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Analysis of The Climate Change Technology Initiative

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Preface

In February 1999, the Administration sent its fiscal year 2000 budget request to the U.S. Congress. It includes more than $4 billion in programs related to climate change. Nearly $1.8 billion of the funding is proposed for tax incentives, research and development, and other spending for the Climate Change Technology Initiative (CCTI). CCTI includes tax credits to serve as incentives for energy efficiency improvements and renewable technologies for buildings, light-duty vehicles, industry, and electricity generation. Other funding covers research, development, and deployment for energy-efficient and renewable technologies, more efficient generating technologies, and carbon sequestration research.

The analysis in this report was undertaken at the request of the Committee on Science of the U.S. House of Representatives. In its request, the Committee asked the Energy Information Administration (EIA) to analyze "the impact of specific policies on the reduction of carbon emissions and their impact on U.S. energy use and prices . . . in the 2008-2012 time frame," as noted in the first letter in the Appendix. The second letter from the Committee specified that EIA "analyze the impact of the President's Climate Change Technology Initiative, as defined for the 2000 budget, on reducing carbon emissions from the levels forecast in the *Annual Energy Outlook 1999* reference case."

The projections and quantitative analysis in this report were conducted primarily using the National Energy Modeling System (NEMS), an energy-economy model of U.S. energy markets designed, developed, and maintained by EIA, which is used each year to provide the projections in the *Annual Energy Outlook*. Chapter 1 of this report provides background discussion of CCTI and the methodology of the analysis. Chapters 2, 3, and 4, respectively, analyze the impacts of the tax credits; research, development, and deployment programs; and funding for accelerated appliance standards proposed in CCTI.

The legislation that established EIA in 1977 vested the organization with an element of statutory independence. EIA does not take position on policy questions. It is the responsibility of EIA to provide timely, high quality information and to perform objective, credible analyses in support of the deliberations of both public and private decisionmakers. This report does not purport to represent the official position of the U.S. Department of Energy or the Administration.

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Executive Summary

In February 1999, the Administration's fiscal year 2000 budget request was sent to the U.S. Congress. The request includes more than $4 billion in programs related to climate change. Nearly $1.8 billion of the funding consists of tax incentives, research, development, deployment, and other spending for the Climate Change Technology Initiative (CCTI). CCTI includes tax credits to serve as incentives for deploying energy efficiency improvements and renewable technologies for buildings, light-duty vehicles, industry, and electricity generation. Other funding covers research, development, and deployment for energy-efficient and renewable technologies and appliance efficiency standards. One focus of these programs is climate change; but they often have additional benefits for improved air quality due to reductions in criteria pollutants, energy security, and maintaining U.S. leadership in science and technology. Although the tax credits are largely new initiatives, many of the other programs are continuations or expansions of ongoing research, development, and deployment programs. The total CCTI budget request of $1.8 billion for all Federal agencies includes almost $1.4 billion for research, development, and deployment and nearly $0.4 billion for tax incentives. Of the $1.4 billion in expenditures for programs other than tax incentives, $397 million is the increase over the fiscal year 1999 budget.

At the request of the Committee on Science, U.S. House of Representatives, the Energy Information Administration (EIA) conducted an analysis of the potential impacts of CCTI, relative to the baseline energy projections in the *Annual Energy Outlook 1999* (*AEO99*).[1] This analysis was conducted primarily using the National Energy Modeling System (NEMS),[2] EIA's energy-economic modeling system of domestic energy markets. This analysis discusses all programs in CCTI with the exception of $4 million proposed for electricity restructuring at the U.S. Environmental Protection Agency (EPA), $14 million for management, planning, and analysis for the U.S. Department of Energy (DOE) and EPA, $3 million for EIA, and $10 million for carbon sequestration programs within EPA and the U.S. Department of Agriculture (USDA). The analysis primarily focuses on the tax incentives in CCTI, which are new initiatives or extensions of current tax credits. We are not able to link research and development expenditures directly to program results or to separate the impacts of incremental funding requested for fiscal year 2000 from ongoing program expenditures. Therefore, the research, development, and deployment programs are either addressed qualitatively, analyzed via their impact in the *AEO99* reference case, or analyzed by assuming that certain program goals are achieved. Other programs that may have benefits for climate change, but are not part of CCTI, are not included in the analysis. These include electricity restructuring and renewable portfolio standards. Renewable portfolio standards are addressed in the report by referring to analysis in *AEO99* on a 5.5-percent standard.

NEMS represents energy-consuming and producing technologies with a high degree of detail; however, the pace of technology development and penetration remains a major uncertainty. To project the future of energy markets, EIA relies upon engineering evaluations of the availability, costs, and characteristics of new technologies, continuing patterns of research and development; however, it is not possible to foresee with certainty how energy-using technologies will develop in the future. To be successful a technology must be developed and penetrate the market. Barriers that may limit or slow the penetration of apparently cost-effective technologies include: lack of information, subsidies or regulated prices that may hold energy prices artificially low, differences in incentives between builders

[1]Energy Information Administration, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998).
[2]Energy Information Administration, *National Energy Modeling System: An Overview*, DOE/EIA-0581 (Washington, DC, February 1998).

and users of energy equipment, consumer preference for other equipment attributes instead of efficiency, consumer preference for short payback periods, and uncertainties about reliability, installation and maintenance, future technology developments, and infrastructure requirements. EIA analyzes empirical evidence to estimate price elasticities and consumer preferences in order to project consumer reaction to changes in energy prices or improvements in energy efficiency; however, models cannot predict shifts in consumer tastes or market transformations associated with the rapid adoption of new technologies, such as the Internet.

Tax Incentives

Tax incentives have played a significant role in energy policy for many years. Some incentives have been able to accelerate substantially the introduction of new technologies into the market, while others have had little impact. Both the level of the incentives and likely market conditions are important factors in any assessment of the impacts of changes in the tax laws. Compared to some earlier tax credits, such as the solar tax credit of 40 percent which was enacted in 1978 and expired in 1985, the incentives currently proposed are of small to modest magnitude and of relatively short duration.

CCTI proposes investment tax credits for buildings, vehicles, and industry to lower the initial costs of more energy-efficient and renewable technologies and production tax credits for renewable generation technologies. These tax credits are in effect for only a few years for the intended purpose of encouraging the penetration of these technologies, reducing costs, and creating a more mature market. Administration estimates of the revenue impact of the credits are $383 million in fiscal year 2000 and $3.6 billion from fiscal year 2000 through fiscal year 2004.

The tax credits proposed in CCTI are as follows:

- *Buildings*
  - *Tax Credit for Energy-Efficient Homes.* A new $1,000 tax credit would be established for new homes purchased between 2000 and 2001 that are at least 30 percent more efficient than the 1998 International Energy Conservation Code (IECC), a $1,500 credit for homes between 2000 and 2002 that are at least 40 percent more efficient, and a credit of $2,000 for homes between 2000 and 2004 that are at least 50 percent more efficient.
  - *Tax Credit for Energy-Efficient Equipment in Existing Homes and Buildings.* A new tax credit of 10 percent, up to $250 per unit, would be established for electric heat pumps, central air conditioners, and advanced natural gas water heaters purchased in 2000 and 2001 meeting specified efficiency levels and a 20-percent credit for purchases between 2000 and 2003 of fuel cells, electric heat pump hot water heaters, electric heat pumps, central air conditioners, advanced natural gas water heaters, and natural gas heat pumps meeting specified efficiency levels. The cap is $500 per kilowatt for fuel cells, $1,000 per unit for natural gas heat pumps, and $500 per unit for all other equipment.
  - *Tax Credit for Rooftop Solar Systems.* A new 15-percent tax credit, subject to a cap, would be established for rooftop photovoltaic systems installed between 2000 and 2006 and solar water heating systems installed from 2000 and 2004 but is not available for solar-heated swimming pools. The cap is $2,000 for the photovoltaic systems and $1,000 for the solar water heating systems.
- *Transportation*
  - *Tax Credit for Electric Vehicles and Fuel Cell Vehicles.* Under current law, the 10-percent tax credit, subject to a $4,000 cap, for the purchase of qualified electric vehicles and fuel cell vehicles begins to phase down in 2002, phasing out by 2005; however, this proposal would extend the credit at its full level through 2006.

- *Tax Credit for Highly Fuel-Efficient Hybrid Vehicles*. The proposal would provide a new tax credit of $1,000 for qualifying hybrid vehicles, including cars, minivans, sport utility vehicles, and pickup trucks, purchased from 2003 to 2004 that are at least one-third more fuel efficient than a comparable vehicle in the same class; $2,000 for hybrid vehicles from 2003 to 2006 that are at least two-thirds more efficient; $3,000 for hybrid vehicles from 2004 to 2006 that are at least twice as efficient; and $4,000 for hybrid vehicles from 2004 to 2006 that are at least three times as efficient.

• *Industry*

- *Tax Credit for Combined Heat and Power Systems.* A new tax credit of 8 percent would be provided for qualified combined heat and power systems larger than 50 kilowatts, installed between 2000 and 2002. Qualified systems would produce at least 20 percent thermal and at least 20 percent electrical or mechanical power. Systems with electrical capacity higher than 50 megawatts would need at least 70-percent total efficiency, and smaller systems would need at least 60-percent efficiency.

• *Renewable Energy Electricity Generation*

- *Tax Credit for Wind Generation.* Under current law, a tax credit of 1.5 cents per kilowatthour, which is adjusted for inflation from a 1992 base, is provided for systems placed in service after December 31, 1993, and before July 1, 1999. The proposal would extend this credit to systems placed in service before July 1, 2004.

- *Tax Credits for Biomass Generation*. Under current law, a tax credit of 1.5 cents per kilowatthour, which is adjusted for inflation from a 1992 base, is provided for systems using dedicated energy crops placed in service after December 31, 1992, and before July 1, 1999. The proposal would extend the credit to systems placed in service before July 1, 2004, extend the definition of biomass systems eligible for the credit to include certain forest-related, agricultural, and other biomass sources, and provide a new 1.0-cent-per-kilowatthour tax credit, which is adjusted for inflation from a 1999 base, for biomass-fired electricity generated at coal plants using biomass co-firing through June 30, 2004.

Table ES1 presents the impacts of the tax credits in terms of energy savings and reductions in carbon emissions, relative to the *AEO99* reference case, which assumes current law. The carbon savings include only those incremental changes in emissions, relative to the reference case. Where possible, an estimate of the tax revenue implications is provided and compared to the Administration estimates. The year 2010 is the focus because it is the midpoint of the first compliance period in the Kyoto Protocol. Some of the technologies covered by the tax credits are likely to penetrate even without the credits and are included in the reference case; however, the credits are applied to both the units that are added because of the credits and the units that would be added without the credits, which become unintended beneficiaries of the tax credits. For the EIA estimates, both revenue impacts are presented.

In 2010, the tax credits for buildings, industrial, and transportation would reduce primary energy consumption by 31.6 trillion Btu, or 0.03 percent, relative to baseline consumption of nearly 111 quadrillion Btu. In addition, the tax credits for wind and biomass generation would reduce fossil energy consumption for electricity generation by 71.9 trillion Btu, or 0.06 percent of the total. In the reference case, carbon emissions are projected to reach 1,790 million metric tons in 2010, which would be reduced by 3.1 million metric tons, or 0.17 percent, as a total of the individual impacts of the tax credits, reflecting lower energy consumption and a shift in the mix of energy fuels. Although the investment tax credits reduce the initial cost of purchasing the applicable equipment in the buildings, transportation, and industrial sectors, the analysis assumes that consumers will continue to make decisions as indicated by EIA's analysis of historical trends. Consumers are typically reluctant to invest in more expensive technologies with long payback periods to recover the incremental costs. In addition, energy efficiency is only one of many attributes that consumers consider when purchasing new energy-equipment or buildings.

Tax credits of longer duration and/or higher value could encourage greater penetration of the technologies by making them more economically competitive to consumers. The timing of the tax credits is also a key factor in their impacts. For example, the tax credit for combined heat and power systems applies only to systems installed between 2000 and 2002. Since 18 to 36 months are required to plan, design, and install new capacity, there is not much opportunity for incremental investments in the systems. As another example, in the *AEO99* reference case, biomass gasification is assumed to be commercially available in 2005; however, since the credit expires in 2004, there is no opportunity to take advantage of the credit. Only a small quantity of capacity, based on current technology, and demonstration plants for biomass gasification will qualify for the credit. Similarly, the tax credit for fuel cell vehicles extends only through 2006, when the technology is assumed by EIA to become commercially available. The date was advanced from the reference case assumption of 2010 due to the credit.

Table ES1. Summary of Impacts for Selected Climate Change Technology Initiatives, 2010

CCTI Initiative	Reduction[a] in Energy Use[b] (Trillion Btu)	Reduction[a] in Carbon Emissions[c] (Million Metric Tons)	Annual Energy Fuel Expenditure Savings[a] (Million 1998 Dollars)	Tax Revenue Loss, Cumulative, 2000-2004[d] (Million 1998 Dollars)		
				EIA Estimate		
				Without Unintended Beneficiaries	With Unintended Beneficiaries	Administration Estimate
Tax Credits						
Buildings						
- Energy-Efficient Equipment	24.4	1.2	563.1	—[e]	—[e]	1,415
- Energy-Efficient New Homes	6.4	0.2	79.7	407	537	394
- Rooftop Solar Equipment	<0.01	<0.01	<0.01	<1	102[f]	120[g]
Industrial Sector						
- Combined Heat and Power	—[h]	0.15	38.0	15	85 to 125[i]	309
Transportation Sector						
- Electric, Fuel Cell, and Electric Hybrid Vehicles	0.8	<0.01	8.7	562	1,960	790
Wind and Biomass[j]	71.9	1.5	150.7	379	816	293
Total	**103.5**	**3.1**	**840.2**	—	—	—

[a]Reductions are relative to the CCTI reference case which is similar to that in Energy Information Administration, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998). For wind and biomass, the expenditure savings are for expenditures on fossil fuels for electricity generation.
[b]For the wind and biomass tax credits, the change represents the reduction in fossil energy use for electricity generation.
[c]Reductions in carbon emissions from electricity are calculated by displacing marginal generating plants.
[d]EIA's revenue losses are for calendar years, and the Administration's revenue losses are for fiscal years.
[e]The revenue impacts can only be estimated for natural gas heat pumps—$21.6 million without unintended beneficiaries and $61.6 million with unintended beneficiaries.
[f]Assumes a portion of the commitments of the photovoltaic installations under the Million Solar Roofs program. Excludes Federal government installations.
[g]Revenue impacts are for 2000 through 2004 although the proposed tax credit for photovoltaic systems extends through 2006.
[h]Cogenerated electricity substitutes for purchased electricity, and total site use increases due to additional natural gas consumption.
[i]The range results from the possibility that additions currently planned for 1999 or 2003 may be moved to take advantage of the tax credit.
[j]Total revenue impacts for all three wind and biomass programs. Treasury does not disaggregate the revenues into the individual programs.

Table ES2 shows the impacts of the tax credits in 2002 to 2004, which increase through that time period as the more advanced technologies become available and gradually penetrate the market. The total impact on carbon emissions is less in 2010 than in the earlier years because of the buildings equipment and biomass co-firing tax credits. Tax credits for energy-efficient buildings equipment have a larger impact on carbon emissions in the earlier years, which is reduced as the credits expire and some of the new, more efficient equipment begins to be retired and is replaced by equipment with lower efficiency. Without the tax credit, the more efficient equipment is no longer economical. Similarly, the impact of the co-firing tax credit is lower when the credit expires. The co-firing tax credit is a production tax credit that leads to more generation from biomass in coal plants when it makes biomass fuel competitive with coal. The transportation tax credits have a small impact in the earlier years because of the limited availability of eligible technologies. After 2010, the impacts of the tax credits generally remain stable or decline through 2020. For example, the credits for energy-efficient new homes and for combined heat and power systems encourage some incremental investment during the period of the credits, which has a sustained impact on energy consumption and carbon emissions.

Table ES2. Summary of Impacts for Selected Climate Change Technology Initiatives, 2002-2004

CCTI Initiative	2002		2003		2004	
	Reduction[a] in Energy Use[b] (Trillion Btu)	Reduction[a] in Carbon Emissions[c] (Million Metric Tons)	Reduction[a] in Energy Use[b] (Trillion Btu)	Reduction[a] in Carbon Emissions[c] (Million Metric Tons)	Reduction[a] in Energy Use[b] (Trillion Btu)	Reduction[a] in Carbon Emissions[c] (Million Metric Tons)
Tax Credits						
Buildings						
- Energy-Efficient Equipment	22.85	1.42	26.83	1.60	26.83	1.53
- Energy-Efficient New Homes	1.71	0.05	3.64	0.12	6.41	0.20
- Rooftop Solar Equipment	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Industrial Sector						
- Combined Heat and Power Systems	—[d]	0.15	—[d]	0.15	—[d]	0.15
Transportation Sector						
- Electric, Fuel Cell, and Electric Hybrid Vehicles	<0.01	0.00	0.10	0.00	0.25	0.00
Wind and Biomass	69.99	1.60	92.27	2.20	129.76	2.89
Total	**94.55**	**3.22**	**122.84**	**4.07**	**163.25**	**4.77**

[a]Reductions are relative to the CCTI reference case which is similar to that in Energy Information Administration, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998).
[b]For the wind and biomass tax credits, the change represents the reduction in fossil energy use for electricity generation.
[c]Reductions in carbon emissions from electricity are calculated by displacing marginal generating plants.
[d]Cogenerated electricity substitutes for purchased electricity, and total site use increases due to additional natural gas consumption.

Efficiency Standards

Appliance efficiency standards can lead to significant reductions in energy consumption and carbon emissions by accelerating the penetration of more efficient technologies. The example with the largest impact is refrigerators, which will collectively be responsible for fewer carbon emissions in 2010 than in 1990 despite population growth and performance enhancements. The latest refrigerator standards adopted in 1993 and coming into effect in 2001 are aggressive enough to not only take inefficient units off the market but also accelerate the introduction of new technologies.

Within the building technologies program, additional funding is provided to DOE to accelerate the lighting and appliance efficiency standards program in order to encourage the deployment of more energy-efficient appliances and equipment. Program goals include the development of new standards for fluorescent lamp ballasts, water heaters, and clothes washers, with test procedures for residential central air conditioners and heat pumps, distribution transformers, commercial heating, ventilation, and air conditioning, and water heaters.

Because future standards are not specified, the potential impact is analyzed by evaluating the impacts of proposed standards in the American Council for an Energy-Efficient Economy study *Approaching the Kyoto Targets: Five Key Strategies for the U.S.*[3] The results are shown in Table ES3. EIA projects that energy consumption in 2010 would be reduced by 143.9 trillion Btu, or 0.13 percent, and carbon emissions by 5.4 million metric tons, or 0.30 percent. Because of the energy efficiency improvements, consumers would save $2,335 million (1998 dollars) in 2010 alone in expenditures for energy, not accounting for additional equipment costs. As the technologies penetrate the market, the average efficiency of the equipment stock improves. As a result, the assumed efficiency standards have increasing impacts on energy consumption and carbon emissions after 2010. In fact, of the programs evaluated here, efficiency standards have the most significant impact.

Table ES3. Summary of Impacts for Proposed Efficiency Standards, 2010

CCTI Initiative	Reduction[a] in Energy Use (Trillion Btu)	Reduction[a] in Carbon Emissions[b] (Million Metric Tons)	Annual Energy Fuel Expenditure Savings[a] (Million 1998 Dollars)
Accelerated Efficiency Standards	143.9	5.4	2,335

[a]Reductions are relative to the CCTI reference case which is similar to that in Energy Information Administration, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998).
[b]Reductions in carbon emissions from electricity are calculated by displacing marginal generating plants.

Research, Development, and Deployment

CCTI also includes nearly $1.4 billion of funding in the fiscal year 2000 budget request for research, development, and deployment of more energy-efficient and renewable energy and for research into carbon sequestration. More than $1.1 billion is requested for programs within DOE, with additional funding for EPA and the Departments of Housing and Urban Development (HUD), Commerce, and USDA. In addition to developing new technologies, some programs aim to reduce the costs and improve the operating characteristics of existing technologies, making them more economically competitive with conventional technologies. Other initiatives include programs to encourage the deployment of new technologies, such as consultations, partnerships, and voluntary programs.

- *Buildings*. Programs include cooperative efforts with the building industry to improve the energy-efficiency of homes, funding for new Energy Star products, the development of energy-efficient technologies, and partnerships to improve the energy efficiency of commercial buildings and schools.

- *Transportation*. Proposed funding includes the Partnership for a New Generation of Vehicles program, plus other partnerships to develop advanced diesel cycle engine technologies for pickup trucks, vans, and sport utility vehicles and to improve the fuel efficiency of new heavy trucks, and the continued development of ethanol and other biofuels.

[3]American Council for an Energy-Efficient Economy, *Approaching the Kyoto Targets: Five Key Strategies for the U.S.* (Washington, DC, August 1998).

- *Industry*. Programs include partnerships to develop more energy-efficient technologies for the most energy-intensive industries and the continuing development of cogeneration systems and elimination of barriers for combined heat and power technologies.

- *Electricity Generation*. Funding includes continued development for solar energy, biomass power, wind energy, geothermal power, and hydropower; the Renewable Energy Production Incentive, renewable energy demonstration projects; the International Solar Program; improvements for the quality and reliability of power service; distributed generation; hydrogen production and storage; superconducting technology; life extension of nuclear power plants; and development of more efficient coal and natural gas generation.

- *Carbon Sequestration*. This program funds research into the capture and storage of carbon dioxide by enhancing the natural capacity of terrestrial ecosystems and oceans to take up and store carbon dioxide in underground geological structures and the deep ocean.

Accelerating the adoption of new technologies in the market at lower costs through research, development, and deployment can help reduce carbon emissions and also can contribute positively to the overall quality of life. Support for these activities at historic levels is assumed in the *AEO99* reference case. As a result, reductions in these programs could lead EIA over time to raise its carbon projections, and new or expanded programs could lead EIA to lower its carbon estimates.

The impacts of research and development funding for new technologies, whether ongoing or incremental, are difficult to quantify in the same manner as the tax incentives. Some of the proposed technologies may only achieve benefits in a long time frame beyond 2020 or may not achieve success at all; however, predicting which technologies will be successful is highly speculative. A direct link cannot be established between levels of funding for research and development and specific improvements in the characteristics and availability of energy technologies. In addition, successful development of new technologies may not lead to immediate penetration in the marketplace. Low prices for fossil energy and conventional technologies; unfamiliarity with the benefits, use, and maintenance of new products; and uncertainties concerning the reliability and further development of new technologies are all factors that may slow technology penetration and are barriers that the tax credits are intended to address. However, these limitations do not mean that the impacts of the research, development, and deployment programs could not be substantial over time.

It is also difficult to analyze the impacts of information programs, voluntary initiatives, and partnerships on realized technology development and deployment. Some voluntary programs appear to have achieved some success, such as Energy Star. The benefits of past efforts are difficult to quantify but are generally assumed in the reference case. They are even more difficult to quantify for the future.

This analysis addresses these initiatives by discussing the current state of development of the technologies and the economics of their development and deployment. For several of these programs, the potential impacts are addressed by assuming that program goals are achieved, then deriving the impacts on energy consumption and emissions, or by analyzing the impact of technology improvements based on current levels of research and development.

In *AEO99*, the baseline assumptions include continuing improvements in technology, consistent with ongoing research and development. The impacts of these improvements can be evaluated by comparing the reference case with a case in which it is assumed that all future equipment choices in the end-use demand sectors are from technologies available in 1999, building shell and industrial plant efficiencies are frozen at 1999 levels, and new fossil generating technologies do not improve beyond 1999. In 2010, energy consumption in this low technology case is

3.7 quadrillion Btu, or 3.3 percent higher, than in the reference case, increasing carbon emissions by 67 million metric tons, or 3.7 percent.

In the *AEO99* reference case projections, natural gas-fired generating plants are expected to dominate new capacity additions over the next 10 to 15 years, although advanced coal plants become economical after 2010. Renewable electricity generation increases in the reference case projections, particularly biomass, wind, and to a lesser extent geothermal generation; however, solar thermal and photovoltaic technologies do not contribute significantly to the electricity grid within the time frame of the analysis, and almost no new hydropower capacity is projected. In the transportation sector, alternative-fueled vehicle sales account for about 9 percent of the light-duty vehicle sales in 2010, with alcohol flex-fuel vehicles and dedicated electric vehicles each accounting for about one-fourth of the market; however, nearly all the penetration of electric vehicles is driven by mandates.

Analysis indicates that some of the programs for the development of renewable technologies may hold promise, as well as some of the programs for buildings if the program goals can be achieved. Stock turnover can slow the penetration of some of the improved technologies, even if successful, so that significant changes in the average stock of equipment may take a long time, which may be complemented by the tax incentives. In addition, some of the technologies may have non-economic barriers to widespread acceptance. These include unfavorable impressions of the noise, odor, and performance of previous diesel vehicles and limitations on hydropower due to environmental concerns. Some of the CCTI programs may have more longer-term benefits because stock turnover may slow penetration and because some of the research and development programs are likely to achieve success later in or beyond the 2020 horizon of the analysis. For those research, development, and deployment programs that are evaluated quantitatively, most—including the Partnership for Advancing Technology in Housing (PATH), Partnership for a New Generation of Vehicles (PNGV), advanced diesel trucks, and biomass ethanol—have increasing impacts on energy consumption and carbon emissions after 2010. The assumption that the goals of the programs will be met leads to improvements in the technologies that are gradually adopted over the time horizon of the analysis.

This analysis does not necessarily include all costs of technology development and deployment. For example, the full costs of developing and manufacturing new technologies, including costs to the private sector, and infrastructure costs are not included. Certain programs are analyzed by assuming the success of program goals or standards that may not necessarily be economic within the time frame of the analysis, leading to additional costs that are not incorporated into a decisionmaking process. However, in addition to reductions in energy consumption, consumer expenditures for energy, and carbon emissions, there may be other benefits to these programs that are not evaluated. Potential ancillary benefits include improvements in air quality due to reductions in criteria pollutants, energy security from lower energy consumption, maintaining U.S. leadership in science and technology, and revenues from the deployment of more advanced technologies to other countries.

Funding for research and development may accelerate the development of more efficient and advanced technologies at lower cost than might otherwise occur. In addition, research and development may tend to improve the characteristics of technologies that have already been developed to some degree. To the extent that continuing development lowers the costs of technologies or improves their efficiencies, reliability, or other attributes, the technologies become more economically competitive and attractive in the market. Ultimately, the success of technology development depends on the products becoming competitive and penetrating into the marketplace.

There are a number of barriers to technology penetration that may account for seemingly slow penetration of technologies that appear cost-effective. Lack of information about new technologies is one barrier which may be overcome with information programs. Subsidies or regulated prices may hold energy prices artificially low and hamper the penetration of technologies. Builders and homeowners or tenants may have different incentives for energy efficiency. It may be difficult for the builder or landlord to recover the additional costs for more expensive, energy-efficient equipment from a buyer or tenant who may not value energy efficiency highly. Conversely, the buyer or tenant who will be paying the energy bills may not readily have the option of making the equipment choices. Even if energy consumers are aware of potential cost savings from a more efficient technology, they may have preferences for other equipment characteristics, for example, valuing vehicle size over efficiency. Also, consumers may prefer a relatively short payback period for investments in energy-consuming technologies. Technology penetration can also be slowed by uncertainties about reliability, installation and maintenance, availability of the next generation of the technology, and necessary infrastructure.

Some of these barriers can be addressed by information programs, collaborative efforts for development and diffusion, research and development to improve technologies and reduce costs, and incentives to enhance the cost effectiveness of new technologies. All these initiatives may help to encourage earlier penetration of technologies. Subsequently, the initial penetration may have the additional impact of reducing costs through learning, establishing the infrastructure, and increasing familiarity with new technologies. Finally, equipment standards and other mandates such as renewable portfolio standards can also lead to earlier penetration of new, more advanced technologies; however, standards may not be the most cost-effective method for encouraging improvements in energy efficiency. The full costs of standards are not evaluated in this analysis.

1. Introduction

In February 1999, the Administration sent its fiscal year 2000 budget request to the U.S. Congress. The Administration’s budget includes more than $4 billion in programs related to climate change. Nearly $1.8 billion of the funding consists of tax incentives, research, development, and deployment, and other spending for the Climate Change Technology Initiative (CCTI). CCTI includes tax credits to serve as incentives for deploying energy efficiency improvements and renewable technologies for buildings, light-duty vehicles, industry, and electricity generation. Other funding covers research, development, and deployment for energy-efficient and renewable technologies, appliance standards, and carbon sequestration research. One focus of these programs is climate change, but they often have additional benefits for improved air quality due to reductions in other emissions, energy security, and international competitiveness. Although the tax incentives are largely new initiatives, many of the other programs are continuations or expansions of ongoing research, development, and deployment programs. The total budget request for CCTI programs for all Federal agencies comprises almost $1.4 billion for research, development, and deployment (representing an increase of $347 million over the estimated fiscal year 1999 budget) and nearly $400 million for tax incentives.

The analysis described in this report examines all the CCTI programs with the exception of $4 million proposed for electricity restructuring programs at the U.S. Environmental Protection Agency (EPA); $14 million for management, planning, and analysis programs at the U.S. Department of Energy (DOE) and EPA; $3 million for EIA; and $10 million for carbon sequestration programs within EPA and the U.S. Department of Agriculture (USDA). The most detailed analysis in this report is for the tax incentives proposed in CCTI, which are new initiatives or extensions of current tax credits. Generally, we are not able to link research and development expenditures directly to program results or to separate the impacts of incremental funding requested for fiscal year 2000 from ongoing program expenditures.

Other programs related to climate change include the U.S. Global Change Research Program, international assistance, and programs with climate change co-benefits—for example, weatherization and State energy grants. There are additional initiatives supported by the Administration that have a primary or ancillary purpose in reducing emissions. These include, but are not limited to, establishing a program for early action in reducing emissions, industry consultations, electricity restructuring, and changes in Federal procurement to increase energy efficiency and the use of renewable energy technologies in the Federal Government. With the exception of electricity restructuring, the impacts of these programs are difficult to quantify and are not discussed in this analysis.

Tax Incentives

The proposed CCTI tax incentives include investment tax credits—for buildings, vehicles, and industry—that would lower the initial costs of more energy-efficient and renewable technologies and production tax credits for renewable generation technologies. The revenue impacts of the proposed tax credits, as estimated by the Administration, total $383 million in fiscal year 2000 and $3.6 billion from fiscal years 2000 through 2004. Although the tax credits would be short term in nature, their longer term purpose is to encourage the use of energy-efficient and renewable energy technologies, reducing their production costs and creating a more mature market for them.

Some past tax incentives have been able to accelerate substantially the introduction of new technologies into the market. For example, natural gas production from coal seams has grown dramatically since the late 1980's, largely because of tax credits that provide an incentive for the production of high-cost gas supplies. In 1997, 1,090 billion cubic feet, or 6 percent of total U.S. production, came from coal seams, compared with only 41 billion cubic feet in 1988. The tax credit has also contributed to sustained development of natural gas from coal seams by promoting an improved understanding of unconventional gas reservoirs, leading to new and lower cost technologies for its recovery. Other tax credits have had little impact, including the current biomass tax credit and the solar tax credit which was enacted in 1978 and expired in 1985.

Important factors in the success of tax incentives include the timing, duration, and magnitude of the credits. Compared to some earlier tax credits, including the 40-percent solar tax credit, the incentives currently proposed are of small to modest magnitude and of relatively short duration. Other factors include the definition of qualifying entities and the different incentives provided by investment and production tax credits. Investment tax credits provide a return to the investor at the time a capital investment is made, while production tax credits provide a return during the life of the credit.

The proposed incentives are summarized below:

- *Buildings*
  - *Tax Credits for Energy-Efficient Homes*—new graduated tax credits for the purchase of new homes that are at least 30 percent more energy efficient than the 1998 International Energy Conservation Code (IECC). Specifically, the proposal is for a $1,000 tax credit for new homes built between 2000 and 2001 that are at least 30 percent more efficient, a $1,500 credit for homes built between 2000 and 2002 that are at least 40 percent more efficient, and a credit of $2,000 for homes built between 2000 and 2004 that are at least 50 percent more efficient than the IECC standard.
  - *Tax Credits for Energy-Efficient Equipment in Existing Homes and Buildings*—new tax credits, subject to caps, for electric heat pump and natural gas water heaters, electric and natural gas heat pumps, advanced central air conditioners, and fuel cells. A credit of 10 percent, up to $250 per unit, is proposed for electric heat pumps, central air conditioners, and advanced natural gas water heaters purchased in 2000 and 2001 meeting specified efficiency levels. A 20-percent credit is proposed for purchases between 2000 and 2003 of fuel cells, electric heat pump hot water heaters, electric heat pumps, central air conditioners, advanced natural gas water heaters, and natural gas heat pumps meeting specified efficiency levels. The cap is $500 per kilowatt for fuel cells, $1,000 per unit for natural gas heat pumps, and $500 per unit for all other equipment.
  - *Tax Credits for Rooftop Solar Systems*—a new 15-percent tax credit, subject to a cap, is proposed for rooftop photovoltaic systems installed between 2000 and 2006 and solar water heating systems installed from 2000 and 2004 but not applicable to solar-heated swimming pools. The cap is $2,000 for photovoltaic systems and $1,000 for solar water heating systems.
- *Transportation*
  - *Tax Credits for Electric Vehicles and Fuel Cell Vehicles*—the current 10-percent tax credit, subject to a $4,000 cap, for the purchase of qualified electric vehicles and fuel cell vehicles is scheduled to begin to phase down in 2002, phasing out by 2005; however, the proposal would extend the credit at its full level through 2006.
  - *Tax Credits for Highly Fuel-Efficient Hybrid Vehicles*—new graduated tax credits for qualifying hybrid vehicles, including cars, minivans, sport utility vehicles, and pickup trucks. The proposed credits are $1,000 for vehicles

purchased from 2003 to 2004 that are at least one-third more fuel efficient than a comparable vehicle in the same class; $2,000 for vehicles from 2003 to 2006 that are at least two-thirds more efficient; $3,000 for vehicles from 2004 to 2006 that are at least twice as efficient; and $4,000 for vehicles from 2004 to 2006 that are at least three times as efficient.

- *Industry*

  - *Tax Credits for Combined Heat and Power Systems*—a new 8-percent tax credit is proposed for qualified combined heat and power systems larger than 50 kilowatts, installed between 2000 and 2002. Qualified systems would produce at least 20 percent thermal and at least 20 percent electrical or mechanical power. Systems with electrical capacity higher than 50 megawatts would need a total efficiency exceeding 70 percent to qualify, and smaller systems would need at least a 60-percent efficiency.

- *Renewable Energy Electricity Generation*

  - *Tax Credits for Wind Generation*—the current tax credit of 1.5 cents per kilowatthour, which is adjusted for inflation from a 1992 base, for systems placed in service after December 31, 1993, and before July 1, 1999, would be extended to systems placed in service before July 1, 2004.

  - *Tax Credits for Biomass Generation*—the current tax credit of 1.5 cents per kilowatthour, which is adjusted for inflation from a 1992 base, for systems using dedicated energy crops, placed in service after December 31, 1992, and before July 1, 1999, would be extended to systems placed in service before July 1, 2004; the definition of biomass systems eligible for the credit would be extended to include certain forest-related, agricultural, and other biomass sources; a new 1.0-cent-per-kilowatthour tax credit, adjusted for inflation from a 1999 base, would be added for biomass-fired electricity generated by coal plants using biomass co-firing through June 30, 2004.

Research, Development, and Deployment

In addition to tax incentives, CCTI includes nearly $1.4 billion of funding in the fiscal year 2000 budget request for research, development, and deployment of energy-efficient equipment and renewable energy and for research into carbon sequestration. Some of the research and development programs aim to reduce the costs and improve the operating characteristics of existing technologies, making them more economically competitive with conventional technologies. Others are directed toward inventing and developing new technologies. Some of the proposed technologies are speculative and may achieve benefits in a very long time frame or may not achieve success at all.

Past research and development programs have contributed to improved energy efficiency and therefore lower carbon emissions. For example, there has been considerable impact on cost reductions and efficiency improvements for natural gas-fired, combined-cycle electricity generating plants. In the *Annual Energy Outlook 1987*, it was assumed that these plants would cost $855 per kilowatt (1997 dollars) and have an efficiency of 41 percent. By *AEO99*, these assumptions were revised to a cost of $445 per kilowatt and an efficiency of 49 percent. Less conductive windows and improved ballasts for lighting are additional examples of more efficient technologies as a result of research and development. Other benefits, such as improved quality of life and increased economic growth, may also result from research and development. It is difficult, however, to quantify the impacts of research and development on specific improvements. In the reference case of *AEO99*, which projects that carbon emissions in 2010 will increase by 33 percent over 1990 levels, it is assumed that research and development continue at current levels. Reductions in these programs would likely lead EIA to increase its projections of carbon emissions, while new or expanded programs could lead EIA to lower its carbon projections.

Successful development of new technologies does not guarantee market acceptance. Low prices for fossil energy and conventional technologies, unfamiliarity with the use and maintenance of new products, and uncertainties about the reliability and further development of new technologies, among other factors, can work to slow technology penetration. Since some of the benefits may be long term, caution should be applied in using research and development to address short-term problems.

Other initiatives include programs to encourage the deployment of new technologies, such as consultations, partnerships, and voluntary programs. These programs usually have low costs, but the benefits of past efforts are difficult to quantify and also difficult to quantify for the future. Successful programs that have contributed to the adoption of improved technologies include efficiency improvements in buildings, televisions, and computers, among others. However, results reported under many voluntary programs include efforts that would have been taken without the program. Therefore, there may be a tendency to overestimate the impacts of deployment programs on energy consumption and carbon emissions.

In CCTI, more than $1.1 billion is requested for research, development, and deployment programs within DOE, with additional funding for EPA and the Departments of Housing and Urban Development (HUD), Commerce, and USDA. The energy-related programs include buildings, transportation, industry, and electricity generation initiatives, as summarized below:

- *Buildings*
  - *Partnership for Advancing Technology in Housing*—a cooperative effort by DOE, HUD, EPA, and the Federal Emergency Management Agency with the building industry to improve the energy efficiency of new and existing homes, with the goal of building 2,000 highly energy-efficient and cost-effective houses. The goals are to make new homes 50 percent more efficient within a decade and to retrofit 15 million homes to make them 30 percent more efficient.
  - *Energy-Efficient Appliances and Equipment*—DOE and EPA programs to develop new Energy Star products and increase funding for the development of energy-efficient technologies.
  - *Energy-Efficient Commercial Buildings*—DOE and EPA partnership with industry for research, development, and deployment of technologies and practices to improve the energy efficiency of commercial buildings.
  - *Energy Smart Schools*—programs to improve the energy efficiency of school buildings.
- *Transportation*
  - *Partnership for a New Generation of Vehicles (PNGV)*—an ongoing government partnership with industry to develop a prototype mid-size automobile with an efficiency of 80 miles per gallon by 2004.
  - *Light and Heavy Trucks*—government and industry partnerships to develop advanced diesel-cycle engine technologies for pickup trucks, vans, and sport utility vehicles with a 35-percent efficiency improvement by 2002 and engine and vehicle technologies to improve the fuel efficiency of new heavy trucks to 12 miles per gallon from an average of 5.3 miles per gallon.
  - *Biofuels*—continuing programs with USDA to develop the technologies to convert agricultural products to ethanol and other biofuels.

- *Industry*
  - *Industries of the Future*—DOE partnership programs with the most energy-intensive industries to develop more energy-efficient technologies.
  - *Industrial Cogeneration*—continuing DOE programs for the development of cogeneration systems and combined efforts with EPA to eliminate barriers to the dissemination of combined heat and power technologies.
- *Electricity Generation*
  - *Renewable Technologies*—continuing research and development for solar energy, biomass power, wind energy, geothermal power, and hydropower.
  - *Deployment*—funding for the Renewable Energy Production Incentive, renewable energy demonstration projects, and the International Solar Program.
  - *Transmission and Distribution*—development of storage and power quality systems to improve the quality and reliability of power service, and continuing development of distributed generation.
  - *Hydrogen*—acceleration of research on hydrogen production and storage.
  - *High-Temperature Superconductivity*—continuing support for the development of superconducting technology.
  - *Nuclear Energy*—funding for programs to extend the useful life of nuclear power plants.
  - *Fossil Energy*—programs to improve the efficiency of coal- and natural-gas-fired electricity generation.
- *Carbon Sequestration*—research into the capture and storage of carbon dioxide by enhancing the natural capacity of terrestrial ecosystems and oceans to take up and store carbon dioxide in underground geological structures and the deep ocean.

Efficiency Standards

Within the building technologies program, additional funding is provided to DOE to accelerate the lighting and appliance efficiency standards program in order to encourage the deployment of more energy-efficient appliances and equipment. It is proposed that new standards be developed for fluorescent lamp ballasts, water heaters, and clothes washers, as well as test procedures for residential central air conditioners and heat pumps, distribution transformers, commercial heating, ventilation, and air conditioning, and water heaters. Historically, efficiency standards have been successful in improving energy efficiency. For example, refrigerators will use less energy and create fewer carbon emissions in 2010 than in 1990 even with population growth and performance enhancements. The most recent refrigerator standards adopted in 1993 and coming into effect in 2001 are aggressive enough to not only take inefficient units off the market but also accelerate the introduction of new technologies.

Methods of Analysis

At the request of the U.S. House of Representatives Committee on Science, the Energy Information Administration (EIA) conducted an analysis of the likely impacts of CCTI. The analysis was conducted primarily using the National

Energy Modeling System (NEMS),[4] the energy-economic modeling system of domestic energy markets developed and maintained by the Office of Integrated Analysis and Forecasting within EIA. With some minor modifications and ongoing enhancements, the version of NEMS used for this analysis was that used to develop the projections published in EIA's *Annual Energy Outlook 1999* (*AEO99*)[5] in December 1998. Additional offline analysis employed a building code model and building simulation model, both developed by DOE, to evaluate the tax credits for new energy-efficient homes.

For most of the energy-consuming and producing sectors of the economy, NEMS includes individual technologies, characterizing them by capital and operating costs, efficiencies, years of availability, and other relevant attributes. Therefore, NEMS can directly analyze the penetration of new technologies and the impacts of changes in the characteristics of technologies.

For this CCTI analysis, the tax credits for energy-efficient homes and buildings equipment; rooftop solar systems; electric, fuel cell, and hybrid vehicles; and combined heat and power systems were assumed to reduce the initial costs of purchasing the applicable equipment over the years specified in the proposals. The wind and biomass tax credits provide an incentive for these technologies through a production tax credit. Also, in analyzing the impact of the tax credit for fuel cell vehicles, the assumed date of commercial availability of the vehicles was advanced from 2010 to 2006 as a result of the credit, based on the announcement of a prototype vehicle in 2004.

With the exception of some reduction in the costs of advanced technologies for electricity generation, the analysis did not include ancillary benefits that might accrue from cost reductions with increasing market penetration. It is recognized that cost is not the only factor in consumer decisionmaking; however, this analysis assumes that consumer behavior will remain similar to that derived from empirical evidence, because there is no basis for assuming a fundamental change in consumer behavior. Consumer behavior has worked against the adoption of more fuel-efficient technologies in the past, because of the value placed on attributes other than lowering energy consumption. Future consumer behavior could shift to favor novel technologies or technologies that would benefit the climate if there were widespread acceptance of a need to improve energy efficiency or reduce greenhouse gas emissions; however, the incentives and programs in CCTI are unlikely to produce such changes, given their immediate timing and overall level of funding.

The portion of CCTI that includes funds for research, development, and deployment of new technologies is more difficult to quantify. In general, a direct link has not been established between levels of funding for research and development and specific improvements in the characteristics and availability of energy technologies. Similarly, it is difficult to quantify a link between information programs and other programs for voluntary initiatives and partnerships for technology development with realized technology development and deployment. As a result, the analysis of the research and development components of CCTI uses a different approach.

Many of the proposed research and development programs are addressed in qualitative terms in this analysis, discussing the current state of development of the relevant technologies and the economics of their development and deployment. For other programs the potential impacts are analyzed by assuming that certain program goals are achieved or through the impact of ongoing technology improvement in the *AEO99* reference case. EIA analyzed the buildings program for energy-efficient appliances and equipment, which includes acceleration of lighting and

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[4]Energy Information Administration, *National Energy Modeling System: An Overview*, DOE/EIA-0581 (Washington, DC, February 1998). In addition to providing baseline projections of U.S. energy markets, NEMS is used to provide analysis of energy issues at the request of the U.S. Congress, other parts of DOE, and other government agencies.

[5]Energy Information Administration, *Annual Energy Outlook 1999,* DOE/EIA-0383(99) (Washington, DC, December 1998).

appliance efficiency standards and new Energy Star products, by evaluating the impacts of the standards proposed in a study by the American Council for an Energy-Efficient Economy, *Approaching the Kyoto Targets: Five Key Strategies for the U.S.*,[6] in combination with the new Energy Star programs for televisions and video cassette recorders and the goal of the Million Solar Roofs program. The program for the development of more energy-efficient technologies for light and heavy trucks is evaluated by assuming that the program goals for advanced diesel technologies for light trucks and for a variety of fuel-saving technologies for heavy trucks will be achieved and by evaluating the economics of their penetration. In a similar fashion, the Partnership for Advancing Technology in Housing (PATH), which has a goal of improving the energy efficiency of homes, is analyzed by assuming that the goals for new housing construction will be fully realized; however, the costs of achieving those highly efficient homes are not evaluated or incorporated into a decisionmaking process.

For each tax incentive or other program evaluated quantitatively, the impacts were analyzed by using the relevant sector of NEMS in a standalone mode. The results are presented in terms of energy savings and reductions in carbon emissions from the sector, relative to the reference case, along with other key indicators from the sector. Where possible, an estimate of the tax revenue losses is also provided and compared with the Administration's estimates in the budget submission. It is important to recognize that all results are presented as incremental changes to the reference case. Where CCTI encompasses ongoing research, development, and deployment programs already included in the reference case for *AEO99*, the impacts of the proposed funding additions are not evaluated.

It is also possible that some of the more efficient technologies included in the CCTI tax incentives would penetrate even in the absence of the incentives. The tax incentives are applied to both the units that are added incrementally as a result of the incentives and the units that would be added even in the baseline, which become unintended beneficiaries of the tax incentives. Where applicable, this analysis identifies the incremental units that are projected to be introduced as a result of the CCTI provisions. Another unintended effect of an investment tax credit is that part of the value of the credit accrues to equipment manufacturers and suppliers. Because the credit increases the demand for capital equipment, higher equilibrium prices for the equipment result. This effect could result in as much as 70 percent of the tax credit being passed on to equipment suppliers in the form of higher equipment prices.[7] If this situation were to occur, the impact of a tax credit on capital equipment additions could be quite modest. This effect has not been incorporated in the analysis.

The presentation of the results focuses on the year 2010, because it is the midpoint of the first commitment period in the Kyoto Protocol, and also on 2005, because none of the tax credits extends beyond 2006. Some of the CCTI programs may have benefits in the longer term. Because of stock turnover, which can be slow, energy efficiency improvements and standards may take a long time to produce significant changes in the average stock of equipment. In addition, some of the research and development programs may have results later in, or beyond, the 2020 horizon of the analysis. The results are presented primarily in terms of energy savings and carbon reductions. Additional benefits that may occur, but are not evaluated, include improvements in air quality due to reductions in other emissions, energy security from lower energy imports, international opportunities for American companies as a result of improved technologies, and revenues from the deployment of more advanced technologies to other countries.

As noted above, the PATH program is evaluated by assuming that program goals will be met, even though the resulting technologies may not be economical within the time frame of the analysis. New equipment evaluated for

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[6]American Council for an Energy-Efficient Economy, *Approaching the Kyoto Targets: Five Key Strategies for the U.S.* (Washington, DC, August 1998).

[7]Austan Goolsbee, "Investment Tax Incentives, Prices, and the Supply of Capital Goods," Working Paper 6192 (Cambridge, MA: National Bureau of Economic Research, September 1997).

the analysis of energy efficiency standards may similarly be unable to penetrate consumer markets on their own. The additional costs that could be required to make the technologies competitive are not addressed. In addition, there may be others, such as the full private sector costs of developing and manufacturing new technologies, infrastructure costs, and social costs, that are not captured in the analysis.

Uncertainties

It is possible that a standalone analysis of energy efficiency policies may overstate somewhat the potential energy and carbon savings that would be seen in a fully integrated analysis of U.S. energy markets. In other words, the individual energy sector savings are not necessarily additive. As an example, some policies may encourage the development and deployment of more energy-efficient and/or less carbon-intensive technologies for electricity generation. If concurrent policies encourage energy efficiency in the end-use demand sectors and reduce the demand for electricity, however, there may be less opportunity for the generation sector to grow and invest in the new generation technologies. Therefore, evaluating the combined impacts in an integrated model may be important. In this analysis, however, the individual impacts of the CCTI programs are projected to be relatively small, and it is unlikely that an integrated evaluation would provide additional information.

One of the key uncertainties in analyzing the impacts of new, more efficient technologies is consumer price elasticity—the extent to which, and how quickly, energy consumers will react to changes in energy prices or to improvements in the energy efficiency of equipment by purchasing the more efficient technologies. The EIA analysis relies on empirically derived estimates of price elasticities and consumer preferences to evaluate technology penetration; however, models cannot predict shifts in consumer tastes or market transformations associated with rapid adoption of new technologies. The pace of technology development is also a major uncertainty. EIA relies on engineering evaluations of the availability, costs, and characteristics of new technologies assuming continuing patterns of research and development. It is acknowledged, however, that the future development paths of energy-using technologies cannot be foreseen with certainty.

Market Barriers

Although some programs in the CCTI are aimed at the basic research and development of more efficient or renewable technologies, others are focused on the diffusion and deployment of the technologies. There are a number of reasons why new technologies may be slow to penetrate, the foremost of which is cost-effectiveness. Much of the research in new energy technologies, such as photovoltaic and wind generation, is aimed at reducing their costs.

The lack of penetration of technologies that do appear to be cost-effective is often termed “market failure.” More recently, analysts have attempted to separate true market failure from other market barriers. Market failures may result from lack of information about the characteristics of new technologies, which may be helped through a variety of information programs. Another difficulty is exemplified by the difference between the incentives of builders and homeowners. To the extent that newer technologies may be more expensive, it may be difficult for builders or landlords to recover their additional costs from buyers or tenants who may not value energy efficiency as highly as other characteristics. Conversely, the buyer or tenant who will be paying the energy costs may not readily have the option of making equipment choices. Finally, artificially lower prices for energy, through subsidies or regulated prices for example, may hamper the penetration of technologies, because even lower technology costs would be necessary for them to appear cost-effective.

Other items may be viewed as market barriers, not failures. Energy consumers may be fully aware of potential cost savings from a more efficient technology but have a preference for other characteristics of equipment they purchase. The current trend for larger, more powerful vehicles is a prime example, but there are many examples of characteristics for vehicles, appliances, and equipment that compete with energy efficiency. New technology also tends to have a naturally slow penetration for a variety of reasons, including uncertainty as to the reliability and benefits of the new product; lack of familiarity with new techniques for installing and maintaining the equipment; uncertainty about the future availability of the next generation of the technology, which could represent a major improvement; and apprehension about the infrastructure for support and maintenance of the technology.

Perceptions about the payback periods for new equipment purchases may also vary among consumers. A technology may appear cost-effective when the potential fuel cost savings are estimated over a long period of time, but many consumers appear to want a more immediate payback for their higher initial purchase costs. Also, the tendency for homeowners to move frequently works against the purchase of equipment with long payback periods. Finally, uncertainty about future fuel prices and the likely duration of occasional price spikes may discourage consumers from investing in energy-saving equipment.

Market failures can be addressed by a number of programs, including those in the CCTI. Information programs, collaborative efforts for development and diffusion, research and development to improve the technologies and reduce costs, and incentives to enhance the cost-effectiveness of new technologies all may help to encourage earlier penetration of technologies. Subsequently, the initial penetration may have the additional impact of reducing costs through learning, establishing the infrastructure, and increasing familiarity with new technologies. Finally, equipment standards and other mandates, such as renewable portfolio standards, can also accelerate the market penetration of advanced technologies. No attempt was made in this analysis to evaluate the costs of such standards.

2. CCTI Tax Initiatives

Introduction

The Administration's Climate Change Technology Initiative (CCTI) includes a number of proposed tax incentives that would provide tax credits for buildings, vehicles, industry, and renewable electricity generation. The purpose of the tax credits is to reduce the initial costs of more energy-efficient and renewable technologies for buildings, vehicles, and industry and provide tax incentives for the generation of electricity from renewable sources, thereby encouraging their adoption earlier than would otherwise occur. The tax credits are short-term incentives, lasting only a few years and extending no later than 2006; however, in addition to their short-term impacts, they are intended to stimulate the use of the technologies, lower costs, and establish a more mature market for them. The Administration estimates the combined revenue impact of the tax credits at $383 million in fiscal year 2000 and $3.6 billion from fiscal years 2000 through 2004.

In general, this analysis of the tax incentives used the National Energy Modeling System (NEMS),[8] the Energy Information Administration (EIA) model of U.S. energy markets. To evaluate the tax credits for new energy-efficient homes, U.S. Department of Energy (DOE) building code and building simulation models were also used. The results of the analysis highlight the energy savings and reductions in carbon emissions for each of the tax credits, relative to a reference case based on the *Annual Energy Outlook 1999* (*AEO99*),[9] published in December 1998. Where possible, an estimate of the tax revenue implications is also provided and compared to the Administration estimates.

Some past tax incentives have been able to accelerate substantially the introduction of new technologies into the market. For example, natural gas production from coal seams has grown dramatically since the late 1980s, largely because of tax credits that provide an incentive for the production of high-cost gas supplies. Other tax credits have had little impact, including the current biomass tax credit and the solar tax credit, which was enacted in 1978 and expired in 1985.

Important factors in the success of tax incentives include the timing and magnitude of the credits. Compared to some earlier tax credits, including the 40-percent solar tax credit, the incentives currently proposed are of small to modest magnitude and of relatively short duration. Other factors include the definition of qualifying entities and the different incentives provided by investment and production tax credits. Investment tax credits provide a return to the investor at the time a capital investment is made, while production tax credits provide a return during the life of the credit.

It is likely that some of the technologies targeted in the CCTI would penetrate to some degree even in the absence of the proposed tax credits; however, those units would receive the tax credit as well as the marginal units that would come on line purely as a result of the credit. Estimates of the magnitude of such unintended benefits are also provided. Another unintended result of the tax credits may be a tendency on the part of purchasers to either delay or accelerate investments in order to receive the credits, an effect that cannot be quantified. An additional unintended

[8]Energy Information Administration, *National Energy Modeling System: An Overview*, DOE/EIA-0581 (Washington, DC, February 1998).
[9]Energy Information Administration, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998).

effect of an investment tax credit is that part of the value of the credit accrues to equipment manufacturers and suppliers. The credit increases the demand for capital equipment, leading to higher equilibrium prices for the equipment. As a result, as much as 70 percent of the tax credit could be passed to equipment suppliers in the form of higher equipment prices.[10] If this situation were to occur, the impact of a tax credit on capital equipment additions could be quite modest. This effect has not been incorporated in the analysis.

Buildings

The Clinton Administration's proposed budget for fiscal year 2000 includes a package of proposals aimed at promoting energy efficiency and improving the environment. The CCTI package would provide $2.1 billion in targeted tax incentives over 5 years for consumers who purchase energy-efficient products and energy from renewable sources for use in buildings. By offering consumers price reductions on energy-efficient products through reductions in their Federal taxes, the CCTI initiatives are intended to increase demand for the products and, thereby, increase economies of scale in the production process, reduce production and retail costs, and develop a more robust market for the products. The CCTI package also includes $273 million in investments for research, development, and deployment of clean technologies for residential and commercial buildings in fiscal year 2000 (see Chapter 3).

The proposed CCTI tax credits provide incentives for the purchase of more efficient equipment and structures by offering income tax credits for the year in which the equipment or structure was purchased. The Administration estimates reductions in tax revenues of $2.1 billion from fiscal year 2000 through fiscal year 2006 as a result of the proposed initiatives for the buildings sectors. Specific estimates include $1.5 billion in tax incentives for energy-efficient equipment, $429 million for the purchase of new energy-efficient homes, and $132 million for rooftop solar systems.

The EIA has conducted an analysis of the CCTI tax incentive proposals that have the potential to affect levels of energy use and carbon emissions in the buildings sectors. Estimates of the projected impacts were developed by comparing the results from a reference case with results from an analysis case incorporating the proposed tax initiatives. Energy consumption and energy-related carbon emissions were the only effects considered. The reference case included efficiency and price improvements expected under current policy and market conditions. The residential and commercial demand modules of NEMS were used to model the CCTI proposals that could be explicitly represented (tax credits for energy-efficient equipment in existing homes and buildings and tax credits for rooftop solar systems). An off-line analysis using DOE building simulation models and payback analyses was employed to evaluate the potential impacts of the proposed tax credits for energy-efficient new homes. Estimates were developed considering only the buildings sectors, with no analysis of possible feedback effects from other sectors of the economy.

Tax Credits for Energy-Efficient Building Equipment

Background

A two-tier tax incentive program has been proposed to accelerate the development and distribution of energy-efficient technologies, generally providing a 10-percent credit for energy-efficient equipment purchased in 2000 and 2001 and a 20-percent credit for higher efficiency equipment purchased from 2000 through 2003. For example, a small

[10] Austan Goolsbee, "Investment Tax Incentives, Prices, and the Supply of Capital Goods," Working Paper 6192 (Cambridge, MA: National Bureau of Economic Research, September 1997).

commercial business that is planning to install a new cooling system in the year 2000 could receive either a 10-percent tax credit on the purchase price of a residential-type central air conditioner with a cooling efficiency of 13.5 SEER (Seasonal Energy Efficiency Factor) or a 20-percent tax credit for a central air conditioner with a cooling efficiency of 15 SEER. The specific technologies, requirements for eligibility, and applicable credits of the tax incentive program are shown in Table 1.

Table 1. Tax Credit Proposal for Energy-Efficient Building Equipment

Technology	Minimum Efficiency[a]	Time Frame for Purchase	Tax Credit
Efficient Equipment			
Air-source heat pump	Heating: 9 HSPF Cooling: 13.5 SEER	2000-2001	10% of purchase price up to $250
Central air conditioner	13.5 SEER	2000-2001	10% of purchase price up to $250
Advanced natural gas water heater	0.65 EF	2000-2001	10% of purchase price up to $250
Higher Efficiency Equipment			
Air-source heat pump	Heating: 9 HSPF Cooling: 15.0 SEER	2000-2003	20% of purchase price up to $500
Central air conditioner	15.0 SEER	2000-2003	20% of purchase price up to $500
Advanced natural gas water heater	0.80 EF	2000-2003	20% of purchase price up to $500
Electric heat pump water heater	1.7 EF	2000-2003	20% of purchase price up to $500
Natural gas heat pump	Heating COP: 1.25 Cooling COP: 0.70	2000-2003	20% of purchase price up to $1,000
Fuel cell[b]	Electricity generation: 35% Minimum capacity: 5 kilowatts	2000-2003	20% of purchase price up to $500 per kilowatt of capacity

[a]Units for efficiency measures are presented as given in the Department of the Treasury's explanation of the CCTI proposals: HSPF, Heating Seasonal Performance Factor; SEER, Seasonal Energy Efficiency Rating; EF, Energy Factor; COP, Coefficient of Performance.

[b]Uses an electrochemical process to generate electricity and heat.

Source: U.S. Department of the Treasury, "General Explanations of the Administration's Revenue Proposals" (February 1999).

The tax credit is a percentage of the purchase price not exceeding a specified price limit. The purchase prices of the technologies included in the CCTI proposal are such that, in some instances, the tax credit does not exceed the cap. Table 2 illustrates this point by providing the costs and possible tax credits for equipment of the efficiency levels specified in the proposal. Also provided in Table 2, for comparison purposes, is the cost of the equipment that just meets the current energy efficiency standards and thus would receive no tax credit.

In the NEMS residential and commercial modules, the income tax credit is represented as a direct offset to the cost of the equipment. The costs for each of the affected technologies are reduced only for the years specified in the budget language. Once the tax credit expires, it is no longer subtracted from the cost of the technology. Both the reference case and the CCTI analysis case incorporate cost declines for advanced technologies over time as producers gain experience. The size and duration of the credit in the CCTI case are not considered sufficient to alter the rate of the cost declines. The credit is also believed to be too small to affect general consumer behavior toward energy efficiency or to change the barriers to entry that exist in the marketplace. An example of this market phenomenon is the development of heat pump water heaters in the early 1980s. With the help of government and utility supports, sales of heat pump water heaters peaked at about 8,000 units in 1985. Even with continued utility support, however, the decline in real energy prices and uncertainties regarding the technology caused sales to slip to 2,000 units per year, where they have stabilized.[11] While innovative and aggressive marketing strategies by private firms and government information programs could enhance the effectiveness of the tax credits by increasing the exposure and consumer awareness of a given technology, the short lead time and limited duration of the proposed incentives make changes in consumer behavior unlikely.

Table 2. Cost and Performance Data for CCTI Technologies

Technology	Efficiency[a]	Cost[b]	Proposed Tax Credit
Air-source heat pump	6.8 HSPF, 10.0 SEER	$4,100	None
	9.0 HSPF, 13.5 SEER	$5,100	$250
	9.0 HSPF, 15.0 SEER	$5,300	$500
Central air conditioner	10.0 SEER	$2,500	None
	13.5 SEER	$2,950	$250
	15.0 SEER	$3,100	$500
Natural gas water heater	0.54 EF	$350	None
	0.66 EF	$779	$78
	0.86 EF	$2,360	$472
Electric water heater	0.88 EF	$350	None
Heat pump water heater	2.60 EF	$1,025	$205
Natural gas furnace/central air conditioner	0.80 AFUE, 10.0 SEER	$3,800	None
Natural gas heat pump	1.4 GCOP, 0.7 GCOP	$8,000	$1,000
Fuel cell	35%	$3,000 per kilowatt[c]	$500 per kilowatt

[a]Heating and cooling efficiency, respectively, are given for heating and cooling combination units. Units for efficiency measures are presented as given in the Department of the Treasury's explanation of the CCTI proposals: HSPF, Heating Seasonal Performance Factor; SEER, Seasonal Energy Efficiency Rating; EF, Energy Factor; AFUE, Annual Fuel Utilization Efficiency; GCOP, Gas Coefficient of Performance.

[b]Costs are given in 1998 real dollars.

[c]Source: Energy Information Administration, *Technology Forecast Updates: Residential and Commercial Building Technologies—Advanced Adoption Case*, prepared by Arthur D. Little, Inc. (Washington, DC, September 1998). Installed cost is for a phosphoric acid fuel cell ranging in size from 5 to 250 kilowatts of generating capacity.

Sources: Energy Information Administration, *Technology Forecast Updates: Residential and Commercial Building Technologies—Reference Case*, prepared by Arthur D. Little, Inc. (Washington, DC, September 1998).

It is clear from Table 2 that the tax credits offered would not significantly change the economics of the investment decision from the consumer's point of view. Historically, consumers have been unwilling to invest in energy-efficient equipment with long payback periods. Short tenancy rates, lack of information, the fact that builders (as opposed to consumers) generally purchase the energy-using equipment, and limited availability of investment funds are just some of the factors that tend to affect purchase decisions.

Most of the technologies included in the CCTI proposal currently retain very small market shares in the residential arena. Natural gas heat pump prices have been high and volatile due to low sales, which currently total under 6,000 units per year. A consortium of 120 gas utilities currently subsidizes the development of the York Triathlon gas heat

[11]U.S. Department of Energy, Office of Building Equipment, *Market Disposition of High-Efficiency Water Heating Equipment* (Washington, DC, November 1996).

pump in an effort to increase sales to a level at which economies of scale can reduce the installed cost.[12] The tax credits offered for the purchase of this technology could increase sales somewhat; however, the cost—including the tax credit—is still almost double the cost of a traditional gas furnace/central air conditioner system. With energy prices expected to remain stable in real terms over time, it is unlikely that significant increases in the market penetration of gas heat pumps would occur without substantial subsidies or technological breakthroughs leading to large price reductions.

The only generating technology included in the CCTI tax incentive proposal for energy-efficient building equipment is the fuel cell. Currently, units sized for residential applications are in the prototype stage, with a projected commercialization date of 2001-2002. There is only one manufacturer of fuel cells for commercial-sized units. The current cost for a commercial-sized fuel cell is about $3,000 per kilowatt of capacity; the CCTI tax credit would reduce the cost to $2,500 per kilowatt.[13] As an example, assume that a commercial business purchases a fuel cell system, the tax credit is taken, and the cost of the fuel cell is financed at 9-percent interest for 7 years. Including the fuel savings that would result from using the heat produced by the fuel cell to satisfy the company's hot water needs in place of a natural-gas-fired water heater, the fuel cell could provide electricity for around 20 to 21 cents per kilowatthour, depending on regional natural gas prices. That cost is about three times the average U.S. commercial electricity price. Thus, a much larger incentive or a dramatic drop in fuel cell costs in the next few years would be required to spur adoption of this technology.[14]

Results

The analysis results indicate that the CCTI tax incentive proposal for energy-efficient building equipment could reduce projected carbon emissions by 1.5 million metric tons (0.3 percent) and buildings energy use by 26.8 trillion British thermal units (Btu)—0.1 percent of delivered energy—in 2005. Table 3 shows the savings in the CCTI analysis case relative to the reference case. The CCTI case includes the tax credits for all the technologies listed in Table 2.

Table 3. Projected Energy Savings and Carbon Emissions Reductions from the CCTI Tax Incentive for Energy-Efficient Building Equipment, 2005, 2010, and 2020

Projection	1997 Total	2005 Savings	2010 Savings	2020 Savings
Delivered Energy (Trillion Btu)	18,551	26.83	24.42	0.02
Energy Bill Savings (Million 1998 Dollars)	—	627.5	563.1	0.7
Carbon Emissions (Million Metric Tons)	522.2	1.47	1.21	0.01

Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

[12]Energy Information Administration, *Technology Forecast Updates: Residential and Commercial Building Technologies—Reference Case*, prepared by Arthur D. Little, Inc. (Washington, DC, September 1998).

[13]Fuel cell costs from Energy Information Administration, *Technology Forecast Updates: Residential and Commercial Building Technologies—Advanced Adoption Case*, prepared by Arthur D. Little, Inc. (Washington, DC, September 1998).

[14]Assumed financing terms also include a 20-percent down payment. Natural gas and electricity prices for this example are 1998 prices from Energy Information Administration, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998).

Given the small increase in the projected market share for the technologies targeted by this tax credit proposal, it follows that a significant portion of the decreased tax revenues could result from tax credits received by consumers who would have purchased the equipment with no additional incentive. For example, sales of all natural gas heat pumps would be eligible for the tax credit, and with sales currently totaling 5,500 units per year, $5.5 million could be claimed by consumers who would have purchased the equipment absent any tax credit. In the years covered by the tax credit (2000-2003), the analysis indicates that a total of 36,444 natural gas heat pumps would be purchased in the reference case,[15] and that an additional 25,119 units would be purchased because of the tax credit in the CCTI case. In the CCTI case, the Treasury would incur a total reduction of $61.6 million in projected tax revenues related to purchases of natural gas heat pumps. Of the $61.6 million, 60 percent of the tax credits paid would go to unintended beneficiaries.

Tax Credits for Energy-Efficient New Homes

Background

The following CCTI tax credits for energy-efficient new homes are proposed:

- In calendar years 2000 and 2001, a credit of $1,000 for new homes that are at least 30 percent more efficient than the International Energy Conservation Code (IECC) (same as Energy Star Home)
- In calendar years 2000 through 2002, a tax credit of $1,500 for new homes that are at least 40 percent more efficient than the IECC
- In calendar years 2000 through 2004, a tax credit of $2,000 for new homes that are at least 50 percent more efficient than the IECC.

The IECC eligibility standard is an update to the more commonly referenced Model Energy Code (MEC), most recently issued in 1995. Given the similarities between the two codes and the data and software availability already established for MEC95, MEC95 was used as the basis for qualifying for the tax credits. Because there is some overlap between the equipment eligible for tax credits under the CCTI energy-efficient building equipment proposal and the eligibility requirements for the credit for energy-efficient homes, only one of the credits can be claimed for a given structure.[16] It is not clear how the energy savings would be certified to assure that the requirements of the tax credit were met.

Given the intricate interactions between building shell measures, equipment measures, building orientation and shading, and equipment sizing, it is difficult for any estimate to incorporate all the potential effects included in designing and building a home. The NEMS residential model is not a building simulation model and therefore cannot handle all the different aspects and interactions of building systems. In order to give some perspective on the magnitude and potential impacts that the CCTI tax incentive might have, an offline analysis was completed using a building simulation model (PEAR),[17] the MECcheck software,[18] and a cash flow/payback model. When the three models are used in concert, energy savings, code compliance, and investment information can be determined. Although the models estimate energy savings and code compliance, they do not address all issues associated with

[15]Reference case results based on assumptions used for the *Annual Energy Outlook 1999* (*AEO99*). *AEO99* and the assumptions for *AEO99* are available on the EIA web site at www.eia.doe.gov.

[16]Personal communication from John McClelland, Office of Tax Analysis, Department of the Treasury, March 8, 1999.

[17]U.S. Department of Energy, *Program for Energy Analysis of Residences (PEAR)*, DOE/SF/00098-H3 (Washington, DC, June 1989).

[18]U.S. Department of Energy, Office of Codes and Standards, *MECcheck, Version 2.05* (Washington, DC, February 1998).

the energy efficiency aspects of new home construction. The software used for this analysis, although possibly not the state of the art, was readily available, and analysts were familiar with its use.[19]

Even with the use of very detailed building simulation models, there are several limitations of note regarding this analysis. The MECcheck and PEAR programs do not include a number of options that may affect the costs of meeting the qualifications for the tax incentives. The software does not allow for orientation properties, which allow builders to minimize sun exposure in the summer and maximize it in the winter. There is no credit for downsizing the heating and cooling equipment, which allows builders to install smaller, less costly units when a tighter building envelope is in place. There is no accounting for more efficient ventilation systems (e.g., tighter duct work), and only conventional building materials are considered. In addition, there is no unique solution for achieving an energy savings target. To the extent that some of these options can be and are used to meet the CCTI efficiency level requirements, their omission in this analysis may cause higher estimated costs of meeting the program's requirements than if the options were included.

As of the end of 1998, 16 States had adopted MEC95 or better building codes,[20] and 36 States had adopted some form of the MEC or its equivalent.[21] Implementation and enforcement of the code are difficult, and construction often is not compliant. Building codes in States without mandatory codes may be set on a county-specific basis, making estimates of an "average new home" building shell difficult. A somewhat different approach to increasing the building of energy-efficient homes is to offer the tax credit to the homebuilder, as opposed to the homeowner. If the credit were offered to the builder, more energy-efficient homes would be made available to prospective buyers, because the builders would receive an incentive to construct more energy-efficient homes. Currently, builders can recoup only the incremental cost of improving energy efficiency in the sales price of the home, because they do not receive the benefits of lower energy bills. To address this issue, Rep. William Thomas (R-CA) is preparing to introduce the Energy Efficient Affordable Home Act of 1999, which would enable the builders of energy-efficient homes to receive the $2,000 tax credit.[22] The CCTI tax credit would be available to homeowners only; however, given the restrictions on allowable tax credits, it is not clear whether all parties interested in receiving the tax credits could claim them.

For this analysis, two prototype houses were used as typical for two climate regions: north and south. Tables 4 and 5 detail the characteristics and costs of efficiency measures for each prototype and the expected tax credit. It is assumed that each percentage level specified in the tax credit proposal relates to energy savings relative to the MEC95 code for heating and cooling only. It is further assumed that the most efficient equipment is installed as a means to meet the credit, because it is generally the cheapest option per Btu saved.

Methodology and Results

MECcheck was used to establish the characteristics of a MEC95-compliant home, which were then input into PEAR, a building simulation model developed by DOE, to establish MEC95-compliant energy consumption for heating and cooling. The characteristics were then changed to achieve the levels of energy consumption specified in the tax credit proposal. The characteristics shown in Tables 4 and 5 are the results of this process. The costs associated with the efficiency improvements were then mapped to each particular characteristic. As noted above, the solutions given in

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[19]DOE-2 and REM-RATE are two examples of building simulation models that are better equipped to handle some of these issues.
[20]Building Standards and Guidelines Program (BSGP), *Setting the Standard*, Vol. 7, No. 2 (1998).
[21]Other MEC codes include 1992 and 1993 versions. See Building Codes Assistance Project, web site www.solstice.crest.org/efficiency/bcap.
[22]Alliance to Save Energy, "e-FFICIENCY NEWS" (March 1999).

the tables above are not necessarily unique, nor are they necessarily the least-cost options for obtaining the goal of the tax credit proposal. Furthermore, there is considerable uncertainty in the estimates of the costs of meeting the CCTI efficiency requirements. It is possible that, for some specific locations, costs could be much lower than portrayed here.

Table 4. South Region Building Code Characteristics[a]

Characteristic	MEC95 Compliant		MEC95 + 30 %		MEC95 + 40 %		MEC95 + 50 %	
	Efficiency[b]	Cost[c]	Efficiency	Cost	Efficiency	Cost	Efficiency	Cost
Heat Pump	10.0/6.8	4,100	15.5/9.4	5,500	15.5/9.4	5,500	15.5/9.4	5,500
Roof Insulation	R-20	1,116	R-27	1,382	R-27	1,382	R-50	2,413
Wall Insulation	R-11	706	R-11	706	R-13	826	R-15	974
Windows	U-.48	924	U-.48	924	U-.48	924	U-.29	2,200
Slab Insulation	None	0	None	0	R-5.2	564	R-5.4	1,486
Air Infiltration	0.63	157	0.63	157	0.63	157	0.63	157
Total Cost		7,004		8,670		9,353		12,730
Incremental Cost		—		1,666		2,230		5,726

[a]Columbia, SC, 1,800 square feet, built on slab.
[b]Equipment efficiencies are given in SEER (Seasonal Energy Efficiency Rating) and HSPF (Heating Seasonal Performance Factor) for heat pumps and as AFUE (Annual Fuel Utilization Efficiency) and SEER for gas furnaces and central air conditioners.
[c]All costs given in 1998 dollars.
Sources: Cost data from Ernest Orlando Lawrence Berkeley National Laboratory, *Energy Data Sourcebook for the U.S. Residential Sector* (September 1997), and Energy Information Administration, *Technology Forecast Updates: Residential and Commercial Building Technologies—Reference Case*, prepared by Arthur D. Little, Inc. (Washington, DC, September 1998).

Table 5. North Region Building Code Characteristics[a]

Characteristic	MEC95 Compliant		MEC95 + 30 %		MEC95 + 40 %		MEC95 + 50 %	
	Efficiency[b]	Cost[c]	Efficiency	Cost	Efficiency	Cost	Efficiency	Cost
Gas Furnace/CAC	78/10.0	3,850	95/16.0	5,450	95/18.0	565	95/18.0	5,650
Roof Insulation	R-31	1,011	R-60	1,788	R-60	1,788	R-60	1,788
Wall Insulation	R-15	1,510	R-27	4,035	R-27	4,035	R-27	4,035
Windows	U-.48	1,319	U-.48	1,319	U-.30	2,195	U-.25	3,793
Floor Insulation	R-15	722	R-15	722	R-15	722	R-21	914
Air Infiltration	0.56	333	0.56	333	0.56	333	0.40	713
Total Cost		8,745		13,648		14,723		16,894
Incremental Cost . . .		—		4,902		5,978		8,148

[a]Chicago, IL, 2,240 square feet, two-story, unheated basement.
[b]Equipment efficiencies are given in SEER (Seasonal Energy Efficiency Rating) and HSPF (Heating Seasonal Performance Factor) for heat pumps and as AFUE (Annual Fuel Utilization Efficiency) and SEER for gas furnaces and central air conditioners.
[c]All costs given in 1998 dollars.
Sources: Cost data from Ernest Orlando Lawrence Berkeley National Laboratory, *Energy Data Sourcebook for the U.S. Residential Sector* (September 1997), and Energy Information Administration, *Technology Forecast Updates: Residential and Commercial Building Technologies—Reference Case*, prepared by Arthur D. Little, Inc. (Washington, DC, September 1998).

To determine the attractiveness of each investment, a spreadsheet model was developed using a cash flow and payback analysis as the means to evaluate the investment. The following assumptions were used in the analysis:

- Homes receiving the tax credit were assumed to be mortgaged at 7.5 percent for 30 years, with a 10-percent down payment. Thus, if the incremental costs of the energy-efficient home were $2,500, an up-front cost of $250 would occur in the down payment, and mortgage payments would increase by $191 per year.
- The penetration of energy-efficient homes was assumed to be a function of the number of years it would take to achieve a positive cumulative cash flow given the estimated costs and savings and assumed mortgage provisions. The concept of number of years to positive cash flow is similar to, but distinct from, the commonly computed simple payback period.
- In the reference case, Energy Star homes are built at an increasing rate, with the starting point closely tied to recent results from the program.[23] For the years 2000 and 2001, during which a $1,000 tax credit applies, it was assumed that Energy Star homes would receive this credit. New homes achieving the 40- and 50-percent energy savings levels were assumed to reduce the baseline of Energy Star homes, which would not be eligible for the tax credits, by 50 percent after 2001. It was assumed that 50 percent of the new homes built in the reference case would be upgraded to receive the tax credit in the CCTI case. Although this is only an assumption, the incremental savings for upgrades to shell efficiency beyond the 30-percent level generally offer rapid returns with the tax credits in place, and some conversions should be expected.
- In the first 3 years of the program, only homes achieving 30- and 40-percent savings over MEC95 would be built. In the last 2 years of the program, homes achieving 50-percent savings over MEC95 would be built. This assumption represents an increase in the efficiency of homes built as the program matures.

The results are as follows:

- Approximately 222,000 additional energy-efficient homes would be built in the CCTI case during the 2000-2004 period. A total of just under 300,000 homes would receive tax credits averaging nearly $1,800. The total reduction in projected tax revenues would approach $540 million.
- Given the length of time that buildings remain in the housing stock, most of the benefits of energy and carbon savings would continue for 50 years or more, although such long-term savings are not illustrated here.
- Energy savings for electricity and natural gas and total reductions in carbon emissions would be as shown in Table 6.

Table 6. Projected Energy Savings and Carbon Emissions Reductions in the CCTI Analysis Case for Energy-Efficient New Homes

Projection	1997 Total	2005 Savings	2010 Savings	2020 Savings
Delivered Energy (Trillion Btu)	10,921	6.4	6.4	6.4
Energy Bill (Million 1998 Dollars)	139,898	79.7	79.7	79.7
Carbon Emissions (Million Metric Tons)	285.6	0.2	0.2	0.2

Source: Energy Information Administration, Office of Integrated Analysis and Forecasting. Assumes constant energy prices.

[23]The U.S. Environmental Protection Agency web site describes the Energy Star Homes program, including results for the past 12 months. See web site http://yosemite.epa.gov/appd/eshomes/eshomes.nsf.

Tax Credits for Rooftop Solar Equipment

Background

The CCTI tax incentive for rooftop solar equipment is aimed at encouraging individuals and businesses to adopt systems that provide heat and electricity without producing greenhouse gases. The credit, equal to 15 percent of the investment cost, applies to rooftop photovoltaic (PV) systems and solar water heating systems located on or adjacent to a building and used exclusively for purposes other than heating swimming pools. Solar water heating systems placed in service during the 5-year period from 2000 through 2004 are eligible up to a maximum credit of $1,000. Rooftop PV systems placed in service during the 7-year period from 2000 through 2006 are eligible for the 15-percent tax credit up to a maximum of $2,000.

Currently, a 10-percent business energy tax credit (BETC) is provided to private businesses for qualifying equipment that uses solar energy to generate electricity, to heat or cool, to provide hot water for use in a structure, or to provide solar process heat. The allowable tax credit for any one year is limited to $25,000 plus 25 percent of remaining taxes after the credit is taken. Credits not allowable in one year may be taken in other tax years. Equipment that uses both solar and non-solar energy must not use more than 25 percent of its total annual energy input from non-solar sources to qualify. Passive solar systems and those owned by public utilities are not eligible. Thus, commercial taxpayers would have to choose between the present tax credit and the proposed CCTI credit for each qualifying investment. For systems that qualify for both credits, only small systems would benefit more from the 15-percent CCTI proposal because of the $1,000 and $2,000 caps. The solar technology costs and tax credits used in the analysis of the proposed CCTI tax credit for rooftop solar systems are shown in Table 7.

Table 7. Cost Data for CCTI Solar Technologies

Technology	Installed Cost[a]	Applicable Tax Credit
Solar Thermal Water Heater . .	$199 per thousand Btu per hour of capacity	BETC: $20 per thousand Btu per hour CCTI: $30 per thousand Btu per hour of capacity, maximum $1,000
Photovoltaic Rooftop System (Current Cost)	$6,944 per kilowatt of capacity	BETC: $694 per kilowatt of capacity
Photovoltaic Rooftop System (Projected Cost, 2000-2006) . .	$6,169 per kilowatt of capacity	BETC: $617 per kilowatt CCTI: $925 per kilowatt of capacity, maximum $2,000

[a]System costs could vary depending on climate, collector quality and type of system.

Sources: Solar thermal costs are based on Energy Information Administration, *Technology Forecast Updates: Residential and Commercial Building Technologies—Reference Case*, prepared by Arthur D. Little, Inc. (Washington, DC, September 1998). PV costs are based on U.S. Department of Energy, Office of Building Technologies, *Building Integrated Photovoltaics (BIPV), Analysis and U.S. Market Potential* (Washington, DC, February 1995). Tax credits from Department of the Treasury, "General Explanations of the Administration's Revenue Proposals" (February 1999). Costs are given in 1998 real dollars. The tax credit is assumed to apply to the purchase price, including installation costs.

Tax credits have been used in the past to create a niche market for solar water heaters. In the early 1980s, shipments of medium-temperature solar thermal collectors (the type used for water heaters) peaked at just under 12 million square feet (enough for roughly 300,000 units) per year. After the Federal 40-percent residential and 15-percent business energy tax credits expired at the end of 1985, shipments fell to less than 1 million square feet per year, and they have never recovered.[24] The business energy tax credit was reinstated at 15 percent for 1986 and phased down to 10 percent by 1992, with the Energy Policy Act of 1992 (EPACT) providing a permanent extension of the BETC.

The credit reinstatement and increasing oil prices after 1986 did not seem to create a rebound of the solar industry. Today, most solar collector shipments (85 percent) are used for heating swimming pool water, which is excluded from the tax credit. In 1997, EIA estimates that roughly 460,000 households (0.5 percent) used solar water heaters to provide some of the energy required to heat the annual load of hot water.[25] Currently, about 9 percent of solar thermal collector shipments are destined for the commercial sector. Only 0.5 percent of all solar thermal collector shipments purchased by the commercial sector are for uses other than heating swimming pools, even with the existing energy tax credit available.

Residential rooftop PV systems are uncommon. Some are used for remote power generation, where connection to the electrical grid would be prohibitively expensive. PV systems are also rare in the commercial sector, used primarily for power generation and communications.[26] The 10-percent BETC is generally not enough to make PV systems economically attractive to the commercial sector, where purchased electricity is readily available. There are Federal, State, and local programs and incentives to encourage use of solar technologies. Locally, under the PV Pioneer I program, the Sacramento Municipal Utility District (SMUD) has created a small market for solar photovoltaics by installing the equipment on residential rooftops for $4 per month for 10 years. The homeowner is, however, obligated to pay SMUD's current rate for electricity. Since 1993, more than 450 homes have participated in the program. SMUD has recently launched PV Pioneer II, which allows homeowners to purchase their own PV systems and participate in net metering, generating their own electricity at no cost and paying for the electricity needed from the electrical grid. Any excess electricity generated from the PV system is sold back to the grid for future credit.[27] With energy prices expected to remain stable in real terms, it is likely that substantial subsidization or technological breakthroughs leading to large price reductions would be required to foster increased penetration of residential PV systems.

The reference case for this analysis includes the current 10-percent BETC for both solar thermal water heaters and PV systems. Installations for DOE's Million Solar Roofs (MSR) program (see Chapter 3) are also included in the reference case. The analysis does not include consideration of any State or local incentives.

Results

A negligible change from reference case results was seen when the CCTI tax incentive for rooftop solar equipment was included in the NEMS residential and commercial modules. It should be noted that many of the units completed under the MSR program could be eligible for the solar tax credit. Approximately 400,000 units—of which 66,000 are included in the reference case—are planned to be constructed under the program from 2000 through 2004, the period for which revenue impacts are estimated.[28] Any such units qualified to receive the tax credits during this interval probably would be unintended beneficiaries, because the MSR program pre-dates the CCTI tax incentives. The proposed tax credit is modest in comparison with the 40-percent residential credit available in the past. Niche markets with local incentives in place and electricity rates much higher than the national average could create a

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[24]Energy Information Administration, *Solar Collector Manufacturing Activity 1993*, DOE/EIA-017(93) (Washington, DC, August 1994).

[25]Energy Information Administration, *Housing Characteristics 1997*, DOE/EIA-0314(97), available on the EIA web site at www.eia.doe.gov/emeu.

[26]Energy Information Administration, *Renewable Energy Annual 1996*, DOE/EIA-0603(96) (Washington DC, March 1997), and *Renewable Energy Annual 1998*, DOE/EIA-0603(98) (Washington DC, December 1998).

[27]For more information on SMUD's PV Pioneer programs, see web site www.smud.org/home/pv_pioneer/index.html.

[28]Interpolation of estimated units from web site www.eren.doe.gov/millionroofs/benchmark.html.

situation in which the CCTI tax incentive would make solar technologies economically attractive; however, the Census Division resolution of NEMS dilutes the ability to capture such instances.

Industry

Background

The CCTI proposal includes a new investment tax credit for the installation of combined heat and power systems (CHP) that meet specified energy efficiency targets. The reduction in capital cost resulting from the tax credit is intended to induce additional investments in CHP. For this analysis, the NEMS industrial demand module was modified to estimate the likely incremental impacts of the CHP tax credit on energy consumption and carbon emissions. Other potential benefits of the CHP tax credit (such as reduction of other pollutants) were not analyzed.

This analysis did not address district energy systems. The NEMS commercial model incorporates consumption of district energy services, but central district energy plants are not modeled explicitly in NEMS. To the extent that district energy plants are owned by governmental entities, however, an investment tax credit is likely to have little impact on expanding district energy systems.[29] There are also significant lead times for site approval, construction, and operating permits for district energy systems.[30] These lead times could cause otherwise qualifying district energy systems to miss the tax credit window.

The analysis did not include the potential effects of removing institutional barriers to CHP and merchant power plants. Elimination or reduction of barriers due to, for example, standby rates, exit fees, establishing uniform interconnection standards, or reform of environmental permitting policies could lead to a substantially larger CHP increase than is likely with the CHP investment tax credit alone. The Administration currently has in place the CHP Challenge Program, which may address some of these barriers.[31] One analysis has concluded that institutional barriers to CHP systems represent a significant impediment to greater deployment of the technology.[32] The study estimated that addressing four types of institutional barriers could lead to an additional 50 gigawatts of CHP by 2010. The specific measures advocated were expedited permitting for CHP systems; output-based air pollution regulations; removal of a variety of "utility-driven" barriers; and establishing a standard depreciation period of 7 years for all new CHP systems.

The analysis specifically did not include any existing, ongoing programs, such as Industries of the Future, the Advanced Turbine System Program, research and development programs, or voluntary programs. The likely energy impacts of those programs are regularly assessed by DOE and are not reviewed here.[33]

[29]While this analysis does not explicitly include district energy systems, there is some indication that the economics of retrofitting existing systems with CHP are not very favorable. See M. Spurr, *District Energy Systems Integrated with Combined Heat and Power*, prepared by International District Energy Association for the U.S. Environmental Protection Agency (March 1999), p. 75.

[30]M. Spurr, *District Energy Systems Integrated with Combined Heat and Power*, prepared by International District Energy Association for the U.S. Environmental Protection Agency (March 1999), p. 43.

[31]While the Administration has not presented a detailed discussion of its intentions in this area, a list of possibilities can be found in T.R. Kasten, *Turning Off the Heat* (New York, NY: Prometheus Books, 1998).

[32]American Council for an Energy-Efficient Economy, *Approaching the Kyoto Targets: Five Key Strategies for the U.S.* (Washington, DC, August 1998).

[33]U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, *Office of Industrial Technologies: Summary of Program Results*, DOE/EE-0184 (Washington, DC, January 1999).

Tax Credit for Combined Heat and Power

The CCTI proposal would implement an 8-percent investment tax credit for qualified CHP systems. A qualified system must be placed in service between 2000 and 2002 and must be larger than 50 kilowatts. The proposed legislation would require that systems which currently have a tax life of 7 years or less adopt a tax life for depreciation purposes of 15 years. This requirement would reduce the effective tax credit to about 4 percent and, presumably, would exclude biomass-fired cogeneration from the pulp and paper industry.[34] Additional conditions, which vary with system size, must also be met (Table 8).

Table 8. CCTI Requirements for Qualifying Combined Heat and Power Systems

System Size[a]	Minimum Electric or Mechanical Power (Percent)	Minimum Useful Thermal Output (Percent)	Minimum Overall System Efficiency (Percent)
Less than 50 Megawatts	20	20	60
Greater than 50 Megawatts	20	20	70

[a]The minimum size requirement is 67 horsepower for mechanical systems. The 50-megawatt system size corresponds to 67,000 horsepower.

Source: U.S. Department of the Treasury, *General Explanation of the Administration's Revenue Proposals* (Washington, DC, February 1999), pp. 45-46.

The efficiency requirements ensure that qualifying systems genuinely produce both heat and power in substantial amounts. In contrast, cogeneration systems qualifying under the Public Utility Regulatory Policies Act of 1978 (PURPA) were only required to produce thermal output equal to 5 percent of useful energy output. As a result, much of the PURPA-induced cogeneration capacity added after 1978 was designed with minimal thermal output and relatively low overall efficiency. Such "nontraditional" cogeneration capacity, which represents approximately one-half the total CHP in operation, generally provides little efficiency improvement over comparable systems (combined-cycle plants) installed by electric utilities.

The proposed tax credit for CHP systems is expected to have its primary impact on traditional cogeneration in the industrial sector, which is the focus of this analysis. There may be some impact on nontraditional or merchant plant facilities, but the CCTI system efficiency standard of 0.7 would exclude many CHP plants that are designed to maximize electrical output rather than total system efficiency. Because total system efficiency falls as the ratio of electrical output to useful thermal output increases, nontraditional CHP plants generally do not meet the system efficiency requirement to qualify for the tax credit. Traditional industrial cogeneration accounts for about 40 percent of total cogeneration capacity (Table 9). The remainder is in refining, oil and gas production, the commercial sector, and the nontraditional category.

Methodology

The effects of the proposed CHP tax credit were assessed by estimating the relationship between CHP project economics and market penetration, using a new methodology developed and implemented in the NEMS industrial module. Industrial CHP market penetration was estimated as a function of steam requirements by industry, existing CHP, CHP system costs and performance, and investment payback acceptance rates, providing a quantitative

[34]This analysis did not address the likelihood of the successful demonstration and widespread adoption of black liquor gasification combined-cycle technologies, which could lead to such a large increase in self-generation that the industry would become a net seller of electricity after 2010.

Table 9. Components of Cogeneration Capacity in the Reference Case, 1999 and 2002
(Gigawatts)

Component	1999	2002
Traditional Industrial	20.8	21.7
Refining	2.9	2.9
Enhanced Oil Recovery	2.3	2.3
Commercial	0.6	0.6
Nontraditional	26.2	26.2
Total	**52.7**	**53.6**

Source: Energy Information Administration, National Energy Modeling System run AEO99R.D033099A.

framework for evaluating the effect of policies to improve CHP economics, as well as the removal of barriers to CHP (such as high standby electricity rates imposed on CHP facilities by some electric utilities). The analysis was limited to an assessment of gas turbine CHP systems, which are well-suited for a wide range of applications and represent the predominant technology used for new CHP installations.[35]

The methodology was designed to determine the technical potential for CHP, evaluate its economic potential, and estimate annual capacity additions. The technical potential for CHP exists at facilities with significant thermal energy uses, generally in the form of process steam. Because steam is relatively expensive to transport, industrial CHP systems are typically sited at the facility where the thermal energy will be used. Electric power from CHP is most often applied to the facility's own uses, but it can also be supplied to the grid. Thus, the thermal needs of a facility, not necessarily its electric power needs, determine the technical potential for CHP.

The assessment of the potential for new CHP begins with an examination of the thermal requirements of industry and the amount of CHP, or cogeneration, already in place. Many of the best sites for cogeneration in the industrial sector currently are being used, and 35 to 40 percent of the steam used in the industrial sector is produced through cogeneration. Still, additional cogeneration could meet some portion of the remainder of the existing steam requirements, as well as any growth in steam requirements as industry expands. The incremental technical potential appears to be over 50 gigawatts,[36] almost 40 percent of which arises in industries with relatively small thermal requirements, where the economic desirability of CHP systems is sharply reduced.

To estimate CHP growth, the potential thermal (steam) capacity for new cogeneration was estimated under the assumption that cogeneration systems can replace or supplant existing boiler capacity to meet a portion of the steam load not already being met with CHP. The prototype CHP systems are assumed to be sized to meet a facility's average hourly steam loads (net of steam already being produced by CHP). In addition, the ratio of power to steam produced by typical cogeneration systems was used to estimate the corresponding electric generating capacity. Because the characteristics of cogeneration systems vary with size, the analysis accounted for several ranges of thermal output that candidate CHP systems would supply. The thermal requirements of each industry were divided among these thermal ranges, based on the size distribution of boiler capacity. For each thermal load range, one of five candidate CHP systems was selected as a prototype by matching the average hourly thermal requirement within the range.

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[35]Other analyses of CHP potential have assumed that most CHP additions will be gas-fired. See, for example, American Council for an Energy-Efficient Economy, *Approaching the Kyoto Targets: Five Key Strategies for the U.S.* (Washington, DC, August 1998), p. 28.
[36]Onsite Energy Corporation, "Basis for 60 GW of Remaining Cogeneration Potential in the Industrial Sector" (May 1997).

The five prototype cogeneration systems were assumed to have the characteristics shown in Table 10, which were developed from information supplied by manufacturers, as well as several industry studies.[37] Although the technical specifications are often available, the typical total costs of installed systems—about twice those for gas turbine generators—are not available. As summarized in one study: "Thus the installed cost of a gas turbine with an HRSG [heat recovery steam generator] can be estimated from the FOB price by multiplying this price by a factor of the order of 1.8-2.3."[38]

Table 10. Characteristics of Candidate Cogeneration Systems

Characteristics	Prototype System				
	1	2	3	4	5
Electricity Capacity (Kilowatts)	1,000	2,500	5,000	10,000	40,000
Total System Cost (1997 Dollars per Kilowatt)	1,600	1,400	1,200	1,000	950
Capacity Factor	0.8	0.8	0.8	0.8	0.8
Overall Efficiency	0.7	0.7	0.7	0.75	0.8
Heat Rate (Btu per Kilowatthour)	14,217	13,132	11,263	10,515	9,749
Net Heat Rate (Btu per Kilowatthour)	6,042	5,907	5,673	4,922	4,265
Steam Output (Million Btu per Hour)	6.5	14.5	22.4	44.7	175.5
Power-Steam Ratio (Btu Electric per Btu Steam)	0.52	0.59	0.76	0.76	0.78

Source: Energy Information Administration estimates based on information from Caterpillar, Allison Gas Turbines, and Centre for the Analysis and Dissemination of Energy Technology (CADDET): *Gas-Turbine-Based CHP in Industry* (1993) and *Small-Scale Cogeneration* (1995).

A prototype system for each thermal size range was evaluated as a discretionary investment opportunity, based on regional prices of natural gas and electricity. The evaluation estimated the payback period for a CHP investment. The payback estimates, together with the system size characteristics, were used to estimate market penetration.

The total technical potential for CHP was calculated with the assumption that all the prototype systems would be installed, irrespective of economics. The economic potential, or the fraction of technical CHP potential that would be realized on the basis of relative economic attractiveness, was estimated from the payback periods. To estimate economic potential, an assumed quantitative relationship was formulated to describe the general notion that the shorter the payback period is, the greater is the likelihood that an investment will be undertaken. This assumed relationship, the "payback acceptance curve," quantifies the fraction of CHP investments that would occur for a given payback period. The midpoint on this "sliding scale" is 2.5 years, reflecting an assumption that half of all CHP technical opportunities with a payback period of 2.5 years would be adopted. For longer payback periods, a smaller fraction of the CHP opportunities would be adopted. For example, 10 percent of CHP opportunities with a 5-year payback period are assumed to be adopted. The assumed payback requirements are meant to reflect typical financial requirements, as well as some of the institutional and regulatory barriers that limit CHP market penetration. A study prepared for DOE indicates that 21 percent of proposed cogeneration projects with a 3.3-year payback period have

[37]The economic evaluation methodology draws heavily from two recent analyses of CHP from the Centre for the Analysis and Dissemination of Energy Technology (CADDET): *Gas-Turbine-Based CHP in Industry* (1993) and *Small-Scale Cogeneration* (1995). Some characteristics, such as heat rates of gas turbines, are based on data provided from Solar Turbines (owned by Caterpillar) and Allison Gas Turbines.

[38]Centre for the Analysis and Dissemination of Energy Technology (CADDET), *Gas-Turbine-Based CHP in Industry* (1993), p. 45.

been implemented.[39] The values assumed for the payback acceptance curve for industrial cogeneration are shown in Table 11.

Table 11. Assumed Values for the CHP Investment Payback Acceptance Curve

Payback Period for CHP Investment (Years)	Percentage of Firms Willing to Invest	Payback Period for CHP Investment (Years)	Percentage of Firms Willing to Invest	Payback Period for CHP Investment (Years)	Percentage of Firms Willing to Invest
0	100.0	5	9.8	10	0.9
1	88.5	6	5.5	11	0.3
2	64.0	7	3.8	12	0.0
3	39.5	8	2.5		
4	20.5	9	1.6		

Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

The market penetration of industrial CHP over the 2000 to 2002 period was estimated with and without the proposed 8-percent investment tax credit. The primary effect of the credit in the CCTI analysis case is to reduce the capital cost of the cogeneration system, and thus the investment payback period, by 8 percent,[40] thereby reducing a project's payback period and increasing the likelihood that the project will be undertaken. The result is higher overall economic potential and higher annual additions, as a greater share of candidate sites find CHP sufficiently attractive to invest in it. For CHP systems with a 7-year tax life, the effect of the tax credit is reduced by increasing the depreciation period that can be used for tax purposes to 15 years. For those companies with no current liability, the tax credit would have no impact.

Although a small amount of refinery CHP is projected to be induced by the tax credit, the impact is likely to be significantly attenuated by other capital demands that are being placed on the refining industry. Over the next few years, the refinery industry must make substantial capital investments to meet fuel quality and plant emissions requirements of the Clean Air Act Amendments and upcoming regulations.[41] The most costly capital spending requirement for the industry is likely to be a restriction on the allowable sulfur content of all gasoline. The U.S. Environmental Protection Agency (EPA) has determined that reduced sulfur levels in gasoline are necessary to reduce vehicle emissions.[42] Thus, in early 1999, the EPA is expected to propose a reduction in the average allowable

[39]U.S. Department of Energy, *Analysis of Energy-Efficiency Investment Decisions by Small and Medium-Sized Manufacturers*, DOE/PO-0043 (Washington, DC, March 1996), Table 4-2. The same study reported that more than 40 percent of energy conservation projects with an immediate payback were not undertaken.

[40]The effective reduction in payback period is somewhat less than 8 percent. This results from the lower present value of depreciation allowances, since the depreciable basis is reduced by the amount of the credit.

[41]Investments should be nearing completion that will allow refineries to produce reformulated gasoline to meet reduced emissions requirements in January 2000. Capital investments may also be required to meet new standards that will reduce emissions of hazardous air pollutants (HAPS) from certain refinery units by 2002. In addition to these Federal requirements, separate gasoline requirements being adopted by States may require further investments. For instance, the State of Georgia has a requirement that the Atlanta area must use gasoline with reduced volatility and sulfur content. Upcoming rulemakings that would reduce the allowable sulfur content of gasoline and diesel are expected to require sizable investments. Further expenditures may also be required if concerns about methyl tertiary butyl ether (MTBE) contaminating water supplies lead to restrictions on its use as an oxygenate in gasoline.

[42]U.S. Environmental protection Agency, Office of Mobile Sources, *EPA Staff Paper on Gasoline Issues*, EPA-420-R-98-005 (Washington, DC, May 1998).

sulfur content of gasoline to 30 parts per million (ppm)—down from the current average of 340 ppm.[43] Although the exact level of sulfur reduction is unknown, refineries seem likely to shift planning and investment toward clean fuels, rather than CHP, in the face of mounting pressure from the EPA, environmentalists, and automobile manufacturers.

The oil and gas production industry is also unlikely to expand the use of CHP for enhanced oil recovery (EOR) within the 2000-2002 period. Current low crude oil prices would not support an increase in steam production from EOR development. About 20 percent of EOR capacity has been idled, and that capacity would be returned to service before new plants or additions were built. In this economic environment, an 8-percent tax credit for investment in CHP equipment is not likely to induce additional CHP for EOR steam production.

Results

In the reference case for this analysis,[44] 873 megawatts of new cogeneration capacity are projected to be added between 2000 and 2002 (Table 12). In the CCTI analysis case, an additional 190 megawatts of new CHP capacity is projected to be installed during the 3-year period.[45] However, all the capacity projected to be added in the 2000-2002 period—1,064 megawatts—would qualify for the credit. If the average system capital cost were $1,000 per kilowatt, the total reduction in projected tax revenues would be $85 million. If capacity additions that would have occurred in the absence of the tax credit in 1999 or 2003 were moved to the 2000-2002 window, total additions qualifying for the ITC would be 1,567 megawatts, bringing the total reduction in tax revenues to $125 million.[46]

Table 12. Projected Effects of the CCTI Tax Credit on Traditional Industrial Cogeneration, 2000-2002

Cumulative Capacity Additions in the Reference Case (Megawatts)	873
Incremental Capacity Additions in the CCTI Analysis Case (Megawatts)	190
Cumulative Capacity Additions in the CCTI Analysis Case (Megawatts)[a]	1,064 to 1,567
Reduction in Projected Tax Revenues (Million Dollars)	85 to 125
Net Carbon Reduction, 2002 (Million Metric Tons)	0.150

[a]The range results from the possibility that currently planned additions will be moved from 1999 or 2003 to take advantage of the CCTI tax credit.

Source: Energy Information Administration, National Energy Modeling System runs AEO99R.D033099A and CCTITAX.D033099A.

The increased penetration of CHP is likely to reduce carbon emissions overall. Although an increase in CHP would increase total industrial fuel consumption, the resulting reduction in electricity purchases would displace fuel used by central power stations. With CHP, the incremental amount of fuel used to produce a unit of electricity is generally

[43]Low-sulfur gasoline specifications will be implemented in NEMS when the regulations are finalized. EPA estimates that low-sulfur gasoline will cost 1 to 3 cents more per gallon. Because gasoline sulfur and automotive emissions are linked, the proposal will be issued in conjunction with the new “Tier 2” vehicle exhaust emissions standards, which would take effect between 2004 and 2007. Also expected in 1999 is a preliminary notice of proposed rulemaking that would reduce the sulfur content of diesel fuel to accommodate reductions in emissions of NO_x and particulates.

[44]The reference case for this analysis differs slightly from the reference case used for the *Annual Energy Outlook 1999*. The difference reflects the revised methodology used to project cogeneration.

[45]Note that this estimate does not include the “bunching effect” that could arise if projects that would have been undertaken without the credit in 1999 or 2003 were moved to the 2000-2002 window to take advantage of the tax credit.

[46]By comparison, in “President Clinton’s FY 2000 Climate Change Budget,” p. 2, the Administration estimates that the credit will reduce tax revenues by $332 million. Assuming that the installed cost for CHP systems averages $1,000 per kilowatt, this implies that the Administration anticipates that qualifying CHP additions during the 3-year period will be 3,750 megawatts. It is not known what portion of the Administration’s tax revenue reduction estimate is due to unintended beneficiaries.

lower than for central power stations. Increased CHP reduces purchased power requirements and leads to lower emissions from central-station electricity producers. Because additional natural gas is required for CHP, higher site emissions result. The net carbon reduction is the difference between the reduced central-station emissions and the increased site emissions. For presentation purposes, the net change in carbon emissions is attributed to the industrial sector. The CCTI tax incentive has the potential to reduce carbon emissions by 0.15 million metric tons per year—less than 0.1 percent of the 512 million metric tons of industrial carbon emissions projected for 2002. There may, however, be additional reductions in other pollutants that would contribute to the environmental benefits of the projects.

The results presented above could be altered significantly if a variety of institutional barriers that impede CHP projects could be reduced. For example, EPA has encouraged States to provide CHP plants with set-aside allowances in their proposed NO_x trading program.[47] One result of reduced institutional impediments could be a greater willingness to invest in CHP projects with longer payback periods, because the required payback period incorporates the potential for unforeseen complications and delays due to existing institutional arrangements, as well as the strictly financial aspects of a project. To assess the effects of this possibility, a sensitivity analysis was conducted assuming that a much longer (approximately doubled) payback period would be acceptable. The sensitivity analysis indicated that as much as 645 megawatts of additional new CHP capacity could be induced. In this situation, net carbon reductions of 0.5 million metric tons could occur.

The cost of the CHP tax incentive program would be higher if nontraditional cogenerators (merchant plants) were able to qualify for the credit. Nontraditional cogenerators are facilities built mainly to sell power. Because their production of useful thermal energy is typically small relative to their power output, the total system efficiency of merchant units is below the minimum threshold specified in the CCTI proposal. In NEMS, merchant facilities are treated as simple electricity power plants rather than as cogenerators; however, they could have a more significant impact if some regulatory burdens and uncertainties were reduced. For example, establishing a uniform interconnection standard could lead to more additions of merchant power plant capacity, as well as more traditional cogeneration capacity.

Because the proposed investment tax credit would expire in 2002, no additional induced change is projected after 2002. It is possible, however, that a "momentum" effect could lead to some additional inducement even after the tax credits expire (Table 13). In 2010, carbon emissions are projected to be 0.15 million metric tons (less than 0.1 percent) lower than in the reference case.

Finally, the analysis indicates that there could be a high ratio of unintended beneficiaries for this program. The projected ratio of unintended beneficiaries (capacity that would be added in the absence of the credit) to induced capacity additions is more than 4 to 1, in part because of the short time frame for the proposed credit. It takes 18 to 36 months to plan, design, and install new CHP capacity and perhaps much longer for district energy systems, and most of the facilities that would qualify for the credit would also be installed without it. Further, the proposed tax credit would shorten the payback period for investments in new CHP capacity by less than 3 months—a marginal benefit that is unlikely to affect the economic decision for most firms.

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[47] U.S. Environmental Protection Agency, Office of Atmospheric Programs, Office of Air and Radiation, *Guidance on Establishing an Energy Efficiency and Renewable Energy (EE/RE) Set-Aside in the NOx Budget Trading Program* (Washington, DC, March 1999).

Table 13. Projected Effects of the CCTI Tax Credit for Traditional Combined Heat and Power (CHP) Systems, 2005, 2010, and 2020

Projection	1997	2005		2010		2020	
		Reference Case	CCTI Case	Reference Case	CCTI Case	Reference Case	CCTI Case
CHP Capacity (Gigawatts)	23.1	25.3	25.5	26.4	26.6	27.9	28.1
CHP Generation (Billion Kilowatthours)	154.8	165.0	166.4	172.6	174.0	181.8	183.3
Industrial Carbon Emissions (Million Metric Tons)	482.1	520.2	520.0	546.9	546.7	579.4	579.3

Note: Carbon emissions for the CCTI case cannot be taken directly from an integrated NEMS run because of the interaction effects.
Source: Energy Information Administration, National Energy Modeling System runs AEO99R.D033099A and CCTITAX.D033099A.

Transportation

Background

Sales of alternative-fuel vehicles (AFVs) and advanced vehicle technology (AVT) vehicles are expected to make up approximately 4 percent of all U.S. light-duty vehicle (LDV) sales in 1998.[48,49] More than 58 percent of those sales are alcohol flexible vehicles, which can run on any combination of alternative fuel and gasoline, and 41 percent are AFVs that use either compressed natural gas (CNG) or liquid petroleum gas (LPG). The remaining 1 percent are electric vehicles.

The electric vehicles currently available (Table 14) average 17 to 30 percent higher fuel efficiency than comparable conventional gasoline vehicles. Whereas conventional gasoline vehicles achieve only about 18 to 28 percent efficiency in combustion, electric vehicle motors have almost no loss in thermal efficiency. On the other hand, approximately 66 percent of the primary energy used to produce electricity is lost in production and transmission.

Table 14. Electric Vehicles Currently Available in U.S. Markets and Announced Dates of New Production Prototypes

Manufacturer	Currently Available Electric Vehicles	Production Prototype Availability Dates	
		Hybrid Electric Vehicles	Fuel Cell Vehicles
Chrysler	Epic minivan	—	Gasoline: 2010 Hydrogen or Methanol: 2004
Ford	Ranger pickup	—	2004
GM	EV1 two seater S-10 pickup	2001	2004
Honda	EV Plus compact	1999	2003
Nissan	Altra minivan	1999	2005
Toyota	RAV 4 sport utility	2000[a]	2003

[a]The Toyota Prius hybrid electric vehicle, already being marketed in Japan, will be available to U.S. buyers in 2000.
Sources: *Electric Vehicle Today* and *Alternative-Fuels Today* (various issues, 1999).

[48]Energy Information Administration, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998).
[49]AFVs are vehicles that use alternative fuels (other than gasoline or diesel fuel). AVT vehicles use advanced vehicle technologies but consume conventional fuels (examples include gasoline-electric hybrids, diesel-electric hybrids, and gasoline fuel cells). LDVs include all passenger cars, minivans, sport utility vehicles, and pickup trucks.

Hybrid electric vehicles are just beginning to enter the marketplace. For example, the Toyota Prius, scheduled for introduction in the U.S. market in 2000, uses a gasoline engine and regenerative braking to restore power to an electric battery that runs the vehicle motor. It has been advertised as having reached 66 miles per gallon (mpg) in the Japanese fuel efficiency test cycle, but in the U.S. Federal test procedure (FTP) cycle it has been rated at only 50 to 55 mpg.

Fuel cell vehicle technology is still in the early stages of development. Only a few test vehicles—buses in the Chicago Transit Authority fleet—have been sold, and some mechanical problems with those have been reported. Fuel cell vehicles have the potential to increase fuel economy relative to conventional gasoline vehicles by some 72 percent with gasoline as a fuel, 84 percent with methanol, and 100 percent with hydrogen.

Tax Credits for Electric, Electric Hybrid, and Fuel Cell Vehicles

The CCTI proposes the following tax initiatives for LDVs:

- For qualifying electric and fuel cell vehicles, the current 10-percent tax credit, subject to a $4,000 cap, would be extended at its full level through 2006. The credit currently is scheduled to be phased down beginning in 2002 and eliminated by 2005.

- For qualifying electric hybrid vehicles, graduated tax credits are proposed:

  - $1,000 for each vehicle purchased after December 31, 2002, and before January 1, 2005, that is 33 percent higher in fuel efficiency than a comparable vehicle in its class

  - $2,000 for each vehicle purchased after December 31, 2002, and before January 1, 2007, that is 66 percent higher in fuel efficiency than a comparable vehicle in its class

  - $3,000 for each vehicle purchased after December 31, 2003, and before January 1, 2007, that is twice as high in fuel efficiency as a comparable vehicle in its class

  - $4,000 for each vehicle purchased after December 31, 2003, and before January 1, 2007, that is three times as high in fuel efficiency as a comparable vehicle in its class.

  In order for hybrid vehicles to qualify they must have regenerative braking and an energy storage system that will recover at least 60 percent of the energy used in braking from 70 to 0 mph.

All qualifying vehicles must meet or exceed all emissions requirements for gasoline vehicles.

Analytical Approach

The NEMS transportation module represents conventional gasoline vehicles (including direct injection gasoline technology and 58 other fuel-saving technologies), diesel turbo direct injection, alcohol (both methanol and ethanol) flexible fueled and dedicated vehicles, gaseous (both CNG and LPG) dedicated and bi-fuel vehicles, electric vehicles, electric hybrid (gasoline and diesel) vehicles, and fuel cell vehicles (methanol, hydrogen, and gasoline reformers). Each AFV/AVT technology is evaluated within each of the 12 EPA size classes for both cars and light trucks. For this analysis, the following consumer purchase criteria were evaluated:[50] (1) vehicle price, (2) cost of driving per

[50]Consumer purchase (market penetration) criteria were based on the U.S. Department of Energy's National Alternative-Fuel Vehicle Survey and were implemented in the NEMS transportation module by EIA's Office of Integrated Analysis and Forecasting in coordination with the U.S. Department of Energy, Office of Transportation Technologies, and Argonne National Laboratory.

mile (fuel price divided by fuel efficiency), (3) vehicle range, (4) top speed, (5) acceleration, (6) multiple fuel capability, (7) maintenance cost, (8) luggage space, and (9) fuel availability.

It was assumed that there would be no new requirements or additional costs for catalysts, engine design changes, or advanced reformulated fuels to meet EPA vehicle emissions standards. If stricter EPA standards are passed, they could lower the market penetration rates and carbon emissions reductions projected in this analysis.

The following assumptions were made in modeling the CCTI analysis case:

- All electric vehicles and fuel cell vehicles were provided with a $4,000 vehicle price reduction relative to the reference case price through 2006. The date of commercial availability for fuel cell vehicles was changed from 2010 in the reference case to 2006.[51]
- All electric hybrid vehicles were provided with the tax incentives specified in the CCTI proposal, based on the average fuel efficiency of a comparable gasoline vehicle in each EPA size class. Gasoline-electric hybrids were assumed to be commercially available by 2001 and diesel-electric hybrids by 2005 (both the same as in the reference case).

Results and Discussion

The results for the CCTI analysis case show an early increment in sales of electric vehicles—8,620 total sales in 2002, compared with 8,260 in the reference case. By 2010, however, the projected sales are approximately the same in the two cases at about 299,280 units (Table 15). Sales of fuel cell vehicles, which are assumed to be available at the very earliest by 2006, are projected to total approximately 870 units in 2006, rising to 4,630 in 2010 and 18,430 in 2020 in the CCTI case. Projected sales of hybrid vehicles—particularly, gasoline-electric hybrids—are significantly higher in both cases (at more than 871,000 vehicles) than are sales of either electric vehicles or fuel cell vehicles. Hybrids are anticipated to be available in U.S. markets by 2000, and the technology allows for vehicle characteristics that are similar to those of conventional gasoline vehicles—especially the most important consumer purchase criterion, vehicle price (see discussion below).[52]

Total AFV/AVT sales in the CCTI case represent 6.2 percent of all LDV sales in 2010 (Table 15). Moreover, most of the projected sales also occur in the reference case. Because the proposed CCTI tax incentives would be in effect only through 2006, no significant additional accumulation of AFV/AVT vehicles is projected, even by 2010. Consequently, projected LDV fuel consumption in the CCTI case does not differ significantly from that in the reference case (Table 16). The difference in 2005 is less than 0.5 trillion Btu, consisting almost entirely of a reduction in gasoline consumption. The difference in 2010 is only 0.77 trillion Btu (0.002 percent of total transportation fuel consumption), and in 2020 it is just 0.71 trillion Btu. As a result, the reduction in projected carbon emissions from transportation energy use in the CCTI case relative to the reference case is only about 0.003 million metric tons in 2010—representing just 0.0004 percent of total carbon emissions for the transportation sector (Table 17). In 2020, the CCTI case results in a reduction of 0.01 million metric tons of carbon.

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[51]According to the Partnership for a New Generation of Vehicles (PNGV) program, the earliest possible availability date for a production prototype fuel cell vehicle would be 2004. Chrysler has announced that a production prototype will be available by 2004. Inherent in the 2006 date is a 2-year period to convert production prototypes to actual production vehicles and to modify production lines and facilities.

[52]Only in the State of California may manufacturers meet up to 60 percent of the Low Emission Vehicle Program's Zero-Emission Vehicle (ZEV) mandates with sales of electric hybrid vehicles. However, electric hybrid vehicles receive no more than approximately 30 to 60 percent of one ZEV credit. For example, the Toyota Prius would receive 0.32 ZEV credits. Therefore, electric hybrid sales could be higher in California.

Table 15. Light-Duty Vehicle Sales by Technology Type, 1997-2020
(Thousands)

Vehicle Type	1997	2002		2005		2010		2020	
		Reference Case	CCTI Case	Reference Case	CCTI Case	Reference Case	CCTI Case	Reference Case	CCTI Case
Electric	0.7	8.3	8.6	281.9	283.8	299.3	299.3	299.5	299.5
Fuel Cell	0.0	0.0	0.0	0.0	0.0	4.6	4.6	18.4	18.4
Diesel-Electric Hybrid	0.0	2.3	2.4	21.7	23.5	37.2	39.0	29.2	30.6
Gasoline-Electric Hybrid	0.0	29.0	29.0	198.0	200.2	579.3	579.3	871.9	871.9
All Light-Duty vehicles	13,618	13,274	13,274	13,836	13,836	14,780	14,780	14,893	14,893

Source: Energy Information Administration, National Energy Modeling System runs AEO99TRN.D040699A and AEO99TRN.D040699B.

Table 16. Light-Duty Vehicle Fuel Consumption by Fuel Type, 1997-2020
(Trillion Btu)

Fuel Type	1997	2002		2005		2010		2020	
		Reference Case	CCTI Case	Reference Case	CCTI Case	Reference Case	CCTI Case	Reference Case	CCTI Case
Gasoline	13,902.29	15,521.09	15,521.10	16,309.65	16,308.95	17,444.84	17,443.62	18,604.64	18,603.44
Distillate Fuel	7.43	6.93	6.95	12.48	12.68	46.90	47.46	170.09	171.06
Methanol	1.17	31.21	31.20	50.91	50.75	75.95	75.71	108.45	108.24
Ethanol	0.53	17.76	17.75	30.00	29.90	50.81	50.65	74.06	73.92
Compressed Natural Gas	11.91	108.78	108.77	172.82	172.73	234.07	233.94	294.28	294.17
Liquefied Petroleum Gas	20.97	60.38	60.37	104.38	104.30	154.50	154.37	199.21	199.11
Electricity	0.29	3.10	3.12	40.38	40.82	83.44	83.97	147.48	147.57
Hydrogen	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.12	0.12
Total	**13,944.59**	**15,749.26**	**15,749.25**	**16,720.61**	**16,720.12**	**18,090.53**	**18,089.76**	**19,598.34**	**19,597.63**

Source: Energy Information Administration, National Energy Modeling System runs AEO99TRN.D040699A and AEO99TRN.D040699B.

Table 17. Transportation Sector Carbon Emissions by Fuel Type, 1997-2020
(Million Metric Tons)

Fuel Type	1997	2002		2005		2010		2020	
		Reference Case	CCTI Case	Reference Case	CCTI Case	Reference Case	CCTI Case	Reference Case	CCTI Case
Petroleum	461.9	521.9	521.9	552.0	552.0	600.7	600.6	664.7	664.7
Natural Gas	10.5	12.8	12.8	14.7	14.7	16.7	16.7	19.5	19.5
Electricity	2.9	3.3	3.3	5.2	5.3	7.6	7.6	11.2	11.2
Other	0.0	0.5	0.5	0.9	0.9	1.3	1.3	1.9	1.9
Total	**475.3**	**538.6**	**538.6**	**572.8**	**572.9**	**626.2**	**626.2**	**697.3**	**697.3**

Source: Energy Information Administration, National Energy Modeling System runs AEO99TRN.D040699A and AEO99TRN.D040699B.

Projected AFV / AVT vehicle sales and the corresponding reductions in Federal tax revenues in the CCTI analysis case are shown in Table 18. In 2003, the reduction in tax revenues totals just over $725 million, growing to $1.58 billion in 2005 and $1.75 billion in 2006. The total proposed allocation of Treasury funds for the CCTI tax incentives is $900 million for the years 2000 to 2004, as estimated by the Administration, compared to $1.96 billion in this analysis.

Table 18. Projected Vehicle Sales and Reductions in Projected Tax Revenues in the CCTI Analysis Case by Vehicle Type, 2002-2006

Vehicle Type	2002		2003		2004		2005		2006	
	Reference Case	CCTI Case	Reference case	CCTI Case	Reference Case	CCTI Case	Reference Case	CCTI Case	Reference Case	CCTI Case
Vehicle Sales (Thousands)										
Electric	8.3	8.6	277.2	278.4	278.3	279.9	281.9	283.8	284.7	286.5
Fuel Cell	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.9
Gasoline-Electric Hybrid	29.0	29.0	70.3	70.3	123.6	129.8	198.0	200.2	266.4	271.8
Diesel-Electric Hybrid	2.3	2.4	11.9	12.9	16.5	17.9	21.7	23.5	26.4	28.5
Total	**39.6**	**40.0**	**359.4**	**361.6**	**418.4**	**427.6**	**501.6**	**507.5**	**578.3**	**587.7**
Tax Revenue Reductions (Million 1997 Dollars)										
Electric	24.8	34.5	554.5	1,113.4	278.3	1,119.5	0.0	1,135.2	0.0	1,146.1
Fuel Cell	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5
Gasoline-Electric Hybrid	0.0	58.0	0.0	140.7	0.0	259.6	0.0	400.4	0.0	543.5
Diesel-Electric Hybrid	0.0	4.9	0.0	25.8	0.0	35.9	0.0	47.0	0.0	57.1
Total	**24.8**	**97.3**	**554.5**	**1,279.9**	**278.3**	**1,414.9**	**0.0**	**1,582.6**	**0.0**	**1,750.2**

Source: Energy Information Administration, National Energy Modeling System runs AEO99TRN.D040699A and AEO99TRN. D040699B.

The results above suggest that the proposed CCTI tax initiatives for LDVs would not yield many additional AFV / AVT sales above those projected in the reference case. Consequently, most of the tax benefits would go toward consumer purchases that would have been made even without the proposed tax incentives (more than 98 percent of AFV / AFT sales in 2004)—because of the sales mandated by the Low Emission Vehicle Program in California, New York, and Massachusetts and those resulting from the tax incentives for electric and fuel cell vehicles in EPACT. The CCTI tax initiatives would, however, provide additional incentives for manufacturers to comply with the mandates of the Low Emission Vehicle Program. Additional benefits would result from a reduction in vehicle emissions of criteria pollutants other than carbon, because electric and fuel cell vehicles are zero emission vehicles.

Why are the projected effects of the CCTI tax incentive program for LDVs so marginal? The answer is suggested by an analysis of the barriers to AFV / AVT penetration of the U.S. LDV market. Again, the following criteria are likely to be considered by prospective purchasers: (1) vehicle price, (2) cost of driving, (3) vehicle range, (4), top speed, (5) acceleration, (6) multiple fuel capability, (7) maintenance cost, (8) luggage space, and (9) fuel availability.

The most important consideration in consumer purchase decisions is vehicle price. In the reference case, at low production volumes of approximately 2,500 vehicles per year, the price of an electric, hybrid, or fuel cell vehicle is approximately $10,000 higher than that of a comparable gasoline vehicle. And even at sales volumes approaching 25,000 units per year, the cost differential still would be about $7,000 for electric vehicles, $7,000 for hybrids, and

$2,000 for fuel cell vehicles. Although the CCTI tax initiative would reduce the vehicle price, the effective reduction would amount to only about $4,000 off the reference case price of $10,000 for a compact fuel cell vehicle in 2005.[53,54]

In terms of driving costs, even with the lower vehicle prices at higher sales volumes, consumers may not receive sufficient payback through fuel savings to encourage AFV/AVT purchases if gasoline prices remain low.[55] Because 75 percent of the vehicles purchased in the United States are still on the road after 10 years, vehicle purchases generally are long-run decisions. The pattern of fuel prices over the recent past can be expected to raise doubts among consumers about the prospects for long-term increases in the future. Gasoline prices rose by 31.6 cents a gallon (in 1997 dollars) from 1973 to 1974, but by 1978 they were only 14.5 cents above 1973 levels. From 1978 to 1979, prices rose by 47.1 cents a gallon, only to fall below 1978 prices by 1983. Although consumers switched their purchasing patterns toward smaller cars and away from larger cars during the oil crises, those short-term fuel price spikes caused only short-run adjustments in vehicle purchasing patterns. Moreover, although AFV/AVT fuel economies (miles per gallon) are expected to be significantly higher than those of conventional gasoline vehicles, their driving costs per mile also are likely to remain significantly higher. As long as gasoline prices remain low, electricity will be a more expensive vehicle fuel. Hydrogen currently is more than twice as expensive as gasoline and, at any rate, is not available to the average consumer.

Vehicle range, top speed, and acceleration may also pose barriers to consumer acceptance. For example, electric vehicles can travel a maximum of one-fourth to one-sixth the distance that a conventional gasoline vehicle can travel before refueling. Top speeds generally are similar for the advanced technologies and gasoline vehicles, but all the new technologies have significant acceleration drawbacks that would require higher horsepower and larger engines to match the performance of conventional vehicles, which in turn would reduce their fuel economy.[56]

After price, reliability or quality is often cited as the most important purchase criterion by consumers, who are wary of high maintenance costs. Unfortunately, the maintenance costs for AVT vehicles are virtually unknown. Mechanics are not currently being trained to repair and maintain the vehicles, and the availability and cost of replacement parts are uncertain. For present-day electric vehicles, which use lead-acid batteries, the batteries must be replaced approximately every 3 years at a cost of more than $10,000 for each replacement. Nickel-metal hydride batteries provide 50 percent greater vehicle ranges and last twice as long as lead-acid batteries, but they cost more than four times as much. Lithium-ion batteries can extend vehicle ranges to approximately three times those of lead-acid batteries and may not require replacement during the life of the vehicle, but their costs can be as much as 10 times that of a lead-acid battery.

[53]There is a great deal of uncertainty associated with incremental vehicle cost for present advanced technology vehicles as well as in the future. *Automotive Issues* has estimated the Prius incremental cost to be approximately $15,000 (see *Automotive Issues*, Trends Issue, March 1998). DOE's Office of Transportation Technologies has estimated the incremental vehicle cost at about $4,000 (see U.S. Department of Energy, *Technology Costs of the Toyota Prius*, July 16, 1998); however, the incremental cost does not include vehicle price markups. Toyota has said that the Prius will sell for more than $15,500 but less than $22,000, implying an incremental cost of up to $7,000 including the markup (see *Electric Vehicle Today*, August 27, 1998).

[54]Although some manufacturers have offered price incentives up to approximately $2,000 for advanced vehicles, it is not clear whether they will continue to do so, especially since past vehicle price incentives usually have been offered only for the first 2 years after their introduction.

[55]Energy Information Administration, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), p. 116.

[56]Toyota has publicly announced that it would not introduce the Prius into the U.S. market without improving the efficiency of the ambient vehicle temperatures (air conditioning and heating) and increasing the performance to match recent U.S. consumer demand. Both alterations to the original Prius design will lower its fuel economy.

Interior volume and luggage space are also of concern to potential purchasers, especially with regard to electric battery packs or fuel cell stacks, which may significantly reduce the interior volume. Electric vehicles are likely to be limited in availability to smaller vehicles, because the expense of batteries needed to power larger vehicles would be prohibitive. Two electric minivans are currently on the market (see Table 14), but their purchase price is approximately $100,000 per vehicle. Fuel cell vehicles, in contrast, may only be available in the larger size classes, because of the size and weight of the fuel cell stacks.

Finally, fuel availability is one of the most important barriers to AFV/AVT market penetration. Infrastructure problems are important issues for the production and distribution of both methanol and hydrogen fuel. Methanol refueling stations are sparsely scattered in most States, although more are available in California. Electricity is available in nearly all U.S. homes, but recharging stations are just beginning to appear. Moreover, the recharging time for most electric vehicles is between 3 and 8 hours.

In addition to the above concerns that are expected to dampen the enthusiasm of consumers for AFV/AVT purchases, emissions and environmental issues also pose significant hurdles for the new vehicle technologies. For example, electric vehicles are nearly emissions-free while in operation, but their ability to provide net emissions reductions depends on the primary energy source used to generate the electricity that fuels them. Coal-burning electricity generation provides few benefits relative to gasoline-burning vehicles. Still another environmental issue for electric vehicles is the potential impact of rapid production, elimination, and recycling of vehicle batteries on a large scale.

Emissions issues may also pose problems for diesel-electric hybrid vehicles. Advances in diesel technology have significantly reduced their noise and emissions of particulates, but high levels of nitric oxides and particulates may present significant health problems. EPA is currently revising its NO_x and particulate emissions standards as mandated by Congress under the Clean Air Act Amendments of 1990, and recent regulations passed by the California Air Resources Board are expected to eliminate diesel technologies from further consideration as solutions to higher fuel economy unless they use advanced catalysts and/or new types of low-sulfur or reformulated diesel fuel.

Advanced low-sulfur, low-benzene, and reformulated fuels in combination with advanced catalysts are currently being explored, and Fischer-Tropsch fuels (derived from refinery waste products and natural gas) also are potential candidates for use with advanced diesel technologies. Studies have shown that these advanced diesel fuels and derivatives can reduce both NO_x and particulate emissions by as much as 80 percent. At present, however, the fuels are not cost-competitive with either gasoline or diesel fuel.

Vehicle stock turnover is also very slow in the personal vehicle market, which accounts for the lack of fuel savings and carbon emissions reductions by 2010. Even 1 million vehicle sales amount to just 0.4 percent of the vehicle stock, which is projected to total some 230 million vehicles by 2010.

Renewable Electricity Generation

Background

The proposed CCTI tax initiatives include several provisions aimed at increasing the utilization of zero-carbon fuels, such as wind and biomass, in the generation of electricity. It is hoped that the programs will spur the development of zero-carbon generating technologies and lower their costs in the future. Such incentives for renewable fuels are not entirely new. EPACT (P.L. 102-486) established production incentives for new biomass and wind-powered generating facilities, but their impact has been fairly small.

EPACT provides qualifying new wind and biomass facilities with a 1.5-cent subsidy (adjusted for inflation since 1992) for each kilowatthour of electricity they produce during their first 10 years of operation. In effect, the subsidy reduces the per-kilowatthour cost of new wind plants by 20 to 25 percent and the per-kilowatthour cost of new biomass plants by 20 to 30 percent. To qualify, a new wind plant must have come on line between January 1, 1994, and June 30, 1999 (June 30, 2003, for those brought on by publicly owned entities). For qualifying biomass plants the beginning date is January 1, 1993. The program differs slightly for facilities built by private and public entities. For private companies, the subsidy is paid through a production tax credit (PTC), and biomass plants must be closed-loop facilities to qualify.[57] For public entities, the subsidy is paid by DOE through a renewable energy production incentive (REPI), and the definition of qualifying biomass facilities is much broader.

So far, the REPI and PTC have resulted in only limited additions of biomass and wind generating capacity. No biomass capacity has been built in response to the PTC, because technologies for closed-loop biomass are not yet commercially available. For wind, incentive programs other than the PTC appear to have contributed to the capacity builds during the EPACT PTC period (Table 19). Very little wind capacity was added during the early years of the PTC. Of the 886 megawatts[58] of new wind generating capacity either on line or expected before the expiration of the EPACT PTC in 1999, only 87 megawatts entered service before 1998, of which 31 megawatts are clearly associated with programs independent of the PTC. Of the remaining nearly 800 megawatts, 577 have been encouraged by other programs, principally State mandates, most of which began in 1998. For example, in Minnesota, Northern States Power is legislatively mandated to build 425 megawatts of new wind power, over 240 megawatts of which is expected to be added in 1998 and 1999. Only 223 megawatts of the capacity expected to be added over the 1998 to 1999 period appear to be coming on without a specific mandate. However, even these additions appear to have been influenced by additional factors, including testing, demonstration, and green power programs and other environmental initiatives. Further, the vast majority of the capacity, 602 megawatts, is expected to enter service in 1999, at the end of the PTC period. Some of this capacity probably would have been built in 2000 or later but is being brought on earlier to take advantage of the existing PTC.

Because so little capacity has been added, the revenue effects of the existing PTC and REPI programs are fairly limited. For wind power, PTC-related tax expenditures (tax revenues not received) through 1997 are estimated at less than $4 million, rising to $16.3 million in 1998. If the capacity expected to be added in 1999 is built before the expiration of the PTC, tax revenue reductions this year could rise to a maximum of $55.6 million. For biomass, Federal appropriations data indicate that REPI payments have been made to two biomass plants and eight landfill gas plants. REPI payments for biomass and landfill gas plants were $2.7 million in 1998.

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[57]Closed-loop biomass facilities are fueled by organic material from crops that are planted exclusively for use in electricity production.
[58]This value excludes about 60 megawatts of repowered wind plants in California that are able to qualify for the EPACT PTC.

Table 19. New U.S. Wind Generating Capacity Concurrent with the EPACT Production Tax Credit, 1994-1999
(Megawatts)

Program[a]	Capacity Added Before State Mandates (1994-1997)	Capacity Added After State Mandates (1998-1999)	Total Capacity Added (1994-1999)
Renewable Energy Production Incentive (REPI)	6	2	8
State Mandate	25	575	600
State Renewable Portfolio Standard (RPS)[b]	0	0	0
No Mandate	56	223	278
Total	**87**	**800**	**886**

Note: Totals may equal sum of components due to independent rounding.
[a]Program designations are EIA estimates.
[b]Capacity effects of State renewable portfolio standards begin in 2000.
Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

Climate Change Technology Initiative

The CCTI extends the PTC for wind and biomass for 5 years, through June 30, 2004. In addition, the proposal would expand the types of plants qualifying for the biomass subsidy while slightly narrowing the types of plants qualifying for the wind subsidy. The definition of eligible biomass sources is broadened from only closed-loop biomass to include any solid, nonhazardous, cellulosic waste material that is segregated from other waste materials, and that is derived from the following forest-related sources: mill residues, pre-commercial thinnings, slash, and brush other than old growth timber. Also included would be pallets, crates and dunnage, trimmings, and agricultural byproducts or residues. In essence, this would expand the credit to those facilities that can use wood residues and wood wastes to generate electricity for sale to customers (self-generation does not qualify).

In addition to broadening the definition of eligible biomass, the proposal also provides a 1.0-cent PTC (adjusted for inflation from the 1999 base) for biomass that is co-fired in coal plants to produce electricity during the period July 1, 1999, through June 30, 2004. Unlike the PTC for new wind and biomass plants, the co-firing PTC does not continue for the first 10 years during which a plant co-fires but remains in effect only from 1999 through 2004. This credit would apply to all facilities that are co-firing biomass with coal, including those that are already doing so. For wind, although no final decisions have been made, it is currently believed that the repowering of existing capacity will be excluded from the PTC extension. Therefore, EIA has assumed that no additional existing wind generating capacity (beyond the 260 megawatts covered under current rulings) will receive credits for repowering.

Methodology

For this analysis, the PTC for wind and biomass was modeled in the NEMS electricity market and renewable fuels modules, with no feedback from other NEMS modules. Because the vast majority of biomass-based cogeneration is consumed on site, and therefore is not eligible for the credit, cogeneration was not considered in the analysis. In order to test the potential impacts of the CCTI, it was assumed that the PTC would be extended by 5 years, through 2004.

In the reference case for the analysis, the date of commercial availability for new biomass-fired units (expected to be integrated gasification combined-cycle facilities) was assumed to be 2005, past the period in which new units would qualify for the CCTI tax credit. A few biomass gasification demonstration units are expected to come on line over the next few years, but the technology is not expected to be commercially available until those units have gone through several years of testing. For the CCTI case, the 2005 commercial availability date was maintained, effectively limiting the facilities able to take advantage of the PTC to the expected demonstration units. Fuel inputs were also expanded to include currently available wood residues and waste in addition to dedicated energy crops, which are assumed not to be available until 2010. While it is plausible that the PTC could encourage the construction of some older, less efficient direct-fired biomass boiler units, that technology was not specifically modeled. It is believed that the relatively low efficiency of direct-fired units would make them economically unattractive.

The model was also modified in the CCTI case to allow coal plants to use biomass for a portion of their fuel if it was economical. It was assumed that a coal plant could use biomass to displace up to 4 percent of the coal it would normally use. Current research has shown that a typical coal-fired boiler can fire from 3 to 5 percent biomass without a costly retrofit. Coal plants can consume larger shares of biomass, perhaps as much as 10 to 15 percent of their fuel, if new fuel handling systems are added and boiler firing equipment is modified. Such modifications are expensive, however ($250 or more per kilowatt of capacity), and the short length of the PTC for biomass co-firing makes it unlikely that plant operators would be willing to make such investments.

An offline analysis was performed to match the availability of relatively low-cost biomass with the amount of coal capacity in a State. The maximum co-firing share allowed in any region was the minimum of the available low-cost biomass and the available coal capacity (assuming the use of 4 percent biomass) matched at the State level. Because there were States where the match was not good—large amounts of biomass but few coal plants, or many coal plants but little biomass—the maximum amount of coal that could be displaced by co-firing with biomass was determined to be 1.8 percent nationally. (For example, Oregon has a substantial amount of mill residues that could be used for co-firing in coal plants, but there is very little coal-fired capacity in the State.) Among the regions in the model, the share varied from 0 to 4 percent.

In addition, because there are factors that may constrain the development of a biomass co-firing market that are not represented in the biomass supply curves used, several other modifications were made. The biomass supply curves do not include the costs and time associated with things such as ensuring that an adequate fuel supply is available near a specific plant, testing the fuel to see if plant modifications are needed, designing and making plant modifications, applying for any licenses that are needed, and, potentially, getting air permit changes approved. In addition, because many coal plant operators are in the midst of making changes to comply with new environmental regulations and preparing for a restructured electricity market, they are reluctant to entertain other changes at this time. To reflect the impact of these factors, the co-firing shares were phased in over time, and a hurdle rate was added to the cost of biomass fuels. In the reference case, the co-firing shares were phased in between 1999 and 2015, and a hurdle rate of 1 cent per kilowatthour was assumed. In other words, for biomass fuel to be considered, it had to lower the operating costs of the plant by 1 cent per kilowatthour. In the CCTI co-firing case, the shares were phased in between 1999 and 2005, and the hurdle rate was assumed to start at 1 cent before declining to 0.1 cent by 2005. Essentially it was assumed that the availability of the biomass co-firing PTC would lead to faster development of the biomass co-firing fuel market and a reduction in the costs incurred in preparing to use the fuel.

Results

Biomass

As discussed in the methodology section, because new biomass gasification plants are not expected to be commercially available until 2005, the extension and broadening of the biomass PTC does not lead to more capacity being added solely on an economic basis (Table 20). However, the extension of the PTC may encourage additional demonstration efforts. In the reference case, 248 megawatts of testing and demonstration plants were assumed to come on line within the PTC period. In the CCTI case, an additional 30 megawatts of biomass gasification demonstration plants, bringing the total to 278 megawatts, are expected to be added from 1999 through 2004. The increase in biomass generation and reduction in carbon emissions because of the 30 additional megawatts added in the CCTI case are small. In 2010, the carbon savings amount to 0.4 million metric tons, less than 0.1 percent of total electricity carbon emissions. However, because the full 278 megawatts added are expected to take the tax credit, the tax consequences are larger. In 2010, if all the expected demonstration plants took advantage of the PTC, tax collections would be $23 million lower. Approximately 11 percent of the tax savings would go to the 30 megawatts induced by the program, and the remaining 89 percent would go to capacity expected to be built even without the program.

Table 20. Projected Effects of the CCTI Biomass Energy Production Tax Credit, 2005, 2010, and 2020

Projection	1997	2005		2010		2020	
		Reference Case	CCTI Case	Reference Case	CCTI Case	Reference Case	CCTI Case
Biomass-Fired Generating Capacity (Gigawatts)	1.66	1.97	2.00	2.17	2.20	2.94	2.99
Biomass-Fired Electricity Generation (Billion Kilowatthours)	4.21	9.66	9.84	11.10	11.35	16.48	16.84
Total U.S. Carbon Emissions (Million Metric Tons)	1,480.0	1,676.3	1,676.2	1,784.3	1,783.9	1,951.8	1,951.4
Tax Revenue Reductions (Million 1998 Dollars)	—	—	32.92	—	23.36	—	0.00

Note: Excludes biomass co-firing at coal plants.
Source: Energy Information Administration, National Energy Modeling System runs CCTIBAS.D040799A and CCTIBIO.D040799A.

The results presented here hinge on the commercial availability of biomass gasification technology and the development of the needed biomass fuel supply within the PTC time frame. The near-term focus of the PTC will make this a challenge. Uncertainties regarding the development of biomass technology include availability and proximity of the biomass fuel supply; the economics, which are highly site specific; the potential of green power programs; and potential sulfur emissions, which have been reported for a Minnesota biomass plant that burns alfalfa.[59]

The biomass co-firing provision of the CCTI has a more significant impact than the PTC for new plants; however, because the co-firing credit expires in 2004, the impact declines somewhat in the later years. In 2004, electricity generation from co-fired biomass is projected to be 18.6 billion kilowatthours in the CCTI case, about 3.4 times the reference case level (Table 21). As a result, total carbon emissions are 3 million metric tons lower in that year. The cost of the subsidy is estimated to be about $595 million in tax revenue reductions, with about 38 percent going to facilities that would have used biomass co-firing without the PTC.

[59] Anecdotal information suggests that new units recently or about to come on line are using some specialized low-cost waste stream.

Table 21. Projected Effects of the CCTI Biomass Energy Co-firing Tax Credit, 2004, 2005, 2010, and 2020

Projection	1997	2004		2005		2010		2020	
		Reference Case	CCTI Case	Reference Case	CCTI Case	Reference Case	CCTI Case	Reference Case	CCTI Case
Co-fired Electricity Generation (Billion Kilowatthours)	0.1	5.4	18.6	6.3	15.2	7.2	15.7	6.7	13.5
Total U.S. Carbon Emissions (Million Metric Tons)	1,480.0	1,657.0	1,654.1	1,676.3	1,674.5	1,784.3	1,783.3	1,951.8	1,951.3
Tax Revenue Reductions (Million 1998 Dollars)	—	—	182.6	—	0.0	—	0.0	—	0.0

Source: Energy Information Administration, National Energy Modeling System runs CCTIBAS.D040799A and CCTICOF.D040799A.

It is assumed in this analysis that the PTC would encourage power plant operators and biomass fuel suppliers to overcome the hurdles that are keeping them from taking advantage of the low-cost supplies that appear to be available. For example, electricity producers might maintain their relationships with biomass fuel suppliers once the PTC has induced such purchases. A recent example of such a change is the use of low-sulfur subbituminous coal in boilers originally designed only for bituminous coal, encouraged by the sulfur emission reduction requirements of the Clean Air Act Amendments of 1990 (CAAA90). Before the CAAA90 requirements were implemented, it was believed that the plants could not burn subbituminous coal. After testing and minimal modification, however, use of subbituminous coal in such boilers expanded significantly.

For both biomass and wind (see below), the actual tax revenue losses may be less than estimated in the CCTI case even if all the projected new capacity enters service. To the extent that new generating capacity (1) is ineligible for the PTC because of minimum tax rules or other requirements effectively disallowing the benefits, (2) enters service later in its initial year or is delayed until a later year, or (3) performs below the 33-percent capacity factor assumed for new wind capacity or the 80-percent capacity factor assumed for new biomass capacity, the tax revenue reductions could be less than estimated here.

Wind

In the reference case, new wind generating capacity is expected to be built after 1999 despite the expiration of the EPACT PTC. In response to State mandates, renewable portfolio standards, and other requirements, 537 megawatts of new wind capacity is projected to be added from 2000 through 2004. No additional wind capacity is expected to be added in this period based solely on economics. Wind technology costs and performance are expected to improve, but they still are not expected to be competitive with new natural gas plants in most situations.

Extending the PTC through 2004 leads to only modest additions of new wind generating capacity beyond those projected in the reference case. In the CCTI case, U.S. wind generating capability is only 50 megawatts above reference case projections (Table 22). The minimal cost declines induced by the addition of this capacity result in little additional wind generating capacity after 2004 and only 10 megawatts more after 2010.

The tax revenue consequences of the CCTI are similarly modest for wind power when applied only to the CCTI-induced additional capacity, totaling only $2.6 million in 2005. The total tax revenue effects of the PTC extension are much greater, however, because the 537 megawatts of wind capacity expected to be added in the reference case can also take advantage of it. As a result, if all the eligible plants take advantage of the extended PTC, the cost could reach $28.9 million in 2005. Because little new wind capacity is expected to be encouraged by the extended PTC, carbon emissions are virtually unchanged, decreasing by less than 0.1 percent of electricity sector carbon emissions.

Table 22. Projected Effects of the CCTI Wind Energy Production Tax Credit, 2005, 2010, and 2020

Projection	1997	2005		2010		2020	
		Reference Case	CCTI Case	Reference Case	CCTI Case	Reference Case	CCTI Case
Wind Generating Capacity (Gigawatts)[a]	1.88	3.24	3.29	3.39	3.44	3.47	3.53
Wind Electricity Generation (Billion Kilowatthours)	3.41	7.24	7.39	7.69	7.84	7.84	8.14
Total U.S. Carbon Emissions (Million Metric Tons)	1,479.6	1,676.3	1,676.2	1,784.3	1,784.2	1,951.8	1,952.0
Tax Revenue Reductions (Million 1998 Dollars)	—	—	28.88	—	22.43	—	0.00

Source: Energy Information Administration, National Energy Modeling System runs CCTIBAS.D040799A and CCTIWND.D040799A.

The PTC could indirectly lead to new capacity additions not captured in the results presented here. Just as the new wind plants added during the EPACT PTC time frame appear to have been encouraged by the combination of the PTC, State mandates, and other incentive programs, the combined stimulus could conceivably continue with the extension of the PTC. Without the PTC extension, the other incentive programs could be less successful. Conversely, green power programs and utility testing programs may grow if the PTC is extended. Some consumers may be willing to pay a small premium to purchase green power, including wind power, but if the PTC is not extended the premium required may exceed what they are willing to pay. Similarly, some power companies have been experimenting with new wind facilities to become familiar with the technology and test how they might use it within their systems. Their willingness to continue those efforts may grow if the PTC is extended.

Overall the impacts of the tax incentives for new wind and biomass generating technologies are expected to have very modest impacts. Their combined impact reduces carbon emissions by only 0.5 million tons (less than 0.1 percent of electricity sector carbon emissions) in 2010. In addition, they slightly reduce the costs of complying with SO_2 and O_x emission caps. While the production tax credits for these technologies do lower the costs faced by potential developers, they are not large enough to overcome the cost disadvantages they face. New gas-fired facilities (and new coal-fired facilities after 2015) are very economical, making it difficult for new wind and biomass plants to break into the market. Even though renewable technologies are improving, the falling costs and improving efficiencies of new fossil generating technologies continue to restrict their penetration in the market.

The story for biomass co-firing is somewhat different. Coal plants can burn small amounts of biomass without significant modifications. Thus, if low-cost biomass fuel can be found, collected, and delivered to the plant at reasonable costs, it may be economical. Data suggest that there is a relatively large amount of low-cost biomass available in the form of mill residues, urban wood waste, and site clearing residues. The production tax credit would be expected to encourage power plant operators or third-party developers to search out these supplies and develop collection and handling systems. In 2004, the biomass co-firing PTC is projected to lead to carbon emissions about 3 million tons (0.5 percent of total electricity sector carbon emissions) below the level projected in the reference case.

While these PTCs are not expected to spur a large increase in renewable power generation, there are other non-CCTI programs being considered that could have a bigger impact. For example, the Comprehensive Electricity

Restructuring Act proposed by DOE in 1998 included a 5.5-percent renewable portfolio standard.[60] The *AEO99* analysis of this proposal found that it could lead to an annual reduction in carbon emissions of 20 to 25 million metric tons during the 2010 to 2020 period, at a cost of about $1 per month for the average residential household.[61]

Conclusion

In general, the impacts of the proposed tax incentives in CCTI are relatively small. In 2004, the tax credits for the buildings, industrial, and transportation sectors are projected to reduce total primary energy consumption by 33.5 trillion Btu, or 0.03 percent, relative to the reference case projection of nearly 104 quadrillion Btu (Table 23). The impact in 2010 is 31.6 trillion Btu (0.03 percent). In the reference case, carbon emissions are projected to reach 1,659 million metric tons in 2004 and 1,790 million metric tons in 2010. These tax incentives lower the projected emissions by 1.9 million metric tons (0.11 percent) and 1.6 million metric tons (0.09 percent) in 2004 and 2010, respectively (Table 24). The wind and biomass generation tax incentives are projected to reduce fossil energy consumption for electricity generation by 129.8 trillion Btu in 2004 and by 71.9 trillion Btu in 2010, reducing carbon emissions by 2.9 million metric tons (0.17 percent) in 2004 and by 1.5 million metric tons (0.08 percent) in 2010.

In 2004, total carbon emissions are reduced by 4.8 million metric tons, or 0.29 percent, as a total of the individual impacts of the tax credits. The reduction reflects lower energy consumption and a shift in the mix of energy fuels. In 2010, the tax credits reduce carbon emissions by 3.1 million metric tons, or 0.17 percent of the reference case projection.

Table 23. Reductions in Energy Use Projected To Result from CCTI Tax Initiatives, 2002-2010
(Trillion Btu)

CCTI Tax Initiative	2002	2003	2004	2010
Buildings Sector				
- Energy-Efficient Equipment	22.9	26.8	26.8	24.4
- Energy-Efficient New Homes	1.7	3.6	6.4	6.4
- Rooftop Solar Equipment	<0.01	<0.01	<0.01	<0.01
Industrial Sector				
- Combined Heat and Power[a]	—	—	—	—
Transportation Sector				
- Electric, Fuel Cell, and Electric Hybrid Vehicles	<0.01	0.1	0.3	0.8
Wind and Biomass[b]	70.0	92.3	129.8	71.9
Total	**94.6**	**122.8**	**163.3**	**103.5**

[a]Cogenerated electricity substitutes for purchased electricity, and total site use increases due to additional natural gas consumption.
[b]For the wind and biomass tax credits, the change represents the reduction in fossil energy use for electricity generation.
Note: Reductions are relative to the CCTI reference case, which is similar to that in Energy Information Administration, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998).

[60]The bill is currently being revised, and the RPS requirement may change.
[61]Energy Information Administration, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998).

Table 24. Reductions in Carbon Emissions Projected To Result from CCTI Tax Initiatives, 2002-2010
(Million Metric Tons)

CCTI Tax Initiative	2002	2003	2004	2010
Buildings Sector				
- Energy-Efficient Equipment	1.4	1.6	1.5	1.2
- Energy-Efficient New Homes	0.1	0.1	0.2	0.2
- Rooftop Solar Equipment	<0.01	<0.01	<0.01	<0.01
Industrial Sector				
- Combined Heat and Power	0.15	0.15	0.15	0.15
Transportation Sector				
- Electric, Fuel Cell, and Electric Hybrid Vehicles	0	0	0	<0.01
Wind and Biomass	1.6	2.2	2.9	1.5
Total	**3.2**	**4.1**	**4.8**	**3.1**

Note: Reductions are relative to the CCTI reference case, which is similar to that in Energy Information Administration, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998). Reductions in carbon emissions from electricity are calculated by displacing marginal generating plants.

The impacts of the tax credits tend to increase from 2002 to 2004, because the more advanced technologies become available and gradually penetrate the market. Their impact is less beyond 2004 due to the buildings equipment and biomass co-firing tax credits. As the buildings equipment tax credits expire, the impact of the tax credits is reduced, because some of the new, more efficient equipment begins to be retired and is replaced by less efficient equipment. The more efficient equipment is no longer economical without the tax credit. The biomass co-firing tax credit expires in 2004, and its incremental impact is subsequently reduced. The co-firing credit is a production tax credit that leads to more generation from biomass in coal plants when it makes biomass fuel competitive with coal. Some other tax credits have a more sustained impacts as a result of earlier investments.

The investment tax credits lower the initial cost of purchasing more equipment; however, the tax credits do not appear to be of sufficient magnitude to overcome consumer reluctance to purchase more expensive equipment with long payback periods. Most consumers are willing to invest in more efficient, but more expensive, equipment only if the higher initial costs are offset by lower fuel expenditures within a period of several years. In the electricity generation sector, the production tax credits may affect some marginally competitive wind and biomass plants; however, new natural-gas-fired, combined-cycle plants generally retain an economic advantage. Also, the more flexible operation of natural-gas-fired generating facilities provides an advantage over wind generation. Higher prices for fossil fuels or higher demand growth could serve to make these technologies more economically attractive.

Tax credits of longer duration and/or higher value could also lead to more significant impacts by making the technologies more competitive. The timing and duration of the credits are critical. The CHP tax credit applies only to systems installed between 2000 and 2002. There is not much opportunity to take advantage of the credit, because 18 to 36 months are required to plan, design, and install new capacity. Biomass gasification is assumed to be commercially available in 2005, but the credit expires in 2004. Therefore, only demonstration biomass gasification plants and traditional biomass plants would receive the credit. Similarly, the fuel cell vehicle tax credit extends only through 2006, when EIA assumes that fuel cell vehicles will first become commercially available. This date was advanced from the reference case assumption of 2010 due to the tax credit.

Although tax credits have benefits in encouraging some incremental investments, there may be some unintended consequences. Some of the technologies covered by the credits would likely penetrate even without the credits, which can be seen by comparing the tax incentive case with the reference case. Those units would receive the tax credits in addition to those units added incrementally as a result of the credits. Such unintended beneficiaries may be a significant portion of the total units: as much as 98 percent for the transportation tax credits, nearly 90 percent for biomass generation, and about 80 percent for CHP. Another unintended result could be a shifting of planned investments to fall within the time period of the credits by purchasers either delaying until the credits begin or accelerating their investments.

3. Research, Development, and Deployment

Introduction

The Administration's Climate Change Technology Initiative (CCTI) proposes fiscal year 2000 funding for a number of programs for the research, development, and deployment of energy-efficient and renewable technologies, more efficient electricity generation technologies, and carbon sequestration research—many of which are continuations or expansions of ongoing programs. The total budget request for CCTI research, development, and deployment programs is almost $1.4 billion, an increase of $347 million over the estimated fiscal year 1999 budget. The initiatives include basic research and development for buildings, industry, transportation, and electricity generation technologies and carbon sequestration, as well as a variety of programs to encourage the adoption and deployment of the technologies, including voluntary and information programs, partnerships, and consultations.

Because it is difficult to relate levels of funding for research and development directly to specific improvements in the characteristics, benefits, and availability of energy technologies, the analysis in this chapter does not attempt to assess the overall impact of the proposed $1.4 billion funding. It is likely that some of the technologies for which research and development would be funded under the CCTI program will be more successful than the goals while others may not be successful at all, but it is difficult to foresee which specific technologies eventually will succeed. Similarly, it is difficult to isolate the effects of information and voluntary programs on technology development and deployment either in the past or in the future.

Some of the programs that would receive CCTI support are ongoing research efforts funded by the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), and the Department of Housing and Urban Development (HUD), and information about their goals and accomplishments to date is available. This chapter reviews the CCTI programs sector by sector. To provide as much insight as possible into the potential efficacy of the CCTI research, development, and deployment initiatives, the following analytical approaches are used:

- First, for each sector—buildings, industry, transportation, and electricity generation—a quantitative estimate of the overall impact of technology advances based on current levels of research and development is given through the technological improvements in the reference case. The reference case projections in this report, like the reference case for the *Annual Energy Outlook 1999* (*AEO99*), include energy savings (reductions in energy use) that are expected to result from technology advances arising from research and development programs currently in place. To provide an estimate of the savings attributable to expected efficiency improvements in each sector, reference case projections are compared with projections from "frozen technology" cases. In the frozen technology case for the buildings sector, all future equipment purchases are based on equipment available in 1999, and new building shell efficiencies are fixed at 1999 levels. In the industrial sector, the efficiencies of new plants and equipment are constant at 1999 levels. New equipment is fixed at 1999 efficiencies for all transportation modes, and the cost and performance characteristics of all electricity generation technologies are held to 1999 levels.

- Second, for ongoing research programs that would receive CCTI funding and for which specific program goals have been published, this analysis includes quantitative assessments of the effects that each program would have on energy use, expenditures for energy purchases, and carbon emissions if the goals of the program were fully realized. The appropriate modules of the National Energy Modeling System (NEMS) were used in standalone mode for these assessments, comparing a reference case with a special case reflecting the assumption that the program goals will be met. Such quantitative assessments are provided in this chapter for the following research, development, and deployment programs: Partnership for Advanced Technology in Housing (PATH) and Million Solar Roofs in the buildings sectors; and, in the transportation sector, the Partnership for a New Generation of Vehicles (PNGV) and advanced technology programs for light and heavy diesel trucks. These analyses do not reflect the specific effects of the proposed CCTI spending levels but, rather, the impacts that the programs themselves would have if they came to fruition.

- Third, for those energy research and development programs that were specifically included in the *AEO99* reference case, quantitative estimates of their effects are provided, based on standalone sectoral analyses in NEMS (with no feedback from other sectors or the overall economy). Program impacts are estimated by comparing reference case results with the results from cases which exclude the improvements that result from a specific program in the reference case. The following programs are addressed with this methodology: Energy Star TVs and VCRs (buildings sector) and ethanol from biomass (transportation).

- Fourth, for programs not susceptible to quantitative analysis by the methods above, qualitative discussions of their goals and likely impacts are provided. Qualitative analyses of the following programs are included in this chapter: Energy Star refrigerated vending machines, Energy Star Buildings and Green Lights Partnership, Energy Smart Schools, Federal Energy Management Program (FEMP), and DOE's Building Technology Program for the buildings sector; DOE's Industries of the Future, Advanced Turbine System, and CHP Challenge programs and EPA's Climate Wise program for the industrial sector; and a variety of technology research, development, and deployment programs for the electricity generation sector, encompassing efficient fossil fuel technologies, carbon sequestration, solar photovoltaics, solar thermal technology, biomass power systems, wind energy, geothermal energy, hydropower, nuclear power, hydrogen fuels, and high-temperature superconductivity.

Funding for research and development may provide benefits by encouraging research into more efficient and advanced technologies that otherwise might not emerge, or in accelerating such research. The research, development, and deployment programs are intended to develop new technologies, reduce costs, and improve operating characteristics of existing technologies to make them more competitive, and to encourage the deployment of advanced technologies. In addition to helping to lower energy consumption and carbon emissions, these programs, if successful, could have additional benefits in terms of lower consumer energy expenditures, improved air quality, international competitiveness, energy security, and the overall quality of life.

Successful development of advanced technologies may not lead to immediate penetration in the marketplace. A number of factors may slow technology penetration, including low prices for fossil energy and conventional technologies, lack of information, unfamiliarity with the use and maintenance of new products, and uncertainties concerning the reliability and further development of new technologies. Gradual stock turnover can also slow the penetration of improved technologies, so that significant changes in the average stock of equipment may take a long time. Information programs, collaborative efforts for development and diffusion, and incentives to enhance the cost-effectiveness of new technologies all may help to encourage technology penetration. Subsequently, the initial penetration may have the additional impact of reducing costs through learning, establishing the infrastructure, and increasing familiarity with new technologies.

These barriers do not mean that the impacts could not be substantial over time. Some of the CCTI programs could provide more benefits in the long term as the capital stock gradually turns over, and some are likely to achieve success beyond the 2020 horizon of the analysis.

Buildings

The CCTI proposal includes $273 million in funding for buildings technology research, development, and deployment. CCTI funding for DOE, EPA, and Department of Housing and Urban Development (HUD) programs in fiscal year 2000 represents a 59-percent increase over fiscal year 1999 spending on buildings technology. Initiatives range from efficiency standards, to voluntary efficiency and partnership programs (such as Energy Star Products and Energy Star Buildings), to programs for new and renewable technologies (such as advanced lighting, space conditioning, and photovoltaic energy systems).

The *AEO99* reference case includes expected energy savings from research programs in place at the time the forecasts were developed. Because it is difficult to represent such programs explicitly in the NEMS modeling framework, their impacts are generally represented as declines in costs for efficient equipment and marginal improvements in building shell efficiency over time. The programs discussed below, to the extent that they existed at the time the reference case was developed, all contribute to the projected increase in efficiency over time. To illustrate the amount of energy savings due to increased efficiency in the buildings sector as a whole, the reference case can be compared with a frozen technology case, which holds equipment and building shell efficiencies at their respective 1999 levels. The comparison shows that, in 2010, projected delivered energy consumption in the buildings sector is 580 trillion Btu (3 percent) lower in the reference case than in the frozen technology case, and projected carbon emissions from the sector are 16 million metric tons (2.6 percent) lower.[62]

The following discussion describes some of the CCTI research, development, and deployment initiatives for the buildings sector and the approaches used to analyze their potential impacts on residential and commercial energy use and carbon emissions. The energy efficiency appliance standards program is addressed separately in Chapter 4. The programs described are just a sampling of the many initiatives included in the CCTI proposal for buildings technology.

Partnership for Advancing Technology in Housing (PATH)

The goal of the PATH program is for Federal agencies to "work with the buildings industry to develop, demonstrate, and deploy housing technologies to make newly constructed homes 50 percent more energy-efficient within a decade and to enable the retrofitting of at least 15 million existing homes within a decade to make them 30 percent more efficient." In addition, DOE's Building America program will help build 2,000 energy-efficient homes and disseminate the results to the builders of 15,000 other houses. The goals associated with this program are similar to those outlined in the tax credit proposal for energy-efficient new homes; however, the incentives provided by the program are less clear.

To demonstrate the impact that the PATH program could have if it were fully successful, a case was developed in the NEMS residential module, assuming that the goals of the PATH program for new construction would be fully realized. By 2010, 70 percent of all new homes constructed were assumed to be 50 percent more energy-efficient in

[62]Energy Information Administration, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Tables F1 and F2.

heating and cooling than today's new homes. (It should be noted that any homes built under the PATH program during 2000-2004 would qualify for the energy efficient new home tax credit mentioned in Chapter 2, although the tax credit analysis in Chapter 2 did not consider the PATH goals.) Table 25 shows the energy, carbon, and energy bill savings projected to come from meeting the goals of the PATH program. In 2010, annual energy savings relative to the reference case are projected at 140.7 trillion Btu (1 percent), saving Americans $1.4 billion and reducing carbon emissions by 3.1 million metric tons (1 percent). In 2020, the projected savings are 307.8 trillion Btu (2 percent of the reference case projection), $2.9 billion in consumer energy bills, and 6.7 million metric tons of carbon emissions (2 percent).

Table 25. Projected Energy Savings and Carbon Emissions Reductions for Successful PATH Program Goals in New Housing, 2005, 2010, and 2020

Projection	1997 Total	2005 Savings	2010 Savings	2020 Savings
Delivered Energy (Trillion Btu)	10,921	39.0	140.7	307.8
Energy Expenditures (Million 1998 Dollars)	139,898	413.4	1,394.9	2,930.3
Carbon Emissions (Million Metric Tons)	285.6	0.9	3.1	6.7

Source: Energy Information Administration, National Energy Modeling System runs RSPATH.D040799C and BLDEF.D040699A.

Energy Star Products

The Energy Star Products program promotes the use of energy-efficient appliances through labeling efficient products and educating consumers about the benefits of energy efficiency. Current programs cover products such as air conditioners, televisions, and office equipment. Many Energy Star programs have the potential to produce carbon emissions reductions in addition to those projected for measures contained in the reference case. Others are already represented in the reference case.

The proposed fiscal year 2000 budget calls for new funding to support the launch of 25 new Energy Star product lines.[63] Possible candidates for the Energy Star label include compact fluorescent lamps, ventilation fans, ducts, water coolers, and internal power supplies. Because the products that would be added to the Energy Star lineup have not been identified as yet, the extent of the potential energy savings is not quantifiable. Two examples of recent additions can, however, be used to illustrate possible savings.

The Energy Star TVs and VCRs program was implemented in 1998 to cut the amount of power each device uses while in standby mode. The current Memorandum of Understanding (MOU) between the manufacturers and EPA is to restrict standby power to 3 watts for TVs and 4 watts for VCRs. Currently, EPA reports that TV shipments show a 30-percent compliance rate with the program.[64] EPA plans to strengthen the MOU to a 1 watt restriction within the next several years. The *AEO99* reference case explicitly added an estimate for the effect of the current MOU in residential households. Over the next 10 years, it is projected that 168 trillion Btu of electricity will be saved (cumulatively), accumulating $3.9 billion dollars of energy bill savings, and abating 8.9 million metric tons of carbon emissions cumulatively (Table 26). In 2010, the program is projected to save 30 trillion Btu of delivered electricity (0.7 percent of residential electricity use) and to reduce carbon emissions by 1.5 million metric tons (0.4 percent) relative to the reference case projections.

[63]"Report to Congress on Federal Climate Change Expenditures," p. 11.
[64]Personal communication with the Energy Star program manager, April 5, 1999.

Table 26. Projected Residential Electricity Savings and Carbon Emissions Reductions for the Energy Star TV/VCR Program in the *AEO99* Reference Case, 2005, 2010, and 2020

Projection	1997 Total	2005 Savings	2010 Savings	2020 Savings
Delivered Electricity (Trillion Btu)	3,656	15.0	30.0	52.8
Electricity Expenditures (Million 1998 Dollars)	91,900	342.3	687.3	1,133.0
Carbon Emissions (Million Metric Tons)	285.6	0.8	1.5	2.4

Source: Energy Information Administration, National Energy Modeling System runs BLDDEF.D040699A and RSESTAR.D040799B.

Another Energy Star program just getting started has the goal of improving the energy efficiency of refrigerated vending machines by 25 percent. One recent estimate puts annual electricity consumption by refrigerated vending machines at about 7.5 billion kilowatthours per year.[65] If the program goals were met, annual electricity consumption for the machines would be reduced to about 5.6 billion kilowatthours per year, saving about 1.9 billion kilowatthours per year. The energy savings would translate into 0.3 million metric tons of carbon emissions avoided in 2010. Because the typical lifetime of a vending machine is 7 to 10 years, it would take a minimum of 7 to 10 years from the time the efficient vending machines are widely available for the entire 25 percent savings to be possible. Some energy savings could be realized earlier if owners decide to install energy-efficient lighting components when existing machines are refurbished (normally after 3 to 5 years of service). The success of the program may depend ultimately on the willingness of bottlers, who typically own the vending machines, to buy new machines that are more expensive initially but have lower maintenance costs. Any energy bill savings would go to the company that pays the utility bills where the vending machine is located, rather than to the owner.

As the above examples illustrate, many Energy Star programs can produce carbon savings in addition to those projected to result from measures included in EIA's reference case. As with many voluntary programs, however, it is possible that many of the actions are included in the reference case and do not create additional savings.

Million Solar Roofs

DOE's Million Solar Roofs (MSR) program is an example of a national voluntary program aimed at increasing the penetration of photovoltaic and solar thermal technologies. The MSR program goal is to facilitate the installation of 1 million solar roofs by 2010. Among the activities fostered to accomplish this goal, the program commits its partners to a variety of actions. Some of the actions MSR partners can undertake include:

- Committing to install solar equipment in a certain number of structures
- Undertaking activities to reduce barriers to the adoption of solar technologies by identifying financial incentives for solar installations, establishing net metering for photovoltaics, and modifying codes and standards for solar installations
- Implementing training and information-sharing programs.[66]

[65]Program goals and estimate of annual electricity consumption are from "Shaking out Savings," Association of Energy Services Professionals, *Strategies*, Vol. 10 No. 1 (Winter 1999), p. 7. The consumption and inventory figures in this article are actually closer to figures for canned beverage vending machines found in Arthur D. Little, Inc., *Energy Savings Potential for Commercial Refrigeration Equipment* (June 1996), which estimated annual consumption for canned beverage vendors at about 7 billion kilowatthours in 1994.

[66]See the Million Solar Roof web site, www.eren.doe.gov/millionroofs/.

Table 27 shows the total energy, carbon, and energy bill savings projected to result from successful realization of the MSR program goals. It should be noted that a portion of the committed units are included in the reference case to account for the energy savings associated with installations under the MSR program. Savings included in the reference case are included in the totals shown in Table 27.

Table 27. Projected Energy Savings and Carbon Emissions Reductions for Successful Million Solar Roofs Program, 2005, 2010, and 2020

Projection	1997 Total	2005 Savings	2010 Savings	2020 Savings
Delivered Energy (Trillion Btu)	10,921	10.9	19.1	19.0
Energy Expenditures (Million 1998 Dollars)	139,898	241.7	411.5	376.8
Carbon Emissions (Million Metric Tons)	285.6	0.6	0.9	0.9

Source: Energy Information Administration, National Energy Modeling System runs RCNOSOL.D040799A and RCMSPV.D040899C.

The impacts of the following programs are difficult to quantify because of the voluntary, informational, and / or cross-cutting nature of their activities. A qualitative discussion is presented to describe the types of services and benefits that could come from the programs.

Energy-Efficient Buildings and Energy Smart Schools

Energy Star programs also exist for commercial buildings and newly constructed homes. The Energy Star Buildings and Green Lights Partnership is a voluntary partnership between U.S. organizations, DOE, and EPA to promote energy efficiency in commercial and industrial facility space. Participants receive technical information, customized support services, public relations assistance, and access to a broad range of resources and tools. Program literature states that U.S. organizations could save an estimated $130 billion by 2010 and reduce their buildings' energy use by up to 30 percent. By 2010, EPA expects this partnership to achieve reductions in greenhouse gas emissions of at least 24 million metric tons carbon equivalent. As of November 1998, the program reported 3,000 organizations participating in the partnership. The program focuses first on energy-efficient lighting upgrades, typically the most cost-effective improvement for commercial buildings. It has enjoyed some success, with 2.8 billion feet of commercial and industrial floorspace upgraded (primarily lighting upgrades) by the end of 1997. EPA reports $514 million in annual energy cost savings from the completed upgrades.[67] The NEMS commercial module includes the effects of this program in its reference case assumptions.

Energy Smart Schools is a new program announced in October 1998 that would garner some of the benefit of the proposed increase in CCTI funding. The initiative proposes to bring together public and private sector resources to cut schools' energy bills 25 percent by 2010, providing savings to be reinvested in education. Energy Smart Schools is primarily an informational and outreach program. This program cuts across several other DOE programs, helping individual schools access existing programs such as Rebuild America, Energy Star, the Million Solar Roofs initiative, and other national, State, and local programs that provide direct technical assistance, tools, and training to schools. Although the program goal is explicitly stated, the potential effects of any informational program are difficult to quantify. Projecting the effects of this program is complicated by the fact that many of the actual savings would be the direct result of other programs and would be counted by those program sponsors as well.

[67]U.S. Environmental Protection Agency, *Helping Build a Better Future—ENERGY STAR Buildings and Green Lights 1997 Year in Review* (Washington, DC, April 1998).

Federal Energy Management Program

The mission of the Federal Energy Management Program (FEMP) is to reduce the cost of government by advancing energy efficiency, water conservation, and the use of solar and other renewable technology. This mission has been shaped by several Federal laws and Executive Orders, including the Federal energy reduction goals set forth in the National Energy Policy Act of 1992 (EPACT) and Executive Order 12902 in 1994. EPACT mandates a 20-percent reduction in energy consumption in Federal buildings by fiscal year 2000, when measured against a fiscal year 1985 baseline on a Btu-per-square-foot basis. Executive Order 12902 requires agencies to achieve a 30-percent reduction by fiscal year 2005.

FEMP activities to help agencies meet their energy goals include creation of partnerships, resource leveraging, technology transfer, and training and support. The fiscal year 2000 budget request includes an increase in funding of $8 million (34 percent) over the 1999 FEMP budget. The nature of FEMP as an organization providing services to other Federal agencies makes it difficult to quantify the effects of additional funding. However, an indication of the benefits gained through FEMP funding can be provided by outlining the progress made toward helping Federal agencies meet their energy reduction goals:

- By the end of fiscal year 1998, the Government had decreased energy consumption in buildings by 15.2 percent per square foot since 1985—halfway to its goal of achieving a 30-percent reduction by 2005.
- Energy efficiency efforts have resulted in cumulative savings of $6.3 billion in the Government's energy bill compared to a 1985 baseline.
- Carbon emissions from energy used in buildings fell by 2 million metric tons from 1985 to 1996.

Funding increases are aimed at accelerating the use of innovative multi-billion-dollar contracts that leverage private-sector funds for Federal savings; increasing procurement of energy efficiency and renewable energy products; expanding the opportunities for solar power; and addressing Federal energy opportunities arising from utility restructuring and green power; other FEMP activities.[68]

Energy-Efficient Buildings Technologies

The CCTI budget proposes an increase of $49 million (51 percent) over the 1999 budget for the DOE Building Technology Program in fiscal year 2000. Included in this request is funding for programs such as Building America, Rebuild America, enhanced appliance standards, and research and development for more efficient building equipment and appliances. Key technologies in the DOE program include low-power sulfur lamps, advanced heat pumps, chillers and commercial refrigeration, fuel cells, insulation, building materials, and advanced windows.

It is difficult to assess the impact that increased funding for research and development might have on future energy consumption. Predicting winners and losers in technological development is far from a science (for example, predicting the outcome of Beta versus VHS for videotape recording). Solar photovoltaics, for example, have had extreme cost declines over the past decades, but their market share remains small. Accordingly, no attempt will be made here to estimate energy savings from a dollar amount spent on technology-related research and development. Successful research and development can, however, play a major role in improving the economics of most of the other programs included in the CCTI proposal. If major short-term progress is made in developing price-competitive energy-efficient alternatives to today's technologies, then all the CCTI programs stand to benefit with increased

[68]Information on FEMP is available at web site www.eren.doe.gov/femp/.

market penetration. For example, price-competitive superinsulating windows can go a long way toward achieving the goal of reducing energy consumption by 50 percent in new housing, providing an economical way to qualify for the tax credits described in Chapter 2.

Industry

Background

DOE supports a wide variety of research, development, and deployment programs and has recently reported that its programs have reduced current energy consumption by 115 trillion Btu.[69] Other benefits from the programs are reduced emissions and improved industrial productivity. DOE's CCTI program for industry would expand efforts to develop innovative technologies and production methods, with specific emphasis on the Industries of the Future program and combined heat and power (CHP) programs. The proposed budget is $172 million, an increase of $15 million over 1999.

One indication of the possible impacts of these programs is provided by the *AEO99* projections. A frozen technology case for the industrial sector projects 630 trillion Btu (2 percent) more delivered energy consumption in 2010 than in the reference case,[70] and a portion of the difference is due to inclusion of the energy effects of the DOE programs.

This analysis does not attempt to quantify the energy or emissions impacts of DOE research, development, and deployment programs; however, the *AEO99* reference case projections embody trends in energy efficiency improvements resulting, in part, from past and ongoing programs. In most cases it is difficult to distinguish the efficiency improvement effects of the industry programs from those resulting from economic forces and autonomous technological progress, not necessarily because the effects are inconsequential but rather because the industrial sector is a dynamic, internationally competitive arena where increased productivity is essential to corporate survival. In this setting, some portion of the technological progress concurrent with public policy initiatives would have occurred in their absence. The aggregate impacts of government programs are included in the reference case, however, as appropriate. For example, EIA has previously assumed that the programs included in the Climate Change Action Program could reduce annual electricity consumption by 41 billion kilowatthours and annual fossil fuel consumption by 90 trillion Btu in 2010.

Industries of the Future

The Industries of the Future program works with the most energy-intensive industries to develop technologies to increase efficiency, lower greenhouse gas emissions, and improve industrial competitiveness.[71] The industries currently included in the program are aluminum, steel, metal casting, glass, mining, agriculture, chemicals, forest products, and petroleum. Industries of the Future includes specific programs that fund collaborative research and development, as well as the development of industry vision statements for future technology trends. The programs are targeted to a number of industries. The aluminum industry is developing an advanced aluminum reduction cell

[69]U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Office of Industrial Technologies, *Summary of Program Results*, DOE/EE-0184 (Washington, DC, January 1999), p. 9.

[70]Energy Information Administration, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table F3.

[71]For a more detailed description of the Industries of the Future program, see U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Office of Industrial Technologies, *Summary of Program Results*, DOE/EE-0184 (Washington, DC, January 1999), p. 9.

that would use 27 percent less energy than the current technology. A major steel industry initiative involves near-net-shape casting. The development of this technique would significantly reduce the energy required to produce finished steel products. In the pulp and paper industry, development and demonstration of black-liquor gasification technologies could lead to a large increase in electricity production at pulp mills.

The Industries of the Future program also has incorporated several existing cross-cutting programs, including Motor Challenge, Steam Challenge, and Compressed Air Challenge, which provide technical expertise and information on how to use specific energy sources more efficiently. The programs are coordinated with several other efforts, including Industrial Assessment Centers and the National Industrial Competitiveness through Energy, Environment, and Economics (NICE3) program. There is also an Inventions and Innovations program that provides grants to individuals and small companies to develop novel methods to improve energy efficiency or environmental performance.

The goal of the Industries of the Future program is to achieve annual carbon reductions of 29 million metric tons by 2010.[72] While this goal cannot be evaluated directly, it would seem to imply that energy consumption would be about 2 quadrillion Btu less than otherwise (neglecting any reductions from process emissions). The *AEO99* forecast for industrial energy consumption in 2010 is 39.4 quadrillion Btu.[73] If industrial energy intensity had stayed constant at its 1997 level, energy consumption would have been 6 quadrillion Btu higher in 2010 than was projected. Thus, it appears feasible that the Industries of the Future programs could make a significant contribution to future emissions reductions.

Industrial Combined Heat and Power

The Advanced Turbine System program is expected to result in a 15-percent increase in turbine efficiency. With other developments in the cogeneration area, DOE states that its program goal is to result in systems that are 15 percent more energy efficient and 80 percent cleaner than conventional power stations, while also reducing electricity costs by 10 percent. DOE and EPA are also jointly supporting the CHP Challenge program, with the goal of eliminating barriers to dissemination of CHP technology and adding 50 gigawatts of additional CHP capacity by 2010.

In terms of the *AEO99* projections, the CHP Challenge goal appears to be quite ambitious. For example, over the 1997-2010 period, projected CHP additions total 5 gigawatts in the reference case.[74] While it is reasonable to expect the CHP Challenge and research programs to have some impact, it seems unlikely that the rate of additions implied by the goal could be achieved. Achieving the technical increase in turbine efficiency looks more likely.

Other Programs

The proposed budget for EPA's industry programs is $54 million, an increase of $33 million from 1999. The EPA is a participant in the CHP Challenge program, with a particular emphasis on modifying environmental regulations that unnecessarily impede expansion of CHP. EPA also participates in Climate Wise, which is a voluntary program to encourage businesses to increase energy efficiency and reduce greenhouse gas emissions. EPA estimates that companies participating in the program will realize annual savings of $240 million by 2000.[75] As with any other

[72]"Report to Congress on Federal Climate Expenditures," p. 18.
[73]Energy Information Administration, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), p. 113.
[74]Energy Information Administration, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), p. 126.
[75]U.S. Environmental Protection Agency, *Climate Wise Progress Report*, EPA 231-R-98-015 (Washington, DC, October 1998), p. 4.

voluntary deployment program, it is not clear to what extent the projected savings can be attributed to the Climate Wise program.

EPA's goal for its industry programs is to reduce annual carbon emissions by 37.9 million metric tons by 2000.[76] The average projected industrial energy price was $4.67 per million Btu in the *AEO99* reference case. Energy expenditure savings of $240 million would imply reduced energy consumption of about 51 trillion Btu. Unless there are substantial contributions from other programs, this change in energy consumption would not yield the carbon reduction goal. Alternatively, it is not clear what starting point for the reductions was used.

The proposed budget for industry programs in the U.S. Department of Agriculture, which were not funded in 1999, is $10 million. The programs are focused on reducing greenhouse gas emissions through improved agriculture and forestry techniques and assessing the impacts of climate change on agriculture.

Transportation

The CCTI proposal for transportation research, development, and deployment consists of two major programs: additional funding for the Partnership for a New Generation of Vehicles (PNGV) and an Advanced Diesel Technologies program. The proposed budget for transportation programs at DOE and EPA is $377 million, an increase of $86 million over the 1999 budget. In the *AEO99* reference case, implicit levels of research and development are included for light-duty vehicles and heavy-duty freight trucks. Fuel economy for new light-duty vehicles in 2010 is projected to be 12 percent higher than the 1999 level, and fuel efficiency for new heavy trucks in 2010 is approximately 7.5 percent above the 1999 level. In comparison with the frozen technology case, transportation energy consumption in the reference case is 1.1 quadrillion Btu (3.2 percent) lower in 2010.[77]

Partnership for a New Generation of Vehicles

Background

The PNGV program, a consortium of U.S. automakers and government partnerships, has set a fuel efficiency goal of 80 miles per gallon (mpg) for a mid-sized sedan, with no loss of performance or increase in cost[78] from a current mid-sized sedan while meeting or exceeding Federal safety and emissions standards. A prototype is expected by 2000 and a production prototype by 2004. Commercial sale of the vehicles would potentially come 1 to 3 years later, making the technology available between 2005 and 2007.

Analytical Approach

For this analysis, the PNGV goals were assumed to be met in the CCTI case by the year 2006 for the three fuel cell vehicle types (gasoline, methanol, and hydrogen) represented in the NEMS model. The incremental vehicle cost above a comparable gasoline vehicle for each EPA size class was assumed to be approximately $2,000, based on an estimate from DOE's Office of Transportation Technologies. Each of the three fuel cell vehicles was also assumed to meet the fuel efficiency goal of three times the fuel efficiency of a similar sized gasoline vehicle.

[76]"Report to Congress on Federal Climate Expenditures," p. 18.
[77]Energy Information Administration, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), Table F4.
[78]Including maintenance and operating costs and purchase price.

The CCTI research and development initiatives include a proposed funding increase of $24 million for DOE's role in the PNGV program, which was funded at $240 million in 1999, with additional funding at EPA. It is not clear, however, that a 10-percent increase in the PNGV budget will lead to attainment of the PNGV goals. The PNGV Committee has made significant progress in the development of advanced technologies, and its efforts have led to several manufacturer announcements of PNGV production prototypes by 2004; however, the National Research Council (NRC), which reviews the PNGV program goals and achievements each year, has made the following assessments:[79,80] (1) Unless the PNGV program receives significantly more funding, its goals most may not be met. (2) The goal of a fuel-efficient mid-sized vehicle with costs similar to those of a conventional gasoline vehicle most likely will not be met.[81]

Results and Discussion

In the CCTI case for this analysis, fuel cell vehicle sales are projected to rise significantly, to 274,000 units in 2010 and almost 425,000 units in 2020 (Table 28), representing more than 2.8 percent of all light-duty vehicle sales in 2020. Electric vehicle and diesel-electric hybrid vehicle sales decline slightly relative to the reference case (by about 2.9 percent in 2010 and 1.4 percent in 2020) because of the increased competition from fuel cell vehicle sales.

Table 28. Light-Duty Vehicle Sales by Technology Type, 1997-2020
(Thousands)

		2002		2005		2010		2020	
Vehicle Type	**1997**	**Reference Case**	**CCTI Case**	**Reference Case**	**CCTI Case**	**Reference Case**	**CCTI Case**	**Reference Case**	**CCTI Case**
Electric	0.7	8.26	8.62	281.91	283.81	299.28	298.41	299.45	299.21
Fuel Cell	0.0	0.00	0.00	0.00	0.00	4.63	274.00	18.45	424.94
Diesel-Electric Hybrid	0.0	2.34	2.43	21.67	23.52	37.19	28.37	29.19	24.71
Gasoline-Electric Hybrid	0.0	28.99	28.99	197.98	200.19	579.26	579.26	871.88	871.88
All Light-Duty Vehicles	13,618	13,274	13,274	13,836	13,836	14,780	14,780	14,893	14,893

Source: Energy Information Administration, National Energy Modeling System runs AEO99TRN.D040699A and AEO99TRN.D040699D.

Fuel consumption for light-duty vehicles is projected to be 49 trillion Btu lower in the CCTI case than in the reference case in 2010 and, because of the heavy volume of sales between 2010 and 2020, 196 trillion Btu lower in 2020 (Table 29). However, these fuel savings result in only a 0.15-percent reduction in total transportation fuel consumption in 2010.

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[79]National Research Council, *Partnership for a New Generation of Vehicles: Fourth Report* (Washington, DC: National Academy Press, 1998).
[80]The NRC will be reviewing the PNGV program in a fifth report,which will be completed by the end of April 1999.
[81]The National Research Council review of the PNGV program in the Fourth Report states on page 77: "Thus, the hybrid features may not meet the PNGV criteria for equivalent cost of ownership and may ultimately have questionable marketability for this class of passenger vehicles." The NRC also commented on the cost and fuel efficiency performance goal: "Fuel cells still face substantial obstacles to meeting performance and cost goals within the 2000 to 2004 time frame . . . [a]lthough the 65 mpg falls short of the 80 mpg target . . . ."

Table 29. Light-Duty Vehicle Fuel Consumption by Fuel Type, 1997-2020
(Trillion Btu)

Fuel Type	1997	2002 Reference Case	2002 CCTI Case	2005 Reference Case	2005 CCTI Case	2010 Reference Case	2010 CCTI Case	2020 Reference Case	2020 CCTI Case
Gasoline	13,902.29	15,521.09	15,521.10	16,309.65	16,308.95	17,444.84	17,412.45	18,604.64	18,433.58
Distillate Fuel	7.43	6.93	6.95	12.48	12.68	46.90	45.86	170.09	169.11
Methanol	1.17	31.21	31.20	50.91	50.75	75.95	69.09	108.45	95.31
Ethanol	0.53	17.76	17.75	30.00	29.90	50.81	46.12	74.06	65.03
Compressed Natural Gas	11.91	108.78	108.77	172.82	172.73	234.07	230.71	294.28	289.68
Liquefied Petroleum Gas	20.97	60.38	60.37	104.38	104.30	154.50	151.70	199.21	194.91
Electricity	0.29	3.10	3.12	40.38	40.82	83.44	83.92	147.48	147.73
Hydrogen	0.00	0.00	0.00	0.00	0.00	0.03	2.24	0.12	6.92
Total	13,944.59	15,749.26	15,749.25	16,720.61	16,720.12	18,090.53	18,042.08	19,598.34	19,402.27

Source: Energy Information Administration, National Energy Modeling System runs AEO99TRN.D040699A and AEO99TRN. D040699D.

Carbon emissions in the CCTI PNGV case are 0.9 million metric tons lower than the reference case projection in 2010, but in 2020, as sales volumes accumulate in the vehicle stock, they are 3.9 million metric tons lower (Table 30). Even in 2020, however, the carbon emissions reductions amount to only 0.56 percent of the total transportation carbon emissions projected in the reference case.

Table 30. Transportation Sector Carbon Emissions by Fuel Type, 1997-2020
(Million Metric Tons)

Fuel Type	1997	2002 Reference Case	2002 CCTI Case	2005 Reference Case	2005 CCTI Case	2010 Reference Case	2010 CCTI Case	2020 Reference Case	2020 CCTI Case
Petroleum	461.9	521.9	521.9	552.0	552.0	600.7	599.9	664.7	661.1
Natural Gas	10.5	12.8	12.8	14.7	14.7	16.7	16.6	19.5	19.4
Electricity	2.9	3.3	3.3	5.2	5.3	7.6	7.6	11.2	11.2
Other	0.0	0.5	0.5	0.9	0.9	1.3	1.2	1.9	1.7
Total	**475.3**	**538.6**	**538.6**	**572.8**	**572.9**	**626.2**	**625.3**	**697.3**	**693.4**

Source: Energy Information Administration, National Energy Modeling System runs AEO99TRN.D040699A and AEO99TRN. D040699D.

Advanced Diesel Technologies for Light and Heavy Trucks

Background

The CCTI research and development initiatives include a proposal to provide funding for government and industry partnerships to develop advanced diesel cycle engine technologies for pickup trucks, vans, and sport utility vehicles and engine and vehicle technologies to improve the fuel efficiency of new heavy trucks. In 1998, diesel-powered light-duty vehicles captured only 0.01 percent of total U.S. light-duty vehicle sales, significantly below their highest shares of 6.1 percent of auto sales in 1981 and 5.0 percent of light truck sales in 1982.

In 1997, Volkswagen began offering a Jetta sedan with a turbocharged direct injection diesel engine (44.95 mpg) in U.S. markets. Although the new diesel engine provided a 60-percent increase in fuel economy over the conventional gasoline Jetta (27.85 mpg), it was soon withdrawn from the market due to lack of sales. Volkswagen is now working on a new direct injection diesel automobile (the Lupo) with a fuel efficiency goal of 78 mpg. For model years 1998 and 1999 Volkswagen is again offering the turbo direct injection engine in the Jetta and the Beetle, with the intention of eventually offering it in the Passat. Preliminary sales of turbo direct injection technology have been slow, according to a few Volkswagen dealers in the Washington metropolitan area.

Heavy trucks are an integral part of U.S. commerce and economic growth. In 1995, total expenditures for highway freight transportation (local and intercity trucks) were over $348 billion, accounting for 79 percent of the Nation's freight bill and approximately 4.8 percent of gross domestic product.[82] On average, a heavy truck travels 37,600 to 86,500 miles each year.[83] Heavy trucks account for 79 percent of freight truck fuel usage, and freight truck travel represented 16 percent of all fuel use in the transportation sector in 1997.

The stated goal of the CCTI proposal for light trucks is a 35-percent improvement in fuel efficiency above conventional gasoline vehicles by 2002 while meeting strict emissions standards. For heavy trucks the goal is to achieve a fuel efficiency of 12 mpg by 2004 for new diesel trucks while still meeting prevailing emissions standards.

Light Trucks

Analytical Approach

For this analysis, the NEMS transportation module was used to model the CCTI research and development initiative.[84] The following assumption was made in modeling the CCTI analysis case: the date of commercial availability for turbo diesel fuel injection technology was advanced to 2002 from 2005, with no change in vehicle prices. The expected sale price for turbo direct injection vehicles is approximately $1,200 higher than that for conventional gasoline vehicles. With large sales volumes approaching 25,000 units per year, the incremental cost could decline to about $800.

Results and Discussion

The results for the CCTI analysis case show that diesel vehicle sales amount to less than 2 percent of total light truck sales in 2010 (Table 31). Consequently, projected light-duty vehicle fuel consumption in the CCTI case is 25 trillion Btu lower than the reference case level in 2010—a reduction of less than 0.15 percent (Table 32). The corresponding reduction in projected carbon emissions from transportation energy use in the CCTI case relative to the reference case is only about 0.1 million metric tons in 2005 and 0.4 million metric tons in 2010—representing just 0.06 percent of total projected carbon emissions for the transportation sector in the reference case (Table 33).

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[82]Energy Resources R&D Portfolio, Draft-2 (2/6/99).
[83]U.S. Department of Energy Office of Transportation Technologies, *Program Analysis Methodology* (Washington, DC, January 15, 1999), p. 21.
[84]For a more detailed description of the transportation module, see Chapter 2, page 30.

Table 31. Light Truck Sales, 1997-2020
(Thousands)

Vehicle Type	1997	2002 Reference Case	2002 CCTI Case	2005 Reference Case	2005 CCTI Case	2010 Reference Case	2010 CCTI Case	2020 Reference Case	2020 CCTI Case
Diesel Direct Injection	0.0	9.3	70.8	38.7	130.3	174.5	224.6	277.3	277.8
Total Vehicle Sales	13,618	13,274	13,274	13,836	13,836	14,777	14,780	14,892	14,893

Source: Energy Information Administration, National Energy Modeling System runs AEO99B.D100198A and CCTITRN.D033199A.

Table 32. Light-Duty Vehicle Fuel Consumption by Fuel Type, 1997-2020
(Trillion Btu per Year)

Fuel Type	1997	2002 Reference Case	2002 CCTI Case	2005 Reference Case	2005 CCTI Case	2010 Reference Case	2010 CCTI Case	2020 Reference Case	2020 CCTI Case
Gasoline	13,902.29	15,517.55	15,515.32	16,308.66	16,280.36	17,448.57	17,382.08	18,604.19	18,571.94
Distillate Fuel	7.43	6.93	11.14	12.48	33.15	46.89	90.86	170.03	193.32
Methanol	1.17	31.35	31.27	51.04	50.77	77.38	75.63	108.67	108.38
Ethanol	0.53	17.84	17.80	30.10	29.91	51.13	50.62	74.32	74.08
Compressed Natural Gas . .	11.91	108.84	108.84	172.90	172.80	234.42	234.17	294.65	294.56
Liquefied Petroleum Gas . . .	20.97	60.50	60.45	104.49	104.41	154.62	154.57	199.48	199.41
Electricity	0.29	2.79	2.79	39.94	39.91	83.13	83.06	147.38	147.39
Hydrogen	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.10	0.10
Total	**13,944.59**	**15,745.80**	**15,747.62**	**16,719.61**	**16,711.31**	**18,096.17**	**18,070.99**	**19,598.83**	**19,589.17**

Source: Energy Information Administration, National Energy Modeling System runs AEO99B.D100198A and CCTITRN.D033199A.

Table 33. Transportation Sector Carbon Emissions by Fuel Type, 1997-2020
(Million Metric Tons)

Fuel Type	1997	2002 Reference Case	2002 CCTI Case	2005 Reference Case	2005 CCTI Case	2010 Reference Case	2010 CCTI Case	2020 Reference Case	2020 CCTI Case
Petroleum	461.9	521.8	521.9	552.0	551.9	600.8	600.3	664.7	664.5
Natural Gas	10.5	12.8	12.8	14.7	14.7	16.7	16.7	19.5	19.5
Electricity	2.9	3.3	3.3	5.2	5.2	7.6	7.5	11.2	11.2
Other	0.0	0.5	0.5	0.9	0.9	1.4	1.3	1.9	1.9
Total	**475.3**	**538.5**	**538.6**	**572.8**	**572.7**	**626.3**	**625.9**	**697.3**	**697.1**

Source: Energy Information Administration, National Energy Modeling System runs AEO99B.D100198A and CCTITRN.D033199A.

Emissions issues may pose problems for direct injection diesel vehicles. Advances in diesel technology have significantly reduced their noise and emissions of particulates, but high levels of nitric oxides and particulates still present significant health problems. EPA is currently revising its NO_x and particulate emissions standards as mandated by Congress under the Clean Air Act Amendments of 1990, and recent regulations passed by the California Air Resources Board are expected to eliminate diesel technologies from further consideration as solutions to higher fuel economy unless they use advanced catalysts and/or new types of low-sulfur or reformulated diesel fuel.

Emissions issues are especially problematic for direct injection diesel technologies. Reduction of both NO_x and particulates has proven difficult, because reduction of one often increases the emissions of the other. Particulate traps are expensive and marginally effective in emissions reduction. Advanced catalysts are being developed, but they are very expensive. Two different avenues of catalyst research and development are currently being pursued: Argonne National Laboratory has developed a plasma membrane that can separate NO_x emissions into pure nitrogen and oxygen, and Daimler-Chrysler has developed an emissions after-treatment procedure that shoots a fine mist of urea into the exhaust, chemically changing NO_x to nitrogen and oxygen. Both catalysts are in the early stages of research.

Advanced low-sulfur, low-benzene, and reformulated fuels in combination with advanced catalysts are currently being explored, and Fischer-Tropsch fuels (derived from refinery waste products and natural gas) also are potential candidates for use with advanced diesel technologies. Studies have shown that these advanced diesel fuels and derivatives can reduce both NO_x and particulate emissions by as much as 80 percent. At present, however, the fuels are not cost-competitive with either gasoline or diesel fuel.

Current diesel technology may not be accepted quickly by the public because of the reliability issues that arose for diesel technology during the 1970s and 1980s. This is evident from the current lack of sales for direct injection diesel vehicles from Volkswagen and the current low level of sales for diesel light-duty vehicles, which made up only 0.01 percent of all light-duty vehicle sales in 1997.

It is also important to note that electric, fuel cell, electric hybrids, and turbo direct injection vehicles are in direct competition with each other for market share. Model runs with the turbo diesel direct injection technology initiative but without the CCTI tax incentives described in Chapter 2 resulted in a drop in fuel cell vehicle sales of almost 2,000 units (42 percent) in 2010. In the CCTI tax incentives case, turbo diesel sales were 50,000 units (28 percent) lower in 2010 than projected in the turbo diesel direct injection technology case.

Heavy Trucks

Analytical Approach

The NEMS freight truck module is a stock model that includes existing and future fuel-saving technologies as well as alternative-fuel vehicles. The model uses projected sales of freight trucks, fuel prices, and output for selected industries from the macroeconomic module to estimate freight truck travel demand, purchases and retirements of freight trucks, and fuel consumption. Sales of new trucks are estimated according to the assumed market penetration rates for existing and future technologies, competition with other technologies, sensitivity to fuel prices, and fuel economy improvement. Relative fuel economies are used to determine the market share of new truck purchases for each technology in each year of the projection period. Capital costs are converted to an equivalent fuel price at which each technology is considered cost-effective, based on an assumption of a 3-year payback period with a 10-percent discount rate applied to the average distance traveled per truck.

For the CCTI analysis case, the following characteristics of heavy trucks were added to the available technology choices:

- **Engine Efficiency:** Currently the best engines have nominal efficiencies of 46 percent. In order to achieve the CCTI goals, it was assumed that engine efficiencies would be increased to 55 percent or higher (an improvement of about 20 percent). The direct injection diesel engine is the most viable near-term engine technology expected to be commercially available by 2006. For this technology to be commercialized, several underlying integrated technologies must also be developed: improved design for cylinders to handle higher pressures, additional exhaust heat utilization through improved turbo systems,[85] improved thermal management (less heat rejection), and lower engine friction.

  Emissions controls are the greatest barrier to the adoption of the direct injection diesel technology, especially with regard to NO_x and particulate matter. As the fuel efficiency of diesel engines improves, NO_x emissions also increase. To address this problem, three approaches are used: (1) in-cylinder process (combustion, air handling) to change the way the fuel is burned; (2) exhaust after-treatment to capture NO_x and particulates; and (3) altered fuel properties to reduce sulfur, which shortens the life of a catalytic converter. Current research on exhaust after-treatment includes particulate filters, NO_x catalysts, and plasma systems. To date, a prototype particulate filter has been developed, small NO_x catalysts have exceeded 50-percent reductions, non-thermal plasma devices have exceeded 70-percent reductions on a small scale, and engine efficiencies of approximately 52 percent have been achieved in test engines. In production engines, reductions of more than 50 percent for NO_x and 80 percent for particulate matter have been achieved.

- **Vehicle Design:** In order to achieve the CCTI goals, it was assumed that fuel efficiency improvements of between 5 and 19 percent would be achieved through improvements in the design of heavy trucks. Several technologies are currently under investigation: reduced aerodynamic drag, reduced rolling resistance, and reduced losses related to auxiliaries and operating modes. To date, a research and development plan on heavy vehicle aerodynamic drag has been developed with industry, and a program has been started to compile data on the heating and cooling of the truck cab, with the goal of reducing idling time.

  In the area of aerodynamic drag, the goal is to reduce drag coefficients from the current value of 0.60 to less than 0.50. Cab and trailer modifications must be cost-effective and must not hinder maintenance, payload, or the ability to meet government regulations and overall size restrictions. Current research is focusing on computational analysis tools for use in cab and trailer development. In the near term the trailer, which traditionally has received less attention than the cab, will be the focus. The main goal is to reduce the backdraft, or vacuum, at the end of a trailer that creates drag. Examples of work being done include curving the top of the trailer and creating a cone at the end; however, in the first case, haulers are unwilling to give up freight capacity to create a curved trailer, and in the second case the trailer may not meet safety regulations or may become a maintenance issue. Another, more promising example is the use of compressors to blow air into the vacuum, creating an airfoil. Similar types of work are being done on rolling resistance, such as the use of “super single” tires to replace the common two-tire set.

  Some of the major obstacles to rapid market penetration of these advanced technologies are ensuring that all State and Federal regulatory standards will be met, and ensuring that the return on investment will be realized within a short period of time.

[85]Energy Resources R&D Portfolio, Draft-2 (2/6/99), p. 204.

Results and Discussion

The heavy-duty truck technology characteristics in Tables 34 and 35 make up a representation of the technologies considered to meet the increased efficiency goal. These characteristics were used in the NEMS transportation freight truck model, which is economically price driven. The adoption of a technology, once introduced, is assumed to gain market share over time. It is also important to note that the trucking industry is very sensitive to fuel prices and demands a relativity short payback period. The fleet owners also place a high value on reliability, which will cause their technology adoption decisions to differ from decisions that would be made on economics alone.

Table 34. Heavy Truck Diesel Technology Characteristics in the Reference Case

Technology	Commercial Availability Date	Capital Costs (1998 Dollars)	Maximum Potential Market Share (Percent)	Fuel Economy Improvement (Percent)
Improved Tires and Lubricants	1994	1,500	100	5
Electronic Engine Controls	1994	1,000	99	4
Electronic Transmission Controls . .	1994	800	98	1
Advanced Drag Reduction	1997	1,000	40	15

Source: Energy Information Administration, *Assumptions for the Annual Energy Outlook 1999*, web site www.eia.doe.gov.

Table 35. Heavy Truck Diesel Technology Characteristics in the CCTI Analysis Case

Technology	Commercial Availability Date	Capital Costs (1998 Dollars)	Maximum Potential Market Share (Percent)	Fuel Economy Improvement (Percent)
Advanced Drag Reduction 2	2008	7,500	75	19
Reduced Rolling Resistance	2006	1,750	75	9
Improved Accessories	1998	1,000	50	5
Improved Engine Efficiency	2006	900	100	10

Source: U.S. Department of Energy, Office of Transportation Technologies.

In Tables 34 and 35, the date of commercial availability is the first year in which a technology has been or is expected to be offered by the manufacturers for possible purchase. Maximum potential market share is the highest percentage of trucks that could employ a given technology. Some technologies will never be utilized in certain vehicle applications regardless of cost. For example, garbage trucks probably will never be equipped with advanced drag reduction technologies.

In 2010, the stock fuel efficiency improvement in the CCTI case relative to the reference case is approximately 0.22 mpg, which results in a reduction of 128 trillion Btu of heavy truck diesel fuel use and a carbon emissions reduction of 2.4 million metric tons (Table 36). Reductions in both fuel use and carbon emissions amount to 0.4 percent of the total for the transportation sector. Two factors cause the projected reductions in fuel consumption and carbon emissions to be relatively small. First, because of their late commercial availability dates (Table 35), two of the most promising technologies, reduced rolling resistance and improved engine efficiency, are projected to have only limited market penetration by 2010 (Table 37). The second factor is the slow turnover rate for the stock of freight trucks. Even by 2020, the fuel economy of the truck stock is only 6.45 mpg in the CCTI case, compared with 5.78 mpg in the reference case (a 12-percent improvement). The difference has the effect of reducing heavy diesel fuel consumption from 4,554 trillion Btu in the reference case to 4,121 trillion Btu in the CCTI case, for a net fuel savings of 433 trillion Btu and carbon emissions reductions of 8.6 million metric tons, or 1.2 percent of the total for the transportation sector.

Table 36. Heavy Truck Diesel Fuel Efficiency, 1997-2020

Projection	1997	2005		2010		2020	
		Reference Case	CCTI Case	Reference Case	CCTI Case	Reference Case	CCTI Case
New Heavy Truck Diesel Fuel Efficiency (Gasoline Equivalent Miles per Gallon)	5.58	5.80	6.09	5.99	6.40	6.07	7.45
Heavy Truck Diesel Fuel Stock Efficiency (Gasoline Equivalent Miles per Gallon)	5.10	5.41	5.58	5.58	5.80	5.78	6.45
Heavy Truck Diesel Fuel Consumption (Trillion Btu)	3,126	3,939	3,855	4,219	4,091	4,554	4,121
Transportation Petroleum Carbon Emissions (Million Metric Tons)	461.9	552.8	551.3	601.9	599.5	666.2	657.6

Source: Energy Information Administration, National Energy Modeling System runs CCTIB1.D033199H and CCTI3.D033199B.

Table 37. Market Penetration of CCTI Proposal Technologies in the CCTI Analysis Case
(Percent)

Technology	2005	2010	2020
Advanced Drag Reduction 2 (More Advanced)	0	0	0
Reduced Rolling Resistance	0	5	65
Improved Accessories	10	36	50
Improved Engine Efficiency	0	6	86

Source: Energy Information Administration, National Energy Modeling System runs CCTIB1.D033199H and CCTI3.D033199B.

Fuel efficiency in Table 36 refers to both the on-road stock average under real driving conditions and the new fuel efficiency average. With the CCTI new technology characteristics supplied by DOE's Office of Transportation Technologies, the fuel efficiency of new heavy trucks is projected to be 6.09 mpg in 2005 and 6.40 mpg in 2010.

Improved accessories has a larger market share than improved engine efficiency in 2010 because of its earlier availability date. By 2010, improved accessories will have been on the market for 12 years, whereas improved engine efficiency will have been available for only 4 years (Table 35). By 2020 the market share of improved engine efficiency technologies is projected to reach 86 percent of new sales and improved accessories 50 percent (Table 37).

Table 38 provides a summary of the fuel savings and carbon emissions reductions projected from implementing the CCTI light truck and heavy truck technology proposals simultaneously.

Table 38. Combined Effects of CCTI Light Truck and Heavy Truck Technology Initiatives, 2005, 2010, and 2020

Projection	2005	2010	2020
Fuel Savings (Quadrillion Btu)	0.08	0.14	0.45
Carbon Emissions Reduction (Million Metric Tons)	1.7	2.8	8.8

Source: Energy Information Administration, National Energy Modeling System runs CCTIB1.D033199H and CCTITRN.D033199B.

Ethanol from Biomass

Ethanol is a renewable source of energy that has been primarily produced domestically. Since 1979, its use as a motor gasoline blending component has been encouraged through tax credits and subsidies, extending the supply of gasoline and thus reducing oil import requirements.[86] Gasoline can contain up to 10 percent ethanol without significantly reducing the performance of a standard gasoline vehicle engine. In addition, a new engine design that burns 85 percent ethanol and 15 percent gasoline has been developed, and its usage is projected to grow in the future.

Ethanol also contains oxygen and, with the onset of the oxygenated gasoline program in 1992 and the reformulated gasoline program in 1995, has been used to increase the oxygen content of gasoline, helping to lower carbon monoxide emissions. In 1997, 50,000 barrels per day of ethanol were blended into traditional and oxygenated gasoline, and another 32,000 barrels per day were blended in the production of reformulated gasoline.

Because it is a renewable fuel, ethanol can help reduce carbon dioxide emissions. Most of the ethanol currently used in gasoline blending is produced through a corn fermentation process. The carbon in the fuel does not increase net carbon emissions, because an equivalent amount of carbon will be absorbed from the atmosphere by the next rotation of crops. On the other hand, corn cultivation, fertilizer manufacture, and the distillation of alcohol are energy-intensive processes that generate significant greenhouse gas emissions.[87]

Ethanol can also be made from cellulose biomass, such as agricultural residues, switchgrass, and wood residues. Cellulose ethanol is an attractive alternative to corn ethanol for carbon reduction because switchgrass and woody crops require less cultivation and fertilizer than corn. In addition, solid byproducts from the processing of cellulose ethanol can be burned as fuel to cogenerate steam and electricity required to run the ethanol plant. Other advantages of cellulose ethanol include an inexpensive feedstock and possible wider regional distribution. It may be possible to locate the plants much closer to major refining and gasoline-consuming areas than is possible for corn-based ethanol, which is produced primarily in the Midwest.

Gasoline containing 10 percent ethanol currently receives a tax exemption of 5.4 cents per gallon, which translates into 54 cents per gallon for ethanol. This has a significant impact on the price of ethanol. In November 1998, for example, the subsidy lowered the price of ethanol by about half, from $1.08 per gallon to 54 cents per gallon, compared to the methyl tertiary butyl ether (MTBE) spot price of 62 cents per gallon.[88] The tax exemption is pro-rated for blends of less than 10 percent and also applies to ethanol used in the production of ethyl tertiary butyl ether (ETBE). In addition, some States provide tax incentives for the production of ethanol. The ethanol tax exemption has been extended several times since its introduction in 1979, most recently to 2007. Without the subsidy, ethanol's share of the market would likely be much smaller.[89] In the reference case for this analysis, extensions of the tax exemption are assumed through 2020.

The Office of Fuels Development (OFD) in DOE's Office of Transportation Technologies manages the National Biomass Ethanol Program, which encompasses research and development projects aimed at facilitating the evolution

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[86]Ethanol blended into gasoline in 1997 represented 0.9 percent of net petroleum imports and 1.0 percent of motor gasoline product supplied.

[87]U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, *Scenarios of U.S. Carbon Reductions, Potential Impacts of Energy Technologies by 2010 and Beyond* (Washington, DC, September 1997), pp. 5.30-5.31.

[88]*Oxy-Fuel News Monthly Market Update* (December 21, 1998).

[89]Some State environmental agencies are considering restrictions on the use of MTBE. If the use of MTBE were restricted and oxygen content requirements for gasoline remained in place, the use of ethanol would likely increase considerably.

of a competitive domestic cellulosic biomass-to-ethanol production industry. OFD works with DOE national laboratories, other DOE organizations, the U.S. Department of Agriculture, universities, and corporations to develop the technological innovations needed to propel a biomass ethanol industry to market maturity. The major research and development programs focus on biomass feedstock development and ethanol conversion processes.

In 1998, the Nation's first cellulosic biomass-to-ethanol demonstration plant opened in Jennings, Louisiana. DOE's industry partner, BC International, is converting a former grain-to-ethanol plant to a plant that uses agricultural residues as feedstock. In addition, BC International and the City of Gridley, California, are working with a biomass power company, DOE, and others in planning for another ethanol plant using local wood and rice straw as feedstocks. Another DOE partner, the Masada Resources Group, has selected a site in New York State for the final feasibility study of a solid waste recycling and ethanol production facility using municipal solid wastes. These projects are expected to result in commercial ethanol production plants in the 2001-2003 time frame.

The CCTI is not expected to have a large additive affect on the biomass ethanol program but will support the ongoing research and development efforts for this technology. Little additional funding for the ethanol program is expected, although biomass conversion may be included in a series of workshops sponsored under the auspices of the CCTI. The effect of the biomass ethanol program is already incorporated in the reference case. Although the impact of the research and development efforts on the market penetration of cellulose ethanol has not been directly modeled, the reference case assumes that the cost of producing ethanol from biomass will decline by 20 percent from current levels by 2020.[90] The cost decline reflects a learning function consistent with the one used in NEMS for the construction of new types of electricity generation plants.[91]

Ethanol production from corn is projected to increase slightly in the early years of the reference case projections, then fall back to near current levels by 2020. Cellulose ethanol, on the other hand, rises steadily through the forecast, reaching 57,000 barrels per day by 2010 and 127,000 barrels per day by 2020 (Table 39), thus surpassing the level of corn-produced ethanol. Ethanol from cellulose is a relatively new technology, and cost reductions are expected to occur at a much faster pace than for corn ethanol, giving ethanol from biomass a greater impetus for growth. At the same time, because cellulose ethanol is a new industry, investments would be considered higher risk and involve greater uncertainty. For these reasons, a limit was placed on the rate of capacity growth. Cellulose ethanol production capacity was allowed to grow by 50 million gallons per year (about 3,300 barrels per day) from 2001 to 2005. After 2005, if the economics are favorable, up to 250 million gallons per year (about 16,300 barrels per day) of capacity can be added. In those regions where State subsidies for ethanol production are provided in addition to the Federal tax exemption, the State subsidies induce capacity expansion for cellulose ethanol.[92]

Carbon emissions reductions resulting from the displacement of gasoline by cellulose ethanol are projected at 0.3 million metric tons in 2005 (0.05 percent of transportation petroleum carbon emissions), 1.8 million metric tons in 2010 (0.3 percent of transportation petroleum carbon emissions), and 3.9 million metric tons in 2020 (0.6 percent of transportation petroleum carbon emissions).

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[90]This contrasts with the National Biomass Ethanol Program estimate of a 50-percent reduction by 2020.

[91]This learning function was subject to extensive review. See Energy Information Administration, *NEMS Component Design Report: Modeling Technology Penetration* (Washington, DC, March 1993).

[92]Motivated by a desire to develop new markets for agricultural products, States are assumed to provide the same subsidies for cellulose ethanol as for corn ethanol.

Table 39. Ethanol Consumption and Resulting Carbon Emissions Reductions in the Reference Case, 1997, 2005, 2010, and 2020

Projection	1997	2005	2010	2020
Ethanol Consumption (Thousand Barrels per Day)				
Corn-Based Ethanol	82	110	103	90
Cellulose Ethanol	0	8	57	127
Total	**82**	**118**	**160**	**217**
Carbon Emissions Reductions from Displacement of Gasoline by Cellulose Ethanol (Million Metric Tons)	0.0	0.3	1.8	3.9

Sources: **1997:** Energy Information Administration (EIA), *Petroleum Supply Annual 1997*, DOE/EIA-0340(97/1) (Washington, DC, June 1998). **Projections:** EIA, AEO99 National Energy Modeling System run AEO99B.D100198A.

The blending characteristics of ethanol may impede its future growth. As a motor gasoline blending component, ethanol has many attractive qualities. It is high in octane and contains no aromatics, benzene, or olefins. On the other hand, it has a high Reid vapor pressure (Rvp) blending value and is water soluble. The high Rvp indicates a higher tendency for emissions of volatile organic compounds, which would hinder its use in summer gasoline with tighter Rvp specification limits. Because of their water solubility, ethanol blends are not transported via pipeline. Consequently, ethanol use is restricted to splash blending at terminals near final points of gasoline distribution. In the reference case, the use of ethanol for splash blending is projected to remain close to current levels through 2010, increasing to 106,000 barrels per day by 2020 (Table 40).

Table 40. Projected Uses of Ethanol in the Reference Case, 1997, 2005, 2010, and 2020
(Thousand Barrels per Day)

Ethanol Use	1997	2005	2010	2020
Direct Blending	82	56	77	106
ETBE	0	44	51	65
E85	0	19	32	46
Total	**82**	**118**	**160**	**217**

Sources: **1997:** Energy Information Administration (EIA), *Petroleum Supply Annual 1997*, DOE/EIA-0340(97/1) (Washington, DC, June 1998). **Projections:** EIA, AEO99 National Energy Modeling System run AEO99B.D100198A.

In addition to its direct use as a gasoline blending component, ethanol is used to produce another gasoline blending component, ETBE. ETBE is similar to MTBE, a methanol-derived ether used extensively by refiners for oxygenated and reformulated gasoline. ETBE does not have the high Rvp and water solubility problems that hinder ethanol's use. The cost of producing ETBE and the distance from major ethanol-producing areas to major refining centers has limited its use, but it is expected to increase as gasoline specifications become tighter in the future. Ethanol use for ETBE production is projected to increase slowly but steadily in the reference case, to 51,000 barrels per day in 2010 and 65,000 barrels per day in 2020 (Table 40). Ethanol for E85 also increases throughout the forecast, rising to 32,000 barrels per day in 2010 and 46,000 barrels per day in 2020.

Electricity Generation

The CCTI funding request for research, development, and deployment initiatives includes support for continued development for solar energy, biomass power, wind energy, geothermal power, and hydropower; the Renewable Energy Production Incentive and renewable energy demonstration projects; the International Solar Program; improvements in the quality and reliability of power service; distributed generation; hydrogen production and storage; superconducting technology; life extension of nuclear power plants; development of more efficient coal and natural gas generation; and research into the capture and storage of carbon dioxide. Nearly all the programs that would receive new or additional CCTI funding have long-term goals for which quantitative analysis of potential benefits is not feasible. They are described here in general terms, with emphasis on the stated goals of the programs and their reported progress and accomplishments to date.

In the *AEO99* reference case, significant improvement over the next 20 years was assumed for the cost and performance characteristics of electricity generation technologies. Those assumptions were based in part on current private and public research and development efforts, including many of the federally funded programs that are associated with the CCTI proposal. Without the assumption of continued technology improvements, the projections for both electricity sector fuel use and carbon emissions would be higher.

In the frozen technology case for the electricity generation sector, which assumed that the cost and performance characteristics of generating technologies—including fossil and renewable technologies—would stay at 1999 levels, projected fossil fuel use in the electricity sector was 2 percent higher in 2010 and 3 percent higher in 2020 than in the reference case. Similarly, electricity sector carbon emissions were 11 million metric tons (2 percent) higher in 2010 and 28 million metric tons (4 percent) higher in 2020 than in the reference case. It is difficult to estimate the degree to which each of the programs described below might individually affect future electricity fuel use and carbon emissions; however, if total research and development efforts decline significantly from historical levels, the technology improvements assumed in the reference case probably would not be fully realized.

Fossil Fuel Technologies

DOE's Office of Fossil Energy (FE) has requested $37 million in 2000 for climate change funding, a $13 million increase over the 1999 budget (Table 41). Significant increases are requested for research on efficient generating technologies ($9.7 million)—including coal integrated combined-cycle, coal pressurized fluidized bed, fuel cells, gas turbines, and Vision 21 power facilities—and carbon control and sequestration technologies ($3.3 million).

Efficient Electricity Generating Technologies

Background

The proposed CCTI budget requests an increase of $3.85 million for research on more efficient coal-fired generating technologies. In total, the proposed budget for coal technology research and development, $122 million in fiscal year 2000, is slightly less than the 1999 budget of $123 million. However, past efforts have focused primarily on reducing SO_2, NO_x, and particulate emissions from existing plants, whereas future efforts are expected to focus on improving efficiency of the next generation of plants in order to lower their per-kilowatthour carbon emissions.

Table 41. Office of Fossil Energy CCTI Funding, 1999 and 2000
(Thousand Dollars)

Research Area	Fiscal Year 1999 Appropriation	Fiscal Year 2000 Request
Coal		
Advanced Clean/Efficient Power Systems		
Indirect Fired Cycle	$1,000	$1,000
High-Efficiency Integrated Gasification Combined-Cycle	$14,000	$16,250
High-Efficiency Pressurized Fluidized Bed		
Gas Stream Cleanup	0	$1,000
Pressurized Fluidized Bed Combustion	0	$400
Vision 21	0	$200
Advanced Research and Environmental Technology		
CO_2 Control/Sequestration	$5,800	$9,126
Advanced Research and Technology Development		
Coal Utilization Science	$2,000	$2,000
Material & Components	$1,000	$1,000
Gas		
Natural Gas Research		
Turbines		
Vision 21	0	$800
Fuel Cells	0	$5,000
Total	**$23,890**	**$36,776**

Source: U.S. Department of Energy, Office of Fossil Energy.

Technologies such as advanced gasification combined-cycle, pressurized fluidized bed, and gasification fuel cell generating units may lead to significant improvements in efficiency. In addition, FE has begun work on a new generation of plants referred to as Vision 21 facilities. As stated in the FE fiscal year 2000 budget request, "Vision 21 is an extension or continuation of ongoing R&D to lower the cost and dramatically improve the environmental performance and efficiency of coal plants that will lead to the deployment of a family of plants that converts a combination of feedstocks (e.g., coal, natural gas, biomass, opportunity fuels, petroleum residuals, wastes) to electricity, heat (e.g., steam), a suite of high-value products that may include synthesis gas, hydrogen, liquid fuels, chemicals, and by-products (e.g., sulfur and ash or slag)."

For gas-fired generating technologies, the proposed CCTI budget includes $5.0 million for research on fuel cells and $0.8 million for turbine systems. The expenditures would be focused on the development of Vision 21 power plants.

Analysis

EIA has included the improvements in efficiency expected from coal technology research and development in recent analyses. Both in *AEO99* and, previously, in an analysis of the Kyoto Protocol, new advanced coal plants were projected to approach 47 percent efficiency. Even with those improvements, however, new plant additions are expected to be dominated by gas-fired technologies in the next 10 to 15 years. New natural-gas-fired combustion turbines and combined-cycle plants are, in most cases, the most economical options available when new plants are needed. New efficient coal plants are not expected to be added in significant numbers until after 2010, gradually becoming economical as their construction costs decline and the gap between coal and gas prices widens.[93]

[93]Energy Information Administration, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998); and *Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity*, SR/OIAF/98-03 (Washington, DC, October 1998).

If limits were placed on U.S. carbon emissions in the future, it is unlikely that new coal-fired plants would be economically attractive over the next 20 years without the development of an economical carbon sequestration technology. Currently, coal-fired power plants produce more than half of U.S. electricity generation, and their average operating costs are under 2 cents per kilowatthour. They also account for nearly 90 percent of the carbon emissions produced in the generation sector. Even with fairly significant efficiency improvements, the carbon intensity of new coal plants would far exceed that of other options, including other fossil fuels (Table 42). Present-day coal plants produce more than 2.5 times as much carbon per megawatthour of output as do conventional combined-cycle gas-fired plants, and the ratio is expected to remain over 2 to 1 for the next generation of advanced coal plants and advanced gas combined-cycle plants.

Table 42. Carbon Emissions for Fossil Generating Technologies

Technology	Carbon Emissions: Pounds per Million Btu Consumed	Carbon Emissions: Pounds per Megawatthour Generated	Efficiency (Percent) (Illustrative)
Coal Technologies			
Existing Coal	57	571	34
New Pulverized Coal	57	519	38
Advanced Coal	57	418	47
Gas Technologies			
Conventional Turbine	32	336	32
Advanced Turbine	32	253	43
Existing Gas Steam	32	326	33
Conventional Combined-Cycle	32	222	49
Advanced Combined-Cycle	32	201	54
Fuel Cell	32	170	64

Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

U.S. power producers would be expected to rely on natural gas and, to a lesser extent, renewable fuels to reduce their carbon emissions if limits were imposed.[94] No new coal plants are projected to be built in any of the carbon reduction cases EIA has analyzed. It is possible that new efficient coal plants may be attractive in foreign countries where natural gas and renewable resources are limited, and the cleaner, more efficient coal plants developed in the United States could be helpful as part of an overall strategy to reduce global carbon emissions. In addition, in the longer run, if domestic gas and renewable resources become more expensive than expected, efficient coal-fired plants combined with carbon sequestration technologies currently in the early stages of development could be important in the United States as well.

With respect to new gas-fired technologies, EIA expects new power plant additions to be dominated by relatively efficient gas plants. In *AEO99*, new advanced gas-fired generating plants are expected to reach efficiencies of nearly 54 percent. As with the new generation of coal plants, Vision 21 gas plants are not expected to play much of a role

[94]Energy Information Administration, *Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity*, SR/OIAF/98-03 (Washington, DC, October 1998).

in the time frame of the Kyoto Protocol. In the longer run they could be important, but their future may also depend on the development of economical carbon sequestration technologies if carbon reductions beyond those called for in the Kyoto Protocol are eventually needed.

Carbon Sequestration

Most discussions of carbon emissions reduction options focus on improving energy efficiency and increasing the use of low- or zero-carbon fuels. A third option is to capture and store the carbon emitted from fossil-fired power plants. Potential storage options include depleted oil and gas reservoirs, deep underground saline reservoirs, and the ocean. Norway is currently sequestering carbon dioxide (CO_2) in a saline aquifer below the North Sea, and CO_2 injection is being used at about 70 sites worldwide for tertiary oil recovery. Some hazardous wastes are also being placed in long-term storage, but their volumes are extremely small relative to the amounts of carbon (mostly as CO_2) produced by U.S. power plants.

An alternative approach to sequestering carbon is to enhance natural biological processes that remove CO_2 from the atmosphere. Options in this category include forest management, increasing soil carbon content, and increasing ocean biomass productivity (with sequestration by sedimentation of bio-carbon).

The fiscal year 2000 DOE coal technology research and development budget request calls for spending approximately $9 million on carbon sequestration research and development. In addition, the DOE basic science program, the EPA, and the U.S. Department of Agriculture (USDA) have requested funding increases for CO_2 removal and sequestration programs. In total, the CCTI request includes $39 million for these programs, an increase of $25 million over the 1999 appropriation, with increases of $3 million for DOE’s FE budget, $13 million for DOE’s basic science, $4 million for EPA, and $6 million for USDA.

If natural gas and/or renewable resources turn out to be more expensive than expected, or if carbon reductions beyond the Kyoto Protocol targets are required, technologies that remove and store carbon produced by fossil plants may be needed. At present, technologies for removing carbon from the flue gas of fossil power plants are very expensive. Most use a capital-intensive monoethanolamine (MEA) solvent process that can more than double the cost of building a conventional pulverized coal plant and the cost of the power it produces. It should be possible to lower the costs of carbon removal for newer combustion technologies such as coal gasification combined-cycle or fuel cell units with improved CO_2 capture approaches, but much work is needed before the technologies will be economical. Further research is also needed to explore the economics and long-term viability of CO_2 storage. Recent research suggests that the volumes that could be stored in some reservoirs are quite large.

Carbon sequestration technologies are not expected to contribute to carbon emissions reductions in the time frame of the Kyoto Protocol. If their economics can be improved significantly and long-term storage proves viable, they could provide an additional reduction option in the post-2015 time period.

Renewable Technologies

Solar Photovoltaics

Costs for photovoltaics are declining, and it is expected that they will be used more widely for off-grid and niche applications, especially where electric power is highly valued and alternative sources are expensive. U.S. manufacturers and marketers of photovoltaic modules are likely to find ready and growing markets outside the United States, especially where utility grids are weak or nonexistent. Both domestically and abroad, where solar conditions are favorable, and where grid-connected or fossil-fueled generation is unavailable or too expensive, photovoltaics can provide electric power for refrigeration, lighting, monitoring and measuring devices, pumps, communications, and other essential services. However, their costs remain orders of magnitude greater than those of electric utility power for all but a few U.S. applications.

On average, U.S. retail residential electricity prices are expected to remain well below 8 cents per kilowatthour (in 1997 dollars) through 2020. Peaking prices—such as on hot summer days—could occasionally exceed 15 cents per kilowatthour. In comparison, costs for photovoltaic power today probably exceed 25 cents per kilowatthour in most applications. EIA estimates suggest that even in the most efficient (large-scale) wholesale applications, their costs will exceed 10 cents per kilowatthour through 2020, while the costs for more reliable electricity supplies from natural-gas-fired power plants remain at 4 cents per kilowatthour or less.

Consumer costs for electricity from photovoltaic modules, especially if they are installed in very small units by retail commercial installers or include energy storage systems (batteries), are likely to remain multiples of retail electricity rates. Therefore, where grid-supplied electricity is offered, it will almost always be much less expensive and far more reliable than photovoltaic power. Even if notable cost reductions are achieved, it is unlikely that increased research and development will markedly change the relative economics of photovoltaics in the near term or that they will become a significant component of overall U.S. electric power supply before 2020.

For thin-film photovoltaics, the DOE goal for 2000 is to have module efficiency reach 13 percent in prototype CIS or CdTe modules. Progress in thin-film photovoltaics is critical for future U.S. market success, both in achieving further significant drops in capital costs and in providing cost-effective performance. In addition to prototype performance, marked improvements will be needed in commercially available units. DOE estimates current costs at around $9,000 per kilowatt of capacity, with goals of $5,300 per kilowatt by 2000 and $1,500 per kilowatt by 2010. Capacity factors currently are reported at about 21 percent.[95] Given that current crystalline silicon solar technologies are reported to cost about $5,000 per kilowatt and have higher capacity factors than thin-film photovoltaics, accelerated cost reductions for thin-film technologies are needed if they are to replace crystalline technologies and markedly expand U.S. and world applications. It is unlikely, however, that meeting the goals of the DOE research and development program for photovoltaic technology will result in significant penetration of overall U.S. electricity markets.

Solar Thermal

The DOE goal for dish / Stirling (concentrating) solar thermal energy systems for 2000 is to achieve 1,000 hours of unattended operation of a single dish / Stirling system during field testing. The main objective of the DOE program in the near term is to prove the reliability of the system and increase the time of unattended operation. The dish / Stirling solar electricity technology is attractive in providing clean renewable energy, in being modular, and in potentially offering essential electric power to distributed grid-connected or off-grid applications. Applications may be most promising outside the United States, such as for village power, where solar conditions are favorable and grid-connected power is unavailable. However, the dish / Stirling technology is far from commercial today, with test unit capital costs estimated at $10,000 to $20,000 per kilowatt. Goals for the technology include reducing capital costs to around $5,500 per kilowatt by 2000, $3,000 by 2005, and $1,600 by 2010, with capacity factors increasing from an assumed 13 percent today to 50 percent by 2000,[96] and possible beginning penetration of U.S. green power markets.

[95]Electric Power Research Institute and Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, *Renewable Energy Technology Characterizations*, EPRI TR-109496 (December 1997), pp. 4-23–4-24.
[96]*Renewable Energy Technology Characterizations*, EPRI TR-109496 (December 1997), p. 5-57.

The dish/Stirling technology faces large challenges in contributing to U.S. electricity supply before 2010. Meeting year 2000 goals, either in cost or performance, is unlikely, making the challenge of meeting later goals all the greater. Even if all goals are met, dish/Stirling will remain more expensive than almost all fossil and renewable energy alternatives. Moreover, its cost-effective applications are likely to be restricted to small, high-cost applications in the U.S. Southwest. International prospects for the technology are better, and it may eventually compete successfully for rural essential electricity supply—including for both individual and small village service—against fossil fuels, wood, and other renewables, including wind and photovoltaics.

Biomass

The goal of DOE's Biomass Power Systems program is to integrate sustainable biomass feedstock production with efficient biomass power generation and establish a cost-competitive power supply, with construction of 3,000 megawatts of new biomass capacity in all sectors by 2004. The EIA reference case projections indicate that roughly one-third of the new capacity goal is likely to be achieved.

The CCTI budget request for fiscal year 2000 includes $39 million for the Biomass Power Systems research, development, and deployment program, representing an increase of $7.5 million (24 percent) over the allocation for fiscal year 1999 (Table 43). There are three major technology areas in the program: (1) co-firing biomass with fossil fuels, (2) small modular biomass power systems, and (3) advanced biomass gasification. Additional program elements, which generally are supportive of and integrated with the three technologies, include thermochemical conversion research, energy crop development, and the Regional Biomass Program.

Table 43. DOE's Biomass Power Systems Budget
(Million Dollars)

Program	Projects	Goals, 2001-2006	Fiscal Year 1999 Appropriation	Fiscal Year 2000 Request
Co-firing with fossil fuels	Complete two current initiatives:		5.0	8.7
	- Willow with coal in New York	Generate 0.5 quadrillion Btu per year		
	- Switchgrass with coal in Iowa	Offset 4 x 10^6 tons of carbon per year		
	Complete three additional projects			
Small modular systems	Selection of projects from 10 design contracts	Complete test of 2-3 projects	2.0	4.0
Advanced gasification	Vermont wood-fired system	Sustained operation	16.0	19.5
	Minnesota alfalfa gasifier	2001 startup		
Feedstock development	Research to improve grass yields	2-3 high-yield clones	2.3	3.1
	Willow yield improvement	5,000 acres planted		
	Harvesting, etc. cost reduction			
	Feedstock database development	Complete database		
Thermochemical conversion	Gas treatment/cleanup testing	Install Vermont system	1.6	2.7
	Alkali metals problem research			
	NO_x emissions modeling			
	Analytical equipment purchase			
Other programs	Regional Biomass Program		1.3	1.0
	Various demonstration projects		3.4	0
Total			**31.5**	**39.0**

Source: Department of Energy Budget, web site www.cfo.doe.gov/budget/00budget/esrd/ee/renewabl.pdf, pp. 72-83.

DOE has several co-firing projects underway with power producers in a variety of stages. The two primary projects that are cost-shared are in the early stages and are planned for expansion with dedicated sources of biomass. The New York project goal is to have up to 600 acres of willow planted. The co-firing will be tested and the retrofit of two coal plants will be completed. In Iowa, the goal is to have up to 3,600 acres of switchgrass established by 2000 and be generating power in 2000. The program will also seek to expand the use of co-firing with additional cost-shared co-firing demonstrations. Data from retrofitting and testing at four established sites will be used to develop confidence in the method. A goal for co-firing is to reduce carbon emissions by 4 million metric tons per year by 2006. The EIA analysis indicates that half that goal is likely to be reached by 2005. Co-firing coal technology with biomass is discussed in Chapter 2.

The DOE program for small modular systems is directed at commercializing systems providing power in the 5 kilowatt to 5 megawatt size, either gasification or direct-fired systems. They are likely to be employed in industrial applications, possibly as a retrofit of existing biomass units. Funding is to be used for feasibility studies, demonstration units and developing full system integration, with a goal of testing 2 to 3 units. In the *AEO99*, EIA projects an expansion of biomass systems in the industrial sector, where biomass cogeneration capacity increases from 5.5 gigawatts in 1997 to 7.4 gigawatts in 2020.

Advanced gasification development is focused on two projects that are part of the Biomass Power for Rural Development program. They constitute nearly half the budget and are cost-shared with private investors. Program objectives include: (1) facilitating the transition from using residues to the use of dedicated crops, (2) supporting the expansion of large-scale crop production, and (3) developing a more environmentally benign source of power. The Vermont Gasifier project, which has been operating as a gasifier only, will add a combined-cycle generation system and hot-gas cleanup unit. The program goal for the integrated system will be to operate it for 1,000 hours at a capacity of 8 to 12 megawatts. The Minnesota plant will use alfalfa stems and market the leaves as animal feed. Construction of the 75-megawatt unit will begin in 2000, and startup is scheduled for 2001. The EIA analysis described in Chapter 2 characterizes the biomass gasification technology incorporated in *AEO99*; because it is not assumed to be commercially available until 2005, no further penetration under the CCTI tax incentive program is projected. Modest growth in the use of other biomass capacity eligible for the credit is projected, with a minimal effect on carbon emissions by 2004 (when the CCTI tax credits would expire).

The feedstock development program overlaps with other Biomass Power Systems programs in that feedstocks are an important part of the economics of biomass utilization. The NEMS model incorporates biomass resources by way of supply curves, which could be affected by the success of the programs; however, with energy crops not currently projected to be available on a large scale before 2010, no effects would be seen until that time.

Thermochemical conversion programs are a set of longer term research projects. One is for research on gas cleanup options for both large and small gasification systems, a multi-year laboratory program that would support testing at the Thermochemical User Facility of the National Renewable Energy Laboratory. Another project is focused on minimizing problems from the high alkali metal content of many biomass fuels, which can lead to fouling and slagging in boilers and furnaces. The research results are linked to the co-firing performance measures. A third project will evaluate the impact of restructuring in the electricity generation industry on technology development by modeling effects on NO_x emissions and assessing the need for incentives. Finally, some funding will be used for the purchase of analytical equipment as part of the laboratory program.

Wind

The CCTI proposes funding for accelerated research and development of wind power technology, with the goal of developing wind turbines able to produce power at 2.5 cents per kilowatthour (unsubsidized) in good wind conditions by 2002.[97] Wind technologies continue to improve, and extensive global investment in research and development suggests further cost declines in the future. Wind turbine component costs are expected to go down, and improvements in the licensing, siting, and construction of wind projects are expected to continue. Concurrent with growing industry experience worldwide, increased funding for research and development may contribute to lower costs for electricity generated from wind power. Nevertheless, the likelihood of reaching an unsubsidized cost of 2.5 cents per kilowatthour for wind power in good wind conditions by 2002 appears remote.

First, the goal of 2.5 cents appears optimistic in light of DOE characterizations of future wind costs. Current DOE estimates cite a goal of 4.3 cents per kilowatthour for 2000 in "good" (class 4) wind conditions, progressing to 3.1 cents by 2010. A cost of 2.5 cents is estimated only for "excellent" (class 6) winds and not until 2010.[98] Exceeding DOE's 2010 class 4 goal by nearly 20 percent 8 years in advance seems unlikely, unless current costs are already well below published expectations. The current capital costs for wind power generation technologies are almost certainly not below, but markedly above, published expectations. The DOE estimates for 2000 assume capital costs of about $750 per kilowatt. Available information for recent installations shows actual wind facility costs, excluding substation and interconnection costs, nearer to $1,000 per kilowatt, consistent with DOE estimates of about 6.4 cents per kilowatthour.

Second, EIA has not observed recent rates of cost decline or noted clear technological advances suggesting near-term large drops of the type necessary to support the 2.5 cent per kilowatthour wind power cost projection. Whereas the published technology characterizations identify a decline from $1,000 per kilowatt in 1997 to $750 in 2000, installed system costs through 1998, including substation and interconnection costs, appear to average $1,200 per kilowatt. To EIA's knowledge, no generally recognized breakthroughs markedly lowering wind power costs have been publicly demonstrated as of early 1999.

Finally, the 2.5 cent goal may understate the costs to tax-paying entities—those eligible for the production tax credit. The goal of 2.5 cents assumes low-cost, tax-exempt municipal financing, which would not be available to projects eligible for the CCTI tax credit. Cost estimates assuming investor financing raise levelized costs to as much as 3.2 cents per kilowatthour.

Another DOE goal for U.S. wind-powered generating capacity (using technologies developed by DOE) is to increase installed capacity from 1,859 megawatts on line in 1998 to 2,300 megawatts in 2000. EIA's *AEO99* projects that the United States will substantially exceed the target, with 2,800 megawatts of U.S. wind-powered generating capacity on line by 2000.[99] Whereas in 1998 almost all U.S. wind capacity was in California, most of the additional capacity will be built outside California. By the end of 2000, large projects will also be operating in the Midwest, Southwest, and Northwest. The expansion is part of investments of more than $9 billion in wind power worldwide during the 1990s from public and private research and development efforts, in response to environmental concerns, and in order to meet experimentation, testing, mandates, and other national, regional, local, and utility objectives. Worldwide,

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[97]For understanding of DOE's wind technology expectations, EIA relied on the wind technology characterization published jointly by DOE and the Electric Power Research Institute (EPRI) in *Renewable Energy Technology Characterizations*, EPRI TR-109496 (December 1997), pp. 6-1, 6-31.

[98]*Renewable Energy Technology Characterizations*, EPRI TR-109496 (December 1997), pp. 7-3.

[99]Energy Information Administration, *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998), p. 134.

wind generating capacity is increasing rapidly, estimated to have grown from around 2,000 megawatts in 1990 to about 9,600 megawatts in 1998.[100]

Wind power appears to be gaining market interest and to be poised for additional investment and growth, both in the United States and abroad. It is likely, however, that costs will decline more slowly than suggested by the goal of 2.5 cents per kilowatthour goal by 2002.

Geothermal

The mission of DOE's Geothermal Energy Program is to work with industry to establish geothermal energy as a sustainable, environmentally sound, economical source of energy. The proposed research and development program is directed at various approaches to reducing the overall costs of delivering power to consumers. The program has four main elements: reservoir technology, exploration, drilling technology, and energy conversion.

The reservoir technology program element is aimed at improving the understanding of reservoirs and exploring means to improve performance by techniques such as water reinjection. The expected result would be to extend field life so as to establish a more sustainable resource. EIA currently assumes some plant retirements in its projection as a result of enthalpy decline, and this program activity could reduce or possibly eliminate such retirements. The CCTI budget proposal would increase the funding for reservoir technology research from $5.5 million to $8.0 million.

Exploration research is aimed at reducing the number of nonproductive wells drilled, through research on improved seismic methods. At present, the characterization of geothermal fields through seismic strategies remains a high-risk activity, leading to the need for more expensive exploratory drilling. The proposed budget would increase funding for this component from $5.5 million to $7.0 million.

The drilling technology program will complete the testing of high-performance drill bits and other drilling technologies. The effort is aimed at reducing drilling costs, which can constitute up to half the capital costs of a geothermal power unit, with a goal of improvement from exponential cost increases with well depth to linear increases with well depth. The CCTI budget proposal would increase funding for the drilling technology program from $5.0 million to $7.5 million.

The energy conversion program has two principal elements. The first would initiate a cost-shared project to construct and test an 8-megawatt Kalina-cycle binary power plant, which would be more efficient and could expand the low-temperature resource base. The second would continue research and development on small-scale modular power plants, which could help maintain grid voltages and match loads and could also support "mini-grids" in remote applications. Funding for these projects is proposed to increase from $6.0 million to $7.0 million. The overall geothermal energy budget proposal, increasing from $22.0 million to $29.5 million, is aimed at broad incremental cost improvements. The stated goal of lowering levelized costs from $0.035 per kilowatthour to $0.030 per kilowatthour could be achieved if many of the individual programs were successful.

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[100]C. Flavin, "A Force To Be Reckoned With, The Wind Power Market Boomed in 1998," *Renewable Energy World*, Vol. 2, No. 2 (March 1999), p. 17.

Hydropower

DOE is funding the development of a new generation of hydropower turbines that would reduce dangers to fish. In fiscal year 2000, DOE will complete pilot-scale testing of a new conceptual design, budgeting $7 million, up from $3.25 million appropriated in fiscal year 1999.

Conventional hydropower is by far the Nation's largest source of renewable energy for electricity generation, currently providing about 10 percent of all U.S. electricity and more than 80 percent of electricity from renewable energy sources. It is the dominant source of electric power supply in some areas, particularly in the Northwest. Conflicts with hydropower are increasing, however, especially with regard to its dangers to fish populations. As a result, prospects are growing for stalled or even declining U.S. hydroelectric output. Almost no new generating capacity is projected through 2020, and restrictions reducing output from existing hydroelectric facilities are increasing. Future increases in production from other renewables may be in large part offset or even eliminated by decreases in U.S. hydroelectric output, possibly yielding a net decline in overall U.S. electric power production from renewable energy sources.

If conventional hydroelectric power is to retain or increase its contribution to U.S. electricity supply, methods of enhancing its productivity must be found. Among the more attractive prospects is the introduction of safer, "fish friendly" hydroelectric turbines, presumably retrofitted into existing facilities as part of refurbishment and repowering activities.

EIA has not evaluated the prospects for success of DOE's hydroelectric turbine program, and the marginal economic benefits of the specific proposals in the CCTI could not be quantified. Any evaluation of the newer turbines would require additional information on likely costs and performance, particularly the extent to which the safer turbines would sacrifice (or gain) efficiency relative to existing technologies.

Nuclear Power

DOE's Office of Nuclear Energy plans to spend $5 million in 2000 on its Nuclear Energy Plant Optimization (NEPO) program. The goal of the program is "reducing barriers to efficient and safe operation—increasing plant capacity from 71 percent in 1997 to 85 percent in 2010 and addressing issues associated with plant aging." If successful it is hoped that the program will increase the number of nuclear plants for which license renewals are sought at the end of their current operating lives, which in turn would reduce the need for new fossil-fired capacity and the increased carbon emissions that might be associated with it.

Without license renewal a large number of existing nuclear plants will reach the end of their current operating licenses by 2020. In *AEO99*, just over one-fourth of the existing U.S. nuclear capacity is projected to be retired by 2010 and over half by 2020. Plants are expected to be retired rather than relicensed because the costs of their continued operation exceed the costs of power from other sources. In recent years, several nuclear plants have been retired before license expiration when utilities were faced with the need to make large capital expenditures. It is impossible to predict when or if other plants might face the need for expensive maintenance or upgrades.

EIA has incorporated similar capacity factor assumptions in recent analyses. In fact, in the *AEO99* reference case, the capacity factor for nuclear plants is assumed to be slightly higher than 85 percent in 2010. The *AEO99* also included cases based on alternative assumptions about the costs of maintaining U.S. nuclear power plants. The impact on carbon emissions could be important, especially in the years after 2010. In the case where lower costs were assumed, carbon emissions were projected to be 11 million metric tons lower in 2010 and 31 million metric tons lower in 2020 than projected in the reference case.

Other Energy-Related Research

Hydrogen Fuels

The CCTI proposal includes funding for DOE to accelerate research on low-cost hydrogen production and storage, prerequisites to the widespread use of hydrogen as a fuel. A hydrogen-fueled economy would have many environmental benefits over the current fossil-based system, because the chief byproduct of the combustion of hydrogen is water. In addition, hydrogen is very flexible and could be used in mobile as well as stationary applications. Interest in hydrogen as a fuel grew during the energy crises of the 1970s, when it was believed that fossil fuel prices would continue to grow for the foreseeable future and new nuclear plants were expected to be “too cheap to meter.” The prospect of using new nuclear plants to produce hydrogen for use in mobile and stationary applications looked promising under those circumstances.

The conditions described above have not materialized. As a result, there are several major hurdles that must be overcome before a hydrogen-fueled economy could become a reality. The major hurdles involve improving the economics of hydrogen production, fuel distribution and handling, and storage systems. In addition, there is concern about technologies for handling and storing hydrogen safely. Today, the cost of these activities far exceeds the cost of fossil fuel alternatives. As a result, it is unlikely that increased use of hydrogen as a fuel will contribute significantly to efforts to reduce U.S. carbon emissions over the next 10 to 20 years. As stated in the *Hydrogen Program Overview* prepared by Sandia National Labs, “Unfortunately, the widespread use of hydrogen energy is not currently feasible because of economic and technological barriers.”[101] However, if these barriers can be overcome the long-run benefits could be quite large.

Currently most of the hydrogen used in industrial processes is produced from natural gas through a steam reforming process. In the most economical large plants, hydrogen can be produced for $7 to $8 per million Btu. This does not compare well with the direct combustion of natural gas, which sells for $2.20 to $2.30 per million Btu at the wellhead. In addition, because natural gas is used in its production hydrogen from the process is not carbon free. It is possible to produce hydrogen using electricity (produced from renewables to eliminate carbon) and water, but that process is even more expensive—around $30 per million Btu. New photobiological and photoelectrochemical production processes are being studied, but they are in the very early stages of research and development. DOE plans to demonstrate a solar-to-hydrogen conversion system with 12-percent efficiency in 2000.

Similar economic hurdles exist for hydrogen storage systems. Again, as stated in the *Hydrogen Program Overview*, “Current storage methods are too expensive and do not meet the performance requirements of the various applications. This is especially true for hydrogen’s potential use as a transportation fuel, where there is a need for high energy density—energy content per unit of space—and lightweight mobile storage.” This is a significant hurdle because hydrogen has a very low energy density at normal temperature and pressure conditions. As a result, mobile fuel tanks will have to operate at very high pressure—perhaps as much as 2,000 to 2,500 pounds per square inch or more. Current systems that can handle such pressures are large and heavy. Researchers are now testing the use of new materials (lightweight graphite), but more work is needed.

[101]National Renewable Energy Laboratory, *Hydrogen Program Overview*, DOE/GO-10095-088, DE94011827 (February 1995).

In the long run, post-2020, hydrogen could be an important source of energy in the United States. Less costly production processes using low-cost renewable electricity offer the potential for a carbon-free energy sector, particularly if economical fuel cells under development for use in hybrid vehicles—most notably the proton exchange membrane (PEM) fuel cell—are successful. It remains unlikely, however, that the use of hydrogen as a fuel will contribute significantly to reducing anthropogenic carbon emissions over the next 10 to 20 years.

High-Temperature Superconductivity

DOE supports industry-led projects to capitalize on recent breakthroughs in superconducting wire technology, aimed at developing devices such as advanced motors, power cables, and transformers. These technologies would allow more electricity to reach the consumer without an increase in fossil fuel input.

The use of superconductive materials in electric power applications would provide an opportunity to reduce electricity losses and the fuel use and emissions associated with them. The discovery of high-temperature superconductive materials in the late 1980s fundamentally changed the economics of the technology. Before their discovery, superconducting materials had to be cooled to below -400^{o}F, whereas in recent years materials with superconductive properties at temperatures near -200^{o}F have been developed. Although temperatures of -300 to -200^{o}F are still exceedingly cold, they are much less expensive to maintain than the temperatures required for low-temperature superconductors, because relatively inexpensive liquid nitrogen can be used in place of liquid helium.

Even with the advances that have been made since the late 1980s, however, significant technological and economic challenges must be overcome before the use of high-temperature superconductive materials will be widespread. In addition, the losses that occur in the electrical coils in conventional motors and generators are quite small, often 5 percent or less, and the potential savings in fuel and emissions from the introduction of superconducting coils are not large.

The costs of superconductive materials are still quite high. As stated in DOE's *Superconductivity Program Overview*, "Materials used to produce high-temperature superconducting wire are inherently difficult to process into usable forms for electric power applications. This situation is the opposite of that for typical metallic electrical conductors, such as copper. And this fact presents processing obstacles that must be overcome to manufacture devices that can actually be used in electric power system applications."[102] The cost reductions required for them to be competitive are quite large. Again, from the program overview, "the cost of long-length, high-temperature superconducting wire needs to be reduced by 10 to 100 times to be competitive with other technologies."[103] It is possible that high-temperature superconductive materials could eventually lead to lower electricity losses and, thereby, contribute to reducing U.S. carbon emissions. Over the next 10 to 20 years they may find their way into some high-value applications, but it is unlikely that they will play a significant role in U.S. efforts to reduce carbon emissions.

Conclusion

Historically, research and development programs have helped to develop more efficient and advanced technologies at lower cost than might otherwise occur, and to reduce the costs and improve the operational characteristics of existing technologies. Thus, these programs have been successful in accelerating the availability of improved technologies in the marketplace. In addition, there have been a number of information programs, voluntary

[102] National Renewable Energy Laboratory, *Superconductivity Program Overview*, DOE/GO-10095-012, DE95000204 (February 1995).
[103] National Renewable Energy Laboratory, *Superconductivity Program Overview*, DOE/GO-10095-012, DE95000204 (February 1995).

programs, partnerships, and similar initiatives to encourage the penetration and adoption of improved technologies, some of which appear to have achieved some success. In general, these initiatives have contributed to improvements in energy efficiency, carbon emissions, air quality, energy security, international competitiveness, and quality of life.

EIA incorporates the impacts of ongoing research, development, and deployment programs into its reference case, assuming support for these activities at historic levels. Therefore, reductions in these programs over time could lead EIA to raise its projections of energy consumption and carbon emissions, and new or expanded programs could lead to a reduction in the EIA estimates.

While recognizing the success of past and current research, development, and deployment programs, it is difficult to establish a quantitative relationship between levels of funding and specific improvements in the characteristics, availability, and adoption of energy technologies. By its nature, research and development is highly uncertain. Seemingly plausible avenues of research may not achieve success; however, breakthrough developments are also possible.

In addition, successful development of new technologies may not lead to immediate penetration in the marketplace. A number of factors may serve to slow adoption, including consumer preference for product attributes other than fuel efficiency or reduced emissions; higher costs for new technologies; low prices for fossil energy and conventional technologies; unfamiliarity with the benefits, use, and maintenance of new products; and uncertainties concerning the reliability and further development of new technologies. Some of the barriers may be reduced by some of the CCTI initiatives. In any case, these barriers do not mean that the impacts of the research, development, and deployment programs could not be substantial over time. Continued technology development may lower costs or improve technology efficiencies, reliability, or other attributes, so that the technologies become more economically competitive and attractive in the market. Also, gradual penetration may increase familiarity with technologies, establish the supporting infrastructure, and help reduce technology costs.

Some of the research, development, and deployment programs are discussed qualitatively in the analysis, or the impacts of ongoing programs in the reference case are presented. EIA also quantitatively evaluated some of the CCTI programs with specific program goals. For these programs, EIA assumed that the goal was realized and analyzed the impact on energy consumption and carbon emissions. Assuming the success of the PATH program for efficiency improvements in new homes resulted in energy and emissions reductions of about 1 percent in the residential sector in 2010 and about 2 percent in 2020. Carbon emissions were reduced by 3.1 and 6.7 million metric tons in 2010 and 2020, respectively, as a result of the realization of the PATH goals as stated by the Administration; however, the projected impacts of the Administration’s goals for the Million Solar Roofs programs were considerably less, only 0.9 million metric tons in both years.

In the transportation sector, EIA assumed that the goals of PNGV programs were achieved, saving about 0.15 percent of total transportation energy in 2010 and 0.53 percent in 2020. As a result, projected carbon emissions could be reduced by 0.9 million metric tons (0.14 percent) in 2010 and by 3.9 million metric tons (0.56 percent) in 2020. EIA also analyzed the potential impacts of the advanced diesel program for light and heavy trucks by assuming the successful achievement of program goals for the underlying technologies. It is projected that this program would save 0.42 percent of total transportation energy in 2010 and 1.22 percent in 2020, reducing carbon emissions by 2.8 million metric tons (0.45 percent) in 2010 and 8.8 million metric tons (1.26 percent) in 2020, if the development of the technologies met the target goal.

Some of the CCTI programs for technology research, development, and deployment may achieve benefits only in a long time frame beyond 2020, or they may not achieve success at all. Even if technology development is successful new equipment may penetrate slowly, and significant changes in the average stock of equipment may take a long time. Although many of the programs for residential and commercial buildings have the potential for success, the goal of the Million Solar Roofs program is unlikely to be reached because of high equipment costs. Some of the industrial programs also have the potential for success; however, the capacity expansion goals of the CHP Challenge program appear too ambitious, given that equipment stock turns over slowly in this sector and that this sector expects a relatively short payback. For the transportation programs, the most recent report by the NRC evaluating the PNGV programs is skeptical about the prospect for success in meeting its goals, and while technology is improving, the goals appear optimistic to EIA as well. Advanced diesel light trucks may have difficulties with both emissions requirements and public acceptance. Assuming that technology development for heavy trucks is successful, the average efficiency of new heavy trucks could be improved from 6.1 to 7.5 miles per gallon in 2020, raising the average stock efficiency from 5.8 to 6.5 miles per gallon, but that would still be short of the stated efficiency goal of 12 miles per gallon because of slow stock turnover and late introduction dates for some technologies.

Many of the programs for electricity generation may have longer-term success, even beyond the 2020 time frame of the analysis, including the fossil technology programs for efficiency improvements and carbon sequestration. Hydrogen and superconductivity are also much longer-term programs. Some of the renewable technology programs may be successful; however, the goal of reducing the cost of wind technology to 2.5 cents per kilowatthour by 2002 appears unlikely. Even if the renewable programs are successful, they may not make a significant impact by 2020 due to high technology costs relative to fossil fuel technologies and limited opportunities for some of the renewable technologies. On the other hand, higher energy prices or other changing market conditions may serve to make any of the CCTI programs more economically attractive and improve their success. Also, efforts to meet carbon reduction goals may contribute to the success of some of the initiatives.

4. Energy-Efficient Appliances and Equipment

Introduction

In 1987, Congress passed the National Appliance Energy Conservation Act (NAECA), which gave the U.S. Department of Energy (DOE) legal authority to promulgate minimum efficiency requirements for 13 classes of consumer products. The Energy Policy Act of 1992 (EPACT) expanded the coverage to include certain commercial building equipment. The law also mandated that DOE revise and update the standards over time, as technologies and economic conditions changed. From 1988 to 1998, DOE was active in establishing and updating standards for the consumer products it was assigned to evaluate. Table 44 shows the products and years in which standards were either established or revised. The table includes the most recent revisions to the standards for room air conditioners and refrigerators/freezers, which take effect in 2000 and 2001, respectively.

Table 44. Effective Dates of Appliance Efficiency Standards, 1988-2001

Technology	1988	1990	1992	1993	1994	1995	2000	2001
Clothes dryers	X				X			
Clothes washers	X				X			
Dishwashers	X				X			
Refrigerators and freezers		X		X				X
Kitchen ranges and ovens		X						
Room air conditioners		X					X	
Direct heating equipment		X						
Fluorescent lamp ballasts		X						
Water heaters		X						
Pool heaters		X						
Central air conditioners and heat pumps			X					
Furnaces-Central (more than 45,000 Btu per hour)			X					
Furnaces-Small (less than 45,000 Btu per hour)			X					
Furnaces-Mobile home		X						
Boilers			X					
Fluorescent lamps, 8 foot					X			
Fluorescent lamps, 2 and 4 foot (U tube)						X		

Sources: Energy Information Administration, *Annual Energy Outlook 1998*, DOE/EIA-0383(98) (Washington, DC, December 1997), and *Annual Energy Outlook 1999*, DOE/EIA-0383(99) (Washington, DC, December 1998).

Historically, appliance efficiency standards have had a major impact on the amounts of energy needed to power many household devices. The reference case for the *Annual Energy Outlook 1999* (*AEO99*) projects a 28-percent decline in electricity use for refrigerators in 2020 from the 1997 level, despite a projected 30-percent increase in the stock of refrigerators. Table 45 shows historical data for the efficiency of new refrigerators, for which efficiency standards were promulgated in 1990 and 1993 and are planned for 2001.

Table 45. Efficiency of New Refrigerators, 1972-2001
(Kilowatthours of Electricity Used per Unit per Year)

	1972	1985	1990	1993	1996	2001
Efficiency	1,986	1,077	884	664	654	478

Source: Association of Home Appliance Manufacturers (October 1997). The value for 2001 represents the standard that was set for a typical refrigerator with an adjusted volume of 20 cubic feet.

The process for setting standards is by no means trivial. Once a product class is determined, detailed engineering, economic, and manufacturer impact analyses are performed over a period of many months. When the analyses have been completed and made available to the public, an Advanced Notice of Proposed Rulemaking (ANOPR) is published. Approximately 8 months later a Proposed Rule is published, and the Final Rule is published approximately 8 months after that.[104] After the Final Rule is published, a lead time of 2 to 3 years normally is allowed for the standard to take effect. (In some cases, negotiated rulemaking may be able to shorten the process.) DOE plans to publish final rules in the next 2 years that will revise the standards for four product classes under its NAECA authority: central air conditioners, water heaters, ballasts, and clothes washers.

In the CCTI, a portion of the $273 million included in the proposed initiative for buildings technology would be used to accelerate the lighting and energy efficiency standards program.[105] Energy use in buildings may be affected by the acceleration of updates to NAECA standards for residential equipment such as heat pumps and central air conditioners, and for fluorescent lamp ballasts. Updates to EPACT standards for commercial equipment may also affect energy use.

To estimate the potential impact of accelerating the standards-setting process, the timetable and levels used in a recent study by the American Council for an Energy-Efficient Economy[106] were applied in the NEMS residential and commercial modules. The efficiency levels and timetable generally appear feasible, assuming that the process operates smoothly. Given the uncertainty surrounding the effective dates of appliance efficiency standards, EIA's reference case forecasts include only the standards that have been officially promulgated by DOE. Although the standards are in no way related to the specific funding levels in the CCTI proposal, the analysis illustrates the effects that accelerated standards may have on levels of energy use and carbon emissions. As with the tax incentive proposals, model results were obtained with and without the accelerated standards to gauge the projected impacts on the energy use and carbon emissions attributable to buildings. The analysis considered only the residential and commercial sectors, with no feedback from effects on energy prices or the economy. Table 46 shows the assumed efficiency levels and effective dates of the accelerated standards for each appliance in the CCTI analysis case.

[104]The time line discussed here is the one given for central air conditioners by DOE's Office of Codes and Standards.
[105]"President Clinton's FY 2000 Climate Change Budget," p. 6, and "Report to Congress on Federal Climate Change Expenditures," p. 11.
[106]American Council for an Energy-Efficient Economy, *Approaching the Kyoto Targets: Five Key Strategies for the U.S.* (Washington DC, August 1998).

Table 46. Assumptions for Accelerated Minimum Efficiency Standards Affecting Buildings

Technology	Current Standard[a]	Accelerated Standard[a]	Effective Date
Clothes washers	0.82 MEF	1.40 MEF	2006
Air-source heat pump	6.8 HSPF, 10.0 SEER	8.0 HSPF, 13.0 SEER	2005
Central air conditioner	10.0 SEER	13.0 SEER	2005
Room air conditioner	9.7 EER	11.0 EER	2006
Electric water heater	0.86 EF	0.93 EF	2003
Gas water heater	0.54 EF	0.60 EF	2003
Refrigerator	496 kWh	397 kWh	2007
Dishwasher	0.48 EF	0.62 EF	2005
Furnaces (oil and gas)	0.78 AFUE	0.80 AFUE	2007
Commercial packaged air conditioner[b]	8.9 EER	10.3 EER	2005
Fluorescent ballasts[c]	Energy-efficient magnetic	Electronic	2003

[a]Heating and cooling efficiency, respectively, are given for heating and cooling combination units. Units for efficiency measures are presented as given in the Department of the Treasury's explanation of the CCTI proposals: MEF, Modified Energy Factor; HSPF, Heating Seasonal Performance Factor; SEER, Seasonal Energy Efficiency Rating; EER, Energy Efficiency Ratio; EF, Energy Factor; kWh, kilowatthour; AFUE, Annual Fuel Utilization Efficiency.

[b]Effective date changed from that given in source reference. Timetable adjusted from 2001 to 2005 for commercial packaged air conditioners, based on current priority and stage in the rulemaking process.

[c]A small percentage of magnetic ballasts are retained after the electronic ballast standard takes effect, representing exceptions to the standard granted because electronic ballast frequencies interfere with the performance of other electronic equipment.

Source: American Council for an Energy Efficient Economy, *Approaching the Kyoto Targets: Five Key Strategies for the U.S.* (Washington, DC, August 1998).

Analysis Results

Table 47 shows the results of the analysis. Again, the values shown do not indicate the effects of the specific funding levels in the CCTI proposal but rather those of the accelerated standards program represented in Table 46.

Table 47. Comparison of Results: Accelerated Standards Process

Variable	1997	2005		2010		2020	
		Reference Case	Accelerated Case	Reference Case	Accelerated Case	Reference Case	Accelerated Case
Delivered Energy Use (Trillion Btu)	18,551	19,904	19,875	20,792	20,648	22,467	22,193
Carbon Emissions (Million Metric Tons)	522.2	582.7	581.7	614.1	608.7	681.9	672.5
Energy Bill Savings (Million 1998 Dollars)	—	—	431.4	—	2,334.7	—	4,170.1

Source: Energy Information Administration, National Energy Modeling System runs BLDDEF.D040699A and BLDSTND.D040699A.

Efficiency standards are projected to have a greater effect on energy consumption and carbon emissions in the buildings sectors than would the CCTI tax incentives or the voluntary programs discussed elsewhere in this report, because minimum efficiency standards apply to all purchase decisions involving the affected technologies. With the standards assumed for the analysis, it is projected that 144 trillion Btu (0.7 percent) of energy could be saved by 2010, reducing carbon emissions by 5.4 million metric tons (0.9 percent) in 2010.

Once set, standards continue to affect purchase decisions and energy use as new buildings are built and worn-out equipment is replaced. The longer an efficiency standard is in place, the greater the percentage of appliances in use that meet the standard and the greater the benefit in terms of energy and carbon savings compared to a reference case without the standard in place. By 2020, projected energy use in the accelerated standards case is 274 trillion Btu (1.2 percent) lower, and carbon emissions are 9.4 million metric tons (1.4 percent) lower, than in the reference case. The projected annual savings in energy expenditures for residential and commercial consumers exceed $4 billion in 2020.

Appendix A

Letters from the Committee on Science

U.S. HOUSE OF REPRESENTATIVES

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December 16, 1998

The Honorable Jay E. Hakes
Administrator
Energy Information Administration
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Dr. Hakes:

We appreciate the study that you did for us on analyzing the impact of the Kyoto Protocol on the U.S. energy system and the economy. The purpose of this letter is to request that the Energy Information Administration undertake a second study that analyzes the impact of specific policies on the reduction of carbon emissions and their impact on U.S. energy use and prices. Again, we are particularly interested in the 2008-2012 time frame, but the impact beyond this period is also important. The policies we would like you to evaluate should include tax incentives, new equipment standards, and the earlier introduction of new technologies. We are also interested in your evaluation of an earlier start date than 2005 (e.g., 2000), and incorporating whatever regulations the Environmental Protection Agency has specified for particulates.

As with the previous study, our staffs will be happy to work with you. In the next few months, we will provide the policies we want you to examine. We would appreciate the results of your analysis by this fall. Thank you, in advance, for your assistance and for the unbiased and reliable energy analysis that your agency produces.

Sincerely,

F. JAMES SENSENBRENNER, JR.
Chairman

GEORGE E. BROWN, JR.
Ranking Minority Member

U.S. HOUSE OF REPRESENTATIVES

COMMITTEE ON SCIENCE

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March 2, 1999

The Honorable Jay E. Hakes
Administrator
Energy Information Administration
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Dr. Hakes:

On December 16, 1998, we formally requested that the Energy Information Administration undertake a study to analyze the impact of specific policies on reducing carbon emissions. The purpose of this letter is to ask you to analyze the impact of the President's Climate Change Technology Initiative, as defined for the 2000 budget, on reducing carbon emissions from the levels forecast in the *Annual Energy Outlook 1999* reference case. Also, in our previous letter we asked you to evaluate an earlier start date than 2005, which was the first year that the price signal was passed to consumers in your study of the Kyoto Protocol that you conducted at our request. We would like you to use a start date of 2000 and compare the annual and cumulative carbon price for complying with the Protocol for 3 of the cases you considered in the earlier study (24% above, 9% above, and 7% below 1990 levels) with the later start date of 2005.

We would appreciate these analyses in the next few months and may request further analyses as we evaluate other policies that the Administration is contemplating. Our staff will continue to work with your staff on any questions you may have relating to this request.

Sincerely,

F. JAMES SENSENBRENNER, JR.
Chairman

GEORGE E. BROWN, JR.
Ranking Minority Member