragraphs.

Perhaps the most significant limitation of the study is its focus on domestic carbon dioxide emissions. This focus results from these facts:

- Although the United States faces many energy and environmental issues, climate change could be the most challenging.
- Many of the policies and technologies that address carbon emissions have co-benefits such as improved air quality, security of energy supplies, and energy productivity.
- Carbon dioxide emissions from fossil fuel combustion represent 83% of U.S. emissions of greenhouse gases.
- While global climate change is an international issue, and international trading of carbon permits may become a reality, the potential for domestic carbon emission reductions can be evaluated largely independently of the international trading opportunities and is relevant to the international debate.

This focus on carbon emissions means that while we have included some policies directed at other issues (e.g., electric sector restructuring), we have not examined many policies relevant to non-$CO_2$ greenhouse gas emissions, carbon sink development, local air pollution emissions, or international carbon trading or export market opportunities.

In spite of the long-term nature of the global climate change problem, we elected to constrain the study's modeling to a near-term (2020) timeframe to better represent specific policy opportunities and impacts. This timeframe is also consistent with the use of NEMS, which extends only through 2020. One result of "truncating" our analysis at 2020 is that the modeling is not responsive to needs and conditions that emerge in subsequent years. This is not a limitation of the BAU forecast, but it is a limitation of the CEF scenarios. These scenarios could be improved if circumstances after 2020 could be foreseen (e.g., breakthrough technologies, more or less severe environmental conditions, export market developments, etc.) and factored into the design of policies and programs.

Because of the long lifetimes of power plants, refineries, and many other energy investments, decisions made over the next two decades will have far-reaching implications for subsequent decades and may not be optimal for the long run. In addition, the RD&D investments of the next few decades will determine which long-term options become available after 2020 and which are foreclosed. The impact of short-term decisions over the longer term is illustrated vividly by the six global energy scenarios developed for the next century by Nakicenovic, Grubler, and McDonald (1998), which are discussed in Chapter 8.

Although we have examined the direct costs and benefits of the policies included in the different scenarios, we have not assessed the cost of no policies (i.e., the cost of inaction). The study also does not assess the cost of policies to promote low-cost adaptation to climate change (e.g., strengthening physical infrastructures, emergency preparedness programs, and improved air conditioning technologies). An entirely different study would be required to assess the costs of a changing global climate.

The study is also limited in terms of methodology. As discussed in Section 3.7, "Remaining Analysis Needs," a major methodological weakness is our limited ability to analyze non-fiscal policies. These include information and technical assistance programs, demonstration projects, and voluntary agreements. More detailed documentation of program impacts is needed so that analyses such as the CEF study can be better grounded, and future policies and programs can benefit better from past experiences. Modeling the results of R&D programs also proved difficult. We cannot forecast with precision, we can only illustrate by example, the kinds of improvements in technologies over time that can be the determining factor in the acceptance of many clean energy technologies. Resource limitations also prevented this study from analyzing markets at the disaggregated level of detail required for some technologies to be accurately assessed, such as combined heat and power, building shell/equipment interactions, and distributed generation.

The CEF study is also methodologically limited in its assessment of the macroeconomic impacts of policies. This is particularly problematic for policies involving large transfer payments, such as domestic carbon trading with its redistribution impacts, transition costs, and equity issues.

Given these limitations of scope and methodology, caution should be used when applying the CEF study results. First, the study consists of a set of scenarios, not forecasts. The scenarios are distinguished by a range of public perceptions of the severity of the global climate change problem. If the public does not perceive the problem as extremely serious, these scenarios will not materialize. Second, it is not possible in a study of this nature to conceive of all the mechanisms that energy markets will find to deal with the problem. In general, modeling is poorly suited to anticipating the market's capacity to innovate. In particular, studies by Porter and others strongly suggest that, given flexibility and policy signals that "steer" rather than "row" (precisely the kind that are difficult to model), markets will innovate without incurring substantial price penalties (Porter and van Linde, 1995). Thus it is likely that we overestimate the cost of reducing U.S. carbon emissions.

Similarly, not all policy opportunities have been identified. Inasmuch as better opportunities will emerge, the policies of this study should be taken more as well-documented possibilities than as recommendations. Finally, while we identify near-term technology and policy opportunities, these should not be pursued to the exclusion of technologies and policies that will help us address the longer term beyond 2020.

Many of the CEF study's limitation could be improved with a modest amount of further analysis. These analyses could include the following:

- modeling the impacts of non-fiscal policies;
- improved modeling of macroeconomic impacts of policies;
- improved modeling of distributed power generation, such as fuel cells in buildings and combined heat and power in industry;
- expansion of the modeling capabilities to include a fuller range of air pollutants, so that co-control policies (e.g., air quality and carbon reduction policies) can be more easily analyzed; and
- better characterization of the impacts of uncertainties.

The development of models with longer timeframes, finer geographic disaggregation, and a broader array of international considerations would likely require a more significant amount of additional analysis.

## *1.8 CONCLUSIONS*

This analysis documents the important role that policies can play in stimulating the development and market penetration of efficient and clean energy technologies. These technologies, in turn, could help the United States meet a wide array of challenges, including global climate change, energy supply vulnerabilities, air pollution, and economic competitiveness. Our assessment suggests that the incremental technology and policy costs required to implement these technologies would be less than the energy cost savings from the more efficient use of energy throughout the economy in combination with the carbon permit transfer payments.

This report has developed a variety of scenarios. None of them – including the BAU scenario – is a prediction of the future. They all attempt to characterize the results of different assumptions about the future on the energy system (demand, supply, and price) and, to a lesser degree, the economy.

In the discussion that follows, we present our conclusions approximately in order of increasing uncertainty, as we describe what is needed to achieve reductions in carbon emissions and other pollutants in the 2010 to 2020 timeframe. All of the conclusions are, of necessity, tinged by the uncertainty that is inherent in any discussion of the future.

It is clear that a baseline built on current approaches to energy policy in this nation will result in substantial increases in carbon and other pollutant emissions in 2010 and 2020. The BAU case shows increases in carbon emissions of 31% and 43% above 1990 levels in 2010 and 2020, respectively. Although many different futures based on a continuation of current economic and policy trends are possible, virtually all of them would show substantial increases in carbon emissions. Thus we conclude that, without major shifts in policy and/or in the economic environment, the United States will be much further from stabilizing its carbon emissions if today's trends continue.

The Moderate scenario shows what a considerable effort to increase efficiency could achieve. The authors believe that the scenario demonstrates a range of policies and technologies that are conceivable with a modest shift in the present political context. One view of the Moderate scenario, which shows an increase in energy demand of 27% and 31% above 1990 levels in 2010 and 2020, respectively (an energy reduction of 4% and 8% from BAU in those years), is that it is a modest effort to curb demand growth. Others, contemplating the policies and technologies that need to emerge to make this case happen, may view it as a more significant departure from current trends and policies. The authors view this case as one in which uncertainty about technologies and the likelihood of policies to bring them into the market is relatively modest. That is, in all end-use sectors, the technologies with favorable economics to achieve the demand reductions are available. The greatest uncertainty is the willingness of the nation to adopt policies to encourage them. The second greatest uncertainty is the likely effectiveness of the policies and, therefore, the aggressiveness with which they would need to be pursued. In all analyses of this scenario, we observe a favorable direct economic impact.

Another type of measure to reduce carbon emissions is a direct cap on emissions, resulting in a carbon permit value. We have analyzed $25/tC and $50/tC cases and focus on the $50/t case here. If we apply $50/tC to the BAU case, carbon emissions are reduced by 24% and 30% in 2010 and 2020, respectively. Two very different types of uncertainties relating to this reduction. First is the issue of whether and under what circumstances a policy leading to an increase in energy prices, through a domestic carbon trading system, would be adopted. Such a charge is difficult to imagine in the present political environment. It would require a substantial recognition of the importance to the nation of reducing carbon emissions and a willingness to commit resources and effort to do so. The second set of uncertainties relates to the modeling. For example, we have analyzed the economics of retirement of coal-fired plants and their replacement by natural gas–fired plants under different carbon permit prices. These studies are based on costs averaged across a large number of plants and do not necessarily reflect the real-world costs of individual plants. Future work could show greater or lesser replacement of coal-fired power plants at a $50/tC charge. Our analysis suggests that the direct costs of this domestic carbon trading system on the economy would be small (defined as less than the net savings to the economy of the Moderate scenario).

The CEF-NEMS analysis estimates that the measures identified in the Moderate scenario combined with a cap on carbon that resulted in a $50/tC charge would lead to an increase in carbon emissions above 1990 levels of 15% in both 2010 and 2020. We believe there is less uncertainty in the technology or the economics of this case compared with the political feasibility of implementing the policies (e.g., increasing federal budgets for energy efficiency programs and energy technology R&D; implementing selected energy efficiency policies and/or achieving voluntary agreements with industry; and establishing a carbon cap equivalent to a $50/tC charge).

While there is of necessity some uncertainty in domestic supply of natural gas and its cost, the moderate case with a $50/tC charge has a lower natural gas demand than the BAU. Thus the uncertainty of gas availability at low prices is reduced in this case relative to BAU. This realization makes clear the importance of combining energy efficiency programs, which make more natural gas available, with supply policies that increase use of natural gas.

The Advanced scenario, by combining much more aggressive policies and pursuing advanced R&D goals much more actively, shows carbon emission reductions during the second decade of our analysis period. Are these scenarios achievable? What are the preconditions for success, or a degree of success, in achieving them? If they can be achieved, are they affordable?

These questions have no simple answers. The authors of the report view the cases as plausible – that is, nothing in them violates our knowledge of energy technologies or markets. Of the considerable uncertainties, first and foremost is political feasibility. Even more than the Moderate scenario with a carbon permit price, the Advanced scenario requires a dramatic change in political will. Very active market policies, with substantial federal funding, along with regulatory policies, commitment by industry on energy efficiency well beyond present practice, and greatly increased R&D are all prerequisites. There is little to suggest that such fundamental policy and budget changes are conceivable in the present political environment.

The issue here is not likelihood in the present political environment but feasibility in a different one. If for whatever reason – clear evidence of climate change, new scientific findings, international pressures – the nation did commit to a path of significant carbon reductions, then how plausible is a case such as our Advanced scenario and what are the major uncertainties and barriers to achieving the CEF-NEMS modeled results?

We first discuss three large areas of uncertainty. In many cases, technology is not presently available to achieve the Advanced scenario results. The scenario requires substantial progress toward more efficient vehicles. A combination of advanced diesels with greatly lowered emissions, fuel cell hybrids, reduced-cost alcohol fuels, gasoline hybrids, and electric vehicles will need to be commercial and affordable before 2010. Similarly, costs for key renewable energy sources such as wind and biomass co-firing must be significantly reduced over the same time period. Important improvements in energy-efficient technologies – either cost or performance – are needed for both buildings and industry as well; success in these sectors also depends strongly on program implementation. It is not certain that these technological improvements will occur in the timeframe suggested. It is also possible that technology innovation in response to the combined set of policies described in the study plus similar or more aggressive policies enacted in other countries and not analyzed, could lead to greater technical progress than assumed. If the country – government and private sector – invests in the R&D substantially (we assume a doubling), the authors believe that the technology improvements required for the Advanced case are plausible.

The second area concerns the effectiveness of the policies. This is tied closely with the success in technology R&D. If the R&D is successful, and the technologies are available and cost-effective, then the policies need far less aggressive a push. For example, if advanced vehicle design makes 60 mpg cars (and even light-duty vehicles) affordable without degrading performance, then achieving either a voluntary agreement or mandatory standards on fuel economy is far less difficult than under conditions of technological uncertainty. In a world in which the goal of reducing carbon emissions is widely accepted, the consumer is far more likely to trade acceleration for fuel economy, thus making fuel efficiency agreements or standards easier to adopt. Nonetheless, even in a world in which there is strong agreement among many parties agree to reduce greenhouse gas emissions, there remain uncertainties about the efficacy of the policies. Particularly in buildings and in industry, it remains possible that market barriers to energy efficiency will be more stubborn than expected and/or that the real costs of implementing energy efficiency will be higher than estimated. Again, R&D interacts with policies: a successful R&D effort produces technologies that make policy easier to implement.

A related policy issue concerns the transition to an Advanced scenario. The biggest transition issue concerns the movement away from coal. The coal industry would be dramatically affected by the policies and measures that bring about the Advanced scenario: coal production is down 50% from the BAU case in 2020 (down 40% from 1997 levels). This would dramatically and adversely affect the coal industry and its related transportation modes (rail and barge). Other industries – natural gas, renewables, and providers of energy efficiency – would clearly gain.

The final area concerns the cost of the Advanced scenario. The cost results are critical to the plausibility of the scenario. If the scenario saves consumers and society money, then the policies underlying it become more plausible than if there is a substantial net cost to society. The results suggest that society might have benefits of tens of billions of dollars per year by 2020. This estimate depends in large measure on our estimates of the costs and performance of the technologies and, to a lesser extent, of the policies. The technologies could be more expensive than we expect, or the policies could be more costly. (They could also be less costly.) It is also worth repeating that these costs depend on advances in technology combined with smart and efficient policies; without these, the costs are necessarily much higher.

In summary, a variety of viewpoints are possible in the Advanced scenario. The authors believe that it could happen only with dramatic changes in government policy and national will (affecting both consumers and industry). Even with these dramatic changes, there remain important uncertainties. Will the technology advance as much as now appears plausible? Will the advances take place in the timeframe that we anticipate? Will the policies work as well as we expect? To some, the likelihood of “yes” is high, and the Advanced scenario is highly plausible given the transformation of the policy environment. Others who look in detail at the technologies and policies enumerated in the report may feel that a substantial portion of the reductions in energy use and emissions in going from the Moderate to the Advanced scenario is highly plausible – again assuming the technology R&D investment and the willingness to pursue policies. There will be those who are much more pessimistic about technology and policy and who believe that little, if any, of the results of the Advanced scenario are likely. The authors of this report have a range of views about these results, but in all cases find themselves in either the first or second of these three groups: we believe that, with the sufficient commitment, the United States could achieve all or a substantial portion of the Advanced scenario and at a negligible cost (or benefit) to the economy.

Climate change is but one of the concerns that U.S. energy policy must address. This study identifies a set of policy pathways that could significantly accelerate the development and deployment of cost-effective energy technologies. By targeting clean energy technologies, these policies offer the potential for multiple benefits: greenhouse gas reductions, energy bill savings, balance-of-payment benefits, enhanced security through energy diversity, and improved air quality. These multiple benefits are produced by moving forward on many fronts – on policies to remove market and organizational barriers, programs to facilitate deployment, and technology development. These are all key ingredients of a clean energy future.

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