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Analysis of The Climate Change Technology Initiative: Fiscal Year 2001

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Preface

In February 2000, the Administration sent its fiscal year 2001 budget request to the U.S. Congress. It includes about $4 billion in programs related to climate change. The proposal includes about $1.6 billion in fiscal year 2001 for tax incentives, research and development, and other spending for the Climate Change Technology Initiative (CCTI). CCTI includes tax incentives for energy efficiency improvements and renewable technologies for buildings, light-duty vehicles, 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 U.S. House of Representatives, Committee on Government Reform, Subcommittee on National Economic Growth, Natural Resources, and Regulatory Affairs. The Committee asked the Energy Information Administration (EIA) to update its report, *Analysis of the Climate Change Technology Initiative*, released April 14, 1999, accounting for changes in the President's fiscal year 2001 budget request, as noted in the letter in the Appendix.

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 incentives; research, development, and deployment programs; and 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 positions 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 2000, the Administration's fiscal year 2001 budget request was sent to the U.S. Congress. The request includes about $4 billion in programs related to climate change. The proposal includes about $1.6 billion in fiscal year 2001 for tax incentives, research, development, deployment, and other spending for the Climate Change Technology Initiative (CCTI). CCTI includes tax incentives for deploying energy efficiency improvements and renewable technologies for buildings, light-duty vehicles, 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, enhanced energy security, and maintaining U.S. leadership in science and technology. 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 fiscal year 2001 CCTI budget request of about $1.6 billion for all Federal agencies includes about $1.4 billion for research, development, and deployment and $201 million for tax incentives in fiscal year 2001. Of the $1.4 billion in expenditures for programs other than tax incentives, $337 million is the increase over the fiscal year 2000 budget.

At the request of the U.S. House of Representatives, Committee on Government Reform, Subcommittee on National Economic Growth, Natural Resources, and Regulatory Affairs, 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 2000* (*AEO2000*).[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 $65 million for management, planning, and analysis for the U.S. Department of Energy (DOE), the Environmental Protection Agency (EPA), and the U.S. Department of Agriculture (USDA) and $3 million for EIA. The analysis primarily focuses on the tax incentives in CCTI, which are new initiatives or extensions of current tax credits. EIA is not able to link research and development expenditures directly to program results or to separate the impacts of incremental funding requested for fiscal year 2001 from ongoing program expenditures. Therefore, the research, development, and deployment programs are either addressed qualitatively, analyzed via their impact in the *AEO2000* 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, for example, proposals for electricity restructuring and renewable portfolio standards.

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[1]Energy Information Administration, *Annual Energy Outlook 2000*, DOE/EIA-0383(2000) (Washington, DC, December 1999).

[2]Energy Information Administration, *National Energy Modeling System: An Overview 2000*, DOE/EIA-0581(2000) (Washington, DC, March 2000).

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, assuming 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 also 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 and users of energy equipment, consumer preference for other equipment attributes instead of efficiency, consumer preference for short payback periods, and uncertainties about performance, reliability, installation and maintenance, costs, future technology developments, and infrastructure requirements. EIA analyzes empirical evidence to estimate consumer price response and preferences in order to project consumer reaction to changes in energy prices or improvements in energy efficiency; however, models generally 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 intended to encourage the adoption of technologies close to commercial viability. As such, these proposed incentives are of small to modest magnitude and of relatively short duration.

CCTI proposes investment tax credits for buildings and vehicles to lower the initial costs of more energy-efficient and renewable technologies to consumers, production tax credits for renewable generation technologies, and a change in the depreciable life for distributed power property. With the exception of the latter tax incentive, these are generally proposed for 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 loss of the incentives are $201 million in fiscal year 2001 and $4.0 billion from fiscal year 2001 through fiscal year 2005, all in nominal dollars.

The tax incentives proposed in CCTI are as follows:

- *Buildings*
  - *Tax Credits for Energy-Efficient Homes*—new tax credits to the purchasers 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 from 2001 through 2003 that are at least 30 percent more efficient and a credit of $2,000 for homes built from 2001 through 2005 that are at least 50 percent more efficient than the IECC standard.

- *Tax Credits for Energy-Efficient Equipment in Homes and Buildings*—new 20-percent tax credits, subject to caps, to the purchasers of electric heat pump water heaters, natural gas heat pumps, and fuel cells, meeting specified efficiency levels, purchased from 2001 through 2004. The cap is $500 per kilowatt for fuel cells, $1,000 per unit for natural gas heat pumps, and $500 per unit for electric heat pump water heaters.

- *Tax Credits for Rooftop Solar Systems*—a new 15-percent tax credit, subject to a cap, for rooftop photovoltaic systems installed between 2001 and 2007 and solar water heating systems installed from 2001 through 2005 but not applicable to solar-heated swimming pools. The cap is $2,000 for photovoltaic systems and $1,000 for solar water heating systems.

- *15-Year Depreciable Life for Distributed Power Property*—qualified distributed power property placed in service after the date of enactment would be assigned a 15-year depreciation recovery period and a 22-year class life. Qualified systems would include property used in the generation of electricity for primary use in nonresidential real property or residential rental property used in the taxpayer's trade or business and property with a rated total capacity in excess of 500 kilowatts that is used in the generation of electricity for primary use in a taxpayer's industrial manufacturing process or plant activity. Under current law, a distributed power asset used in a commercial or residential building is likely to be classified as a building structural component and depreciated using the straight-line method over 39 years if placed in service after 1993. Although this initiative is listed as an industrial program in CCTI, the proposal represents no change for property used in an industrial manufacturing process or plant activity. Therefore, it is considered a buildings program in this analysis. Distributed power in the residential sector is only represented in the EIA model for single-family homes, therefore any potential impacts from the tax initiative on residential rental property are not reflected in these results.

● *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 in 2005; however, the proposal would extend the credit at its full level through 2006.

- *Tax Credits for Hybrid Vehicles*—new tax credits for qualifying hybrid vehicles, including cars, minivans, sport utility vehicles, and pickup trucks, purchased from 2003 through 2006, ranging from $500 to $3,000, depending on the vehicle's design performance.

● *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 January 1, 2002, would be extended to systems placed in service before July 1, 2004, or, if unfinished by that date but under firm contract or under construction, eligibility is extended through June 30, 2005.

- *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 (closed-loop), placed in service after December 31, 1992, and before January 1, 2002, would be extended to systems placed in service before July 1, 2004, or, if unfinished by that date but under firm contract or under construction, eligibility is extended through June 30, 2005. The definition of biomass systems eligible for the credit would be extended to systems using nondedicated energy crops (open-loop), including certain forest-related, agricultural, and other biomass sources. New open-loop facilities placed in service on or after January 1, 2001, through December 31, 2005, would receive the 1.5-cent-per-kilowatthour credit for ten years, and a 1.0-cent-per-kilowatthour credit, adjusted for inflation from a 2000 base, would be provided for electricity produced from 2001 to 2003 from facilities placed in service prior to January 1, 2001. A new 0.5-cent-per-kilowatthour tax credit, adjusted for inflation from a 2000 base, would be added for biomass-fired electricity generated by coal plants using biomass co-firing from January 1, 2001, through December 31, 2005.

- *Tax Credits for Landfill Gas Generation*—a new tax credit of 1.0 cent per kilowatthour for landfills subject to EPA's New Source Performance Standards (NSPS) and a 1.5-cent-per-kilowatthour credit for landfills not subject to the NSPS for systems placed in service between January 1, 2001, and December 31, 2005. The proposal would also extend the tax credit to December 31, 2006, for facilities under construction but not completed in 2005 or for facilities with a construction contract in place in 2005 to be completed in 2006.

Table ES1 presents the impacts of the tax incentives in terms of energy savings and reductions in carbon emissions in 2010, relative to the *AEO2000* reference case, which assumes current laws and regulations. Note that the EIA model only tracks the carbon equivalent of carbon dioxide emissions from the combustion of energy. The incentives may have additional impacts on other greenhouse gas emissions, for example, reductions in methane emissions from landfills and increases in methane emissions from biomass combustion. These impacts are not quantified in this analysis. The carbon savings include 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 incentives are likely to penetrate even without the incentives and are included in the reference case. Since the tax incentives may be claimed by all units, those units that would be added even without the incentives become unintended beneficiaries of the tax incentives. For the EIA estimates, both revenue impacts are presented.

Table ES1. Summary of Projected Impacts for CCTI Tax Initiatives, 2010

CCTI Initiative	Reduction[a] in Primary 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, 2001-2005[d]		
				EIA Estimate[e] (Million 1998 Dollars)		Administration Estimate (Million Nominal Dollars)
				Without Unintended Beneficiaries	With Unintended Beneficiaries	
Buildings						
- Energy-Efficient Equipment . . .	5.9	0.1	41.4	116[f]	198[f]	201
- Energy-Efficient New Homes	9.5	0.1	68.6	394	454	633
- Rooftop Solar Equipment	<0.01	<0.01	<0.01	<1	102[g]	132
- Distributed Power	1.7	<0.05	11.5	<1	8	10
Transportation						
- Electric, Fuel Cell, and Hybrid Electric Vehicles	27.1	0.5	283.0	1,438	1,912	2,078
Renewable Generation[h]	48.7	0.6	88.8	408	944	976
Total	**92.9**	**1.3**	**493.3**	**2,356**	**3,618**	**4,030**

[a]Estimated reductions are relative to the CCTI reference case which is similar to that in Energy Information Administration, *Annual Energy Outlook 2000*, DOE/EIA-0383(2000) (Washington, DC, December 1999). For renewable generation, the expenditure savings are for expenditures on fossil fuels for electricity generation.
[b]For the renewable generation tax credits, the change represents the reduction in fossil energy use for electricity generation.
[c]Reductions in carbon emissions from electricity are calculated from the estimated emissions of marginal generating plants.
[d]EIA's revenue losses are for calendar years, and the Administration's revenue losses are for fiscal years. Revenue reductions are for 2001 through 2005 although some proposed tax initiatives extend beyond 2005.
[e]If the EIA estimates of revenue losses were in nominal dollars, the estimates would be larger and generally closer to the Administration's estimates.
[f]EIA does not include commercial sector purchases of natural gas heat pumps or heat pump water heaters.
[g]Assumes a portion of the commitments of the photovoltaic installations under the Million Solar Roofs program. Excludes Federal government installations.
[h]Total revenue impacts for all renewable generation programs. For new biomass and wind generating capacity accelerated into service before 2006 in order to receive the production tax credit, only generation in 2006 and after is considered to be an unintended beneficiary. Treasury does not disaggregate the revenues into the individual programs.

In 2010, the tax incentives for buildings and transportation are estimated to reduce primary energy consumption by 44.2 trillion British thermal units (Btu), or 0.04 percent, relative to the consumption of 111 quadrillion Btu projected in the reference case. In addition, the tax credits for renewable generation would reduce fossil energy consumption for electricity generation by 48.7 trillion Btu, or 0.04 percent of total projected energy consumption. In the *AEO2000* reference case, carbon emissions are projected to reach 1,787 million metric tons in 2010, which would be reduced by 1.3 million metric tons, or 0.07 percent, as a result of the impacts of the tax incentives.

Table ES2 presents the cumulative energy and emissions reductions through 2005, 2010, and 2020. From 2000 through 2010, the cumulative reductions in primary energy consumption total 1,062 trillion Btu and the cumulative carbon reductions are 21.5 million metric tons. Over the forecast horizon of this analysis, 2000 through 2020, the cumulative reductions in energy consumption and carbon emissions are 2,801 trillion Btu and 53.4 million metric tons, respectively.

Table ES2. Cumulative Projected Impacts for CCTI Tax Initiatives

CCTI Initiative	Cumulative Reductions[a] in Primary Energy Use[b] (Trillion Btu)			Cumulative Reductions[a] in Carbon Emissions[c] (Million Metric Tons)		
	2000-2005	2000-2010	2000-2020	2000-2005	2000-2010	2000-2020
Buildings						
- Energy-Efficient Equipment . . .	22.6	53.3	102.9	0.5	1.1	2.0
- Energy-Efficient New Homes	18.0	66.0	158.2	0.3	1.1	2.7
- Distributed Power	0.4	5.5	47.3	<0.05	0.1	1.0
Transportation						
- Electric, Fuel Cell, and Hybrid Electric Vehicles	16.8	117.6	611.5	0.3	2.2	11.7
Renewable Generation	529.4	819.8	1,881.0	11.6	17.0	36.0
- Wind	18.7	42.6	317.2	0.2	0.4	3.9
- Biomass Co-firing	407.3	471.3	414.1	9.6	11.2	11.5
- Landfill Gas	103.4	305.9	1,149.7	1.8	5.4	20.6
Total	**587.2**	**1,062.2**	**2,800.9**	**12.7**	**21.5**	**53.4**

[a]Estimated reductions are relative to the CCTI reference case which is similar to that in Energy Information Administration, *Annual Energy Outlook 2000*, DOE/EIA-0383(2000) (Washington, DC, December 1999).
[b]For the renewable generation tax credits, the change represents the reduction in fossil energy use for electricity generation.
[c]Reductions in carbon emissions from electricity are calculated from the estimated emissions of marginal generating plants.
Note: Does not include the rooftop solar and biomass tax credits, which have relatively small carbon emissions reductions.

Although the investment tax credits reduce the initial cost to the purchasers of the applicable equipment in the buildings and transportation 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 incentives of longer duration and/or higher value could encourage greater penetration of the technologies by making them more economically competitive. The timing of the tax incentives is also a key factor in their impacts. For example, the tax credit for fuel cell vehicles extends through 2006, but the technology is assumed by EIA to not become commercially available until 2005.

Tables ES3 and ES4 show the projected impacts of the tax incentives in 2002 through 2005, which generally increase through that time period as the more advanced technologies become available and gradually penetrate the market. When the buildings equipment tax credits expire in 2004 as proposed in CCTI, the impact of the credits is reduced, because some of the new, more efficient equipment begins to need replacement and is replaced by equipment of lower efficiency. Without the tax credit, the more efficient equipment is no longer economic. The total impact on carbon emissions is less in 2010 than in the earlier years because most other tax incentives expire in 2005. The transportation tax credits have a small impact in the earlier years because of the limited availability of eligible technologies; however, later in the period the impacts are larger because the tax credits encourage the penetration of advanced technology vehicles. The initiative for distributed power also has a larger impact later in the projection period because it is a change in the depreciation schedule without a time limit, not a tax credit. After 2010, the impacts of the tax incentives generally remain stable or decline through 2020 with the exception of the distributed power tax initiative and the transportation tax credits.

Table ES3. Projected Reductions in Primary Energy Use for CCTI Tax Initiatives, 2002-2010
(Trillion Btu)

CCTI Initiative	2002	2003	2004	2005	2010
Buildings					
- Energy-Efficient Equipment	3.1	4.8	6.7	6.6	5.9
- Energy-Efficient New Homes	0.8	2.1	5.1	9.8	9.5
- Rooftop Solar Equipment	<0.01	<0.01	<0.01	<0.01	<0.01
- Distributed Power	<0.05	0.1	0.1	0.2	1.7
Transportation					
- Electric, Fuel Cell, and Hybrid Electric Vehicles	0.5	2.5	5.2	8.6	27.1
Renewable Generation[a]	91.4	103.5	127.5	150.9	48.7
Total	**95.8**	**113.0**	**144.6**	**176.1**	**92.9**

[a]For the renewable generation tax credits, the change represents the reduction in fossil energy use for electricity generation.

Note: Estimated reductions are relative to the CCTI reference case, which is similar to that in Energy Information Administration, *Annual Energy Outlook 2000*, DOE/EIA-0383(2000) (Washington, DC, December 1999).

Although the CCTI tax initiatives lower carbon emissions, there is a loss to the Federal government resulting from the lower tax revenues. In Table ES5, the cost per ton of carbon reduced or avoided is presented for each of the tax initiatives, discounting both the tax revenue losses and the emissions reductions and discounting only the revenue losses because there is some disagreement about discounting nonmonetary values. Discount rates of 7 and 15 percent are used, along with no discounting.

Table ES4. Projected Reductions in Carbon Emissions for CCTI Tax Initiatives, 2002-2010
(Million Metric Tons)

CCTI Initiative	2002	2003	2004	2005	2010
Buildings					
- Energy-Efficient Equipment	0.1	0.1	0.2	0.1	0.1
- Energy-Efficient New Homes	<0.05	<0.05	0.1	0.2	0.1
- Rooftop Solar Equipment	<0.01	<0.01	<0.01	<0.01	<0.01
- Distributed Power	<0.01	<0.01	<0.01	<0.01	<0.05
Transportation					
- Electric, Fuel Cell, and Hybrid Electric Vehicles	<0.05	0.1	0.1	0.2	0.5
Renewable Generation	2.0	2.2	2.7	3.2	0.6
Total	**2.1**	**2.4**	**3.1**	**3.7**	**1.3**

Note: Estimated reductions are relative to the CCTI reference case, which is similar to that in Energy Information Administration, *Annual Energy Outlook 2000*, DOE/EIA-0383(2000) (Washington, DC, December 1999). Estimated reductions in carbon emissions from electricity are calculated from the estimated emissions of marginal generating plants.

With no discounting, the cost of carbon reductions ranges from $44 to $267 per ton across the various tax initiatives. For a 7-percent discount rate, the cost ranges from $54 to $460 per ton if carbon emissions are discounted and from $24 to $157 per ton if emissions are not discounted, and, for a 15-percent discount rate, the cost ranges from $55 to $813 per ton if carbon emissions are discounted and from $14 to $98 per ton if emissions are not discounted. The cost per ton of carbon emissions reduction increases with higher discount rates if the carbon emissions are discounted because the revenue reductions occur earlier in the period while the carbon emissions are reduced over the life of the equipment. As requested by the Subcommittee, it is noted that only the landfill gas tax initiative has a cost in the range of the $14 to $23 dollars per ton estimated as the cost of implementing the Kyoto Protocol.

The investment tax credits lower the initial cost of purchasing more efficient 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 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 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 incentives of longer duration and/or higher value could also lead to more significant impacts by making the technologies more competitive.

Table ES5. Projected Tax Revenue Reductions per Ton of Carbon Emissions Reduced
(1998 Dollars)

	Discount Rate				
		7		15	
CCTI Initiative	0	Emissions Discounted	Emissions Not Discounted	Emissions Discounted	Emissions Not Discounted
Buildings					
- Energy-Efficient Equipment	100	158	84	228	70
- Energy-Efficient New Homes	171	256	130	353	98
- Distributed Power	267	303	109	362	46
Transportation					
- Electric, Fuel Cell, and Hybrid Electric Vehicles	247	460	157	813	97
Renewable Generation	74	94	46	108	30
- Wind	142	198	79	275	44
- Biomass Co-firing	51	54	38	55	28
- Landfill Gas	44	61	24	80	14

Note: Calculated through 2020. Does not include the rooftop solar equipment and biomass tax credits, which have tax revenue reductions but relatively small carbon emissions reductions.
Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

Although tax incentives have benefits in encouraging some incremental investments, there may be some unintended consequences. Some of the technologies covered by the incentives would likely penetrate even without the incentives, which can be seen by comparing the tax incentive cases with the reference case. Those units would receive the tax benefits in addition to those units added incrementally as a result of the incentives. Such unintended beneficiaries may be a significant portion of the total units, nearly all of the rooftop solar equipment and 70 percent or more for the distributed power, transportation, wind, and biomass tax initiatives (Table ES6). Another unintended result could be a shifting of planned investments to fall within the time period of the incentives by purchasers either delaying until the incentives begin or accelerating their investments.

Table ES6. Projected Unintended Beneficiaries of CCTI Tax Initiatives
(Percent of Revenue Reductions)

CCTI Initiative	Unintended Beneficiaries
Buildings	
- Energy-Efficient Equipment	42
- Natural Gas Heat Pump (Residential Only)	50
- Electric Heat Pump Water Heater (Residential Only)	4
- Fuel Cell	2
- Energy-Efficient New Homes	13
- Rooftop Solar Equipment	Almost 100
- Distributed Power	77
Transportation	
- Electric, Fuel Cell, and Hybrid Electric Vehicles	84
Renewable Generation	70
- Wind	94
- Biomass	90
- Biomass Co-firing	34
- Landfill Gas	55

Note: Unintended beneficiaries are calculated over the life of the tax incentives, except for distributed power which is calculated from 2001 to 2020.
Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

Efficiency Standards

Appliance efficiency standards can lead to 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 take inefficient units off the market and also accelerate the introduction of new technologies.

Within the building technologies program, additional funding is provided to DOE to accelerate the 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 water heaters, distribution transformers, and commercial heating and cooling.

Because future standards are not specified, the potential impact is analyzed by evaluating the impacts of an accelerated standards case in *AEO2000*, in which it is assumed that standards are revised every 8 years and the efficiency levels increased by 10 percent when technologically feasible. In general, both the schedule and level of the assumed efficiency improvements are aggressive when compared to the history of standards enactment. Because of the timing of these assumed standards, some technologies may have two cycles of improvement in the forecast horizon. The results are shown in Table ES7. In the buildings sector, EIA projects that energy consumption in 2010 would be reduced by 468.3 trillion Btu, or 1.2 percent, and carbon emissions by 7.1 million metric tons, or 1.1 percent. Because of the energy efficiency improvements, consumers are projected to save $3,036 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. Of the programs evaluated here, efficiency standards are projected to have the largest impact although the costs of implementing such standards are not evaluated in this analysis.

Table ES7. Summary of Projected Impacts for Accelerated 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	468.3	7.1	3,036

[a]Estimated reductions are relative to the CCTI reference case which is similar to that in Energy Information Administration, *Annual Energy Outlook 2000*, DOE/EIA-0383(2000) (Washington, DC, December 1999).
[b]Reductions in carbon emissions from electricity are calculated from the estimated emissions of marginal generating plants.

Research, Development, and Deployment

CCTI also includes $1.4 billion of funding in the fiscal year 2001 budget request for research, development, and deployment of more energy-efficient and renewable energy and for research into carbon sequestration. Almost $1.2 billion is requested for programs within DOE, with additional funding for EPA, the Department of Housing and Urban Development (HUD), 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.

- *Industry*. Programs include partnerships to develop more energy-efficient technologies for the most energy-intensive industries and the continuing development of combined heat and power 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, either by enhancing the natural capacity of terrestrial ecosystems and oceans to take up and store carbon dioxide or by separating carbon dioxide from other gases when producing energy and storing it in an environmentally benign manner.

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 *AEO2000* 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 specific 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 of these technologies 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 incentives 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 success, such as Energy Star. The benefits of past efforts are difficult to quantify but are generally assumed in the efficiency trends 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 *AEO2000*, 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 projections with a case in which it is assumed that all future equipment choices in the end-use demand sectors are from technologies available in 2000, building shell and industrial plant efficiencies are frozen at 2000 levels, and new fossil generating technologies do not improve beyond 1999. In 2010, energy consumption in this low technology case is projected to be 2.5 quadrillion Btu, or 2.2 percent higher, than in the reference case, increasing projected carbon emissions by 45 million metric tons, or 2.5 percent. The reference case also incorporates the impacts of voluntary programs and partnerships, as well as other initiatives for improving energy efficiency and reducing carbon emission, such as the Climate Change Action Plan. Consistent with the requirement that EIA remain policy neutral, the reference case of *AEO2000* includes only current laws and regulations, not proposed regulations, policies, and programs. In a similar fashion, this analysis includes only the CCTI programs, as requested, with no other proposed or possible legislation and regulations.

In the *AEO2000* 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 are projected to become economical after 2010. Renewable electricity generation increases in the reference case projections, particularly biomass, wind, and 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, advanced and alternative-fueled vehicle sales are projected to account for nearly 15 percent of the total light-duty vehicle sales in 2020, with gasoline-electric hybrid, turbo direct injection diesels, and alcohol flexible-fuel vehicles leading this portion of the market; however, about 68 percent of advanced technology sales are driven by mandates.

If the program goals can be achieved, analysis indicates that some of the programs for buildings and for the development of renewable technologies may hold promise. 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 accelerated by the tax incentives. In addition, some of the technologies may have noneconomic 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), advanced diesel trucks, and biomass ethanol programs—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, improved energy security from reduced energy imports, maintaining U.S. leadership in science and technology, and revenues from the deployment of more advanced technologies in 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 being accepted in 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 undertaking energy efficiency investments. 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, power, and safety over efficiency. Also, consumers may have a relatively short payback period for investments in energy-consuming technologies. Technology penetration can also be slowed by uncertainties about performance, reliability, installation and maintenance, costs, 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 2000, the Administration sent its fiscal year 2001 budget request to the U.S. Congress. The Administration's budget for fiscal year 2001 includes about $4 billion in programs related to climate change. The proposal includes about $1.6 billion for tax incentives, research, development, and deployment, and other spending for the Climate Change Technology Initiative (CCTI). CCTI includes tax incentives for deploying energy efficiency improvements and renewable technologies for buildings, light-duty vehicles, 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, enhanced energy security, maintaining U.S. leadership in science and technology, and improved 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 fiscal year 2001 budget request for CCTI programs for all Federal agencies comprises about $1.4 billion for research, development, and deployment (representing an increase of $337 million over the fiscal year 2000 budget) and $201 million for tax incentives.

The analysis described in this report examines all the CCTI programs with the exception of $65 million for management, planning, and analysis programs at the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), and the U.S. Department of Agriculture (USDA) and $3 million for the Energy Information Administration (EIA). 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, EIA is not able to link research and development expenditures directly to program results or to separate the impacts of incremental funding requested for fiscal year 2001 from ongoing program expenditures.

Other programs included in the climate change budget include the U.S. Global Change Research Program, the International Clean Energy Initiative, the Biofuels and Bioproducts Initiative, the Clean Air Partnership Fund, and programs with climate change co-benefits—for example, improved coal and natural gas-fired generation, weatherization, and State energy grants. There are additional initiatives supported by the Administration that have a primary or ancillary purpose in reducing greenhouse gas 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 to consumers for buildings and vehicles that would lower the initial costs of more energy-efficient and renewable technologies, a revision to the depreciation schedule for distributed power property, and production tax credits for renewable generation technologies. The revenue impacts of the proposed tax incentives, as estimated by the Administration, total $201 million in fiscal year 2001 and $4.0 billion from fiscal years 2001 through 2005, all in nominal dollars. Although the tax incentives as proposed would generally 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 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 incentives. Compared to some earlier tax credits, including the 40-percent solar tax credit, the incentives currently proposed are generally 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 reduce the after-tax cost 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 tax credits to the purchasers 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 from 2001 through 2003 that are at least 30 percent more efficient and a credit of $2,000 for homes built from 2001 through 2005 that are at least 50 percent more efficient than the IECC standard.
  - *Tax Credits for Energy-Efficient Equipment in Homes and Buildings*—new 20-percent tax credits, subject to caps, to the purchasers of electric heat pump water heaters, natural gas heat pumps, and fuel cells, meeting specified efficiency levels, from 2001 through 2004. The cap is $500 per

kilowatt for fuel cells, $1,000 per unit for natural gas heat pumps, and $500 per unit for electric heat pump water heaters.

- *Tax Credits for Rooftop Solar Systems*—a new 15-percent tax credit, subject to a cap, for rooftop photovoltaic systems installed between 2001 and 2007 and solar water heating systems installed from 2001 through 2005 but not applicable to solar-heated swimming pools. The cap is $2,000 for photovoltaic systems and $1,000 for solar water heating systems.

- *15-Year Depreciable Life for Distributed Power Property*—qualified distributed power property placed in service after the date of enactment would be assigned a 15-year depreciation recovery period and a 22-year class life. Qualified systems would include property used in the generation of electricity for primary use in nonresidential real property or residential rental property used in the taxpayer's trade or business and property with a rated total capacity in excess of 500 kilowatts that is used in the generation of electricity for primary use in a taxpayer's industrial manufacturing process or plant activity. Under current law, a distributed power asset used in a commercial or residential building is likely to be classified as a building structural component and depreciated using the straight-line method over 39 years if placed in service after 1993. Although this initiative is listed as an industrial program in CCTI, the proposal represents no change for property used in an industrial manufacturing process or plant activity. Therefore, it is considered a buildings program in this analysis. Distributed power in the residential sector is only represented for single-family homes, therefore any potential impacts from the tax initiative on residential rental property are not reflected in these results.

- *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 in 2005; however, the proposal would extend the credit at its full level through 2006.

  - *Tax Credits for Hybrid Vehicles*—new tax credits for qualifying hybrid vehicles, including cars, minivans, sport utility vehicles, and pickup trucks, purchased from 2003 through 2006, ranging from $500 to $3,000, depending on the vehicle's design performance.

- *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 January 1, 2002, would be extended to systems placed in service before July 1, 2004, or, if unfinished by that date but under firm contract or under construction, eligibility is extended through June 30, 2005.

  - *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 (closed-loop), placed in service after December 31, 1992, and before January 1, 2002, would be extended to systems placed in service before July 1, 2004, or, if unfinished by that date but under firm contract or under construction, eligibility is extended through June 30, 2005. The definition of biomass systems eligible for the credit would be extended to systems using nondedicated energy crops (open-loop), including certain forest-related, agricultural, and other biomass sources. New open-loop facilities placed in service on or after January 1, 2001, through December 31, 2005, would receive the 1.5-cent-per-kilowatthour credit for ten years, and a 1.0-cent-per-kilowatthour credit, adjusted for inflation from a 2000 base, would be provided for electricity produced from 2001 to 2003 from facilities placed in service prior to January 1, 2001. A new 0.5-cent-per-kilowatthour tax credit, adjusted for inflation from a 2000 base, would be added for biomass-fired electricity generated by coal plants using biomass co-firing from January 1, 2001, through December 31, 2005.

- *Tax Credits for Landfill Gas Generation*—a new tax credit of 1.0 cent per kilowatthour for landfills subject to EPA's New Source Performance Standards (NSPS) and a 1.5-cent-per-kilowatthour credit for landfills not subject to the NSPS for systems placed in service between January 1, 2001, and December 31, 2005. The proposal would also extend the tax credit to December 31, 2006, for facilities under construction but not completed in 2005 or for facilities with a construction contract in place in 2005 to be completed in 2006.

Research, Development, and Deployment

In addition to tax incentives, CCTI includes about $1.4 billion of funding in the fiscal year 2001 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 $866 per kilowatt (1998 dollars) and have an efficiency of 41 percent. By *Annual Energy Outlook 2000 (AEO2000)*,[3] these assumptions were revised to a cost of $449 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 *AEO2000*, 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

[3]Energy Information Administration, *Annual Energy Outlook 2000*, DOE/EIA-0383(2000) (Washington, DC, December 1999).

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, costs, performance, 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 undertaken without the program. Therefore, there may be a tendency to overestimate the impacts of deployment programs on energy consumption and carbon emissions.

In CCTI, almost $1.2 billion is requested for research, development, and deployment programs within DOE, with additional funding for EPA, the Department of Housing and Urban Development (HUD), 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 an affordable prototype mid-size automobile by 2004 that meets all applicable

safety and environmental standards with an efficiency of 80 miles per gallon and a two-thirds reduction in carbon emissions.

- *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 2003 and engine and vehicle technologies to improve the fuel efficiency of new heavy trucks to 10 miles per gallon from the current average of 7 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 technologies that are more efficient, lower emissions, and improve competitiveness.

- *Industrial Combined Heat and Power*—continuing DOE programs for the development of new combined heat and power 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, either by enhancing the natural capacity of terrestrial ecosystems and oceans to take up and store carbon dioxide or by separating carbon dioxide from other gases when producing energy and storing it in an environmentally benign manner.

Efficiency Standards

Within the building technologies program, additional funding is provided to DOE to accelerate the 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 water heaters, distribution transformers, and commercial heating and cooling. 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 take inefficient units off the market and also accelerate the introduction of new technologies.

Methods of Analysis

At the request of the U.S. House of Representatives Committee on Government Reform, Subcommittee on National Economic Growth, Natural Resources, and Regulatory Affairs, 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 *AEO2000* in December 1999. 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 simulate 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; and electric, fuel cell, and hybrid vehicles were assumed to reduce the initial costs to purchasers of the applicable equipment over the years specified in the proposals. The revision to the depreciable life for distributed power property provides a tax incentive for commercial systems. The renewable generation tax credits provide an incentive for these technologies through a production tax credit.

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;

[4]Energy Information Administration, *National Energy Modeling System: An Overview*, DOE/EIA-0581(2000) (Washington, DC, March 2000). 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.

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 *AEO2000* reference case. EIA analyzed the buildings program for energy-efficient appliances and equipment, which includes acceleration of lighting and appliance efficiency standards and new Energy Star products, by evaluating the impacts of an accelerated standards case in *AEO2000* 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 the simulation of the decisionmaking process.

Each of the tax incentives or other programs were addressed relative to the reference case of *AEO2000*, with two exceptions. The *AEO2000* reference case was revised to incorporate updated information on advanced transportation technologies and landfill gas-to-energy, as discussed in Chapter 2. The reference case of *AEO2000* includes continuing improvements in technology, consistent with ongoing research and development, and the impacts of voluntary programs and other initiatives to reduce energy consumption and emissions. Consistent with the requirement that EIA remain policy neutral, only current laws and regulations are incorporated in the reference case. The reference case also represents consumer preferences and price response as derived from available data.

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 *AEO2000*, 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.[5] 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 2007. 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 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 other costs, such as the full

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

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 response—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 consumer price response 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. In addition to the uncertainties of consumer behavior and technology development, it is noted that changes in any single variable, such as world oil prices or natural gas prices, could change the specific impacts noted in this analysis.

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 personal 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, performance, costs, 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 for buildings, vehicles, and renewable electricity generation. The purpose of the tax incentives is to reduce the initial costs to the purchasers of more energy-efficient and renewable technologies for buildings and vehicles and provide tax incentives for the generation of electricity from renewable sources, thereby encouraging their adoption earlier than would otherwise occur. These are short-term incentives, lasting a few years and extending no later than 2007, with the exception of the change in the depreciable life for distributed power property; 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 incentives at $201 million in fiscal year 2001 and $4.0 billion from fiscal years 2001 through 2005, all in nominal dollars.

In general, this analysis of the tax incentives used the National Energy Modeling System (NEMS),[6] the Energy Information Administration's (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 incentives, relative to a reference case based on the *Annual Energy Outlook 2000* (*AEO2000*),[7] published in December 1999. 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 incentives. Compared to some earlier tax credits, including the 40-percent solar tax credit, the incentives currently proposed generally 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

[6]Energy Information Administration, *National Energy Modeling System: An Overview 2000*, DOE/EIA-0581(2000) (Washington, DC, March 2000).
[7]Energy Information Administration, *Annual Energy Outlook 2000*, DOE/EIA-0383(2000) (Washington, DC, December 1999).

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 incentives; however, those units would receive the tax incentive as well as the marginal units that would come on line purely as a result of the incentive. Estimates of the magnitude of such unintended benefits are also provided. Another unintended result of the tax incentives may be a tendency on the part of purchasers to either delay or accelerate investments in order to receive the incentives, an effect that cannot be quantified. An additional unintended 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.[8] 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 2001 includes a package of proposals aimed at promoting energy efficiency and improving the environment. The CCTI package would provide $1.0 billion in targeted tax incentives from fiscal years 2001 through 2005 for consumers who purchase energy-efficient products and energy from renewable sources for use in buildings. These provide incentives for the purchase of more efficient equipment and structures generally by offering income tax credits for the year in which the equipment or structure was purchased. Specific estimates include $201 million in tax incentives for energy-efficient equipment, $633 million for the purchase of new energy-efficient homes, and $132 million for rooftop solar systems from fiscal years 2001 through 2005. In addition, a $10 million incentive is proposed for distributed power property by changing the depreciable life. By offering consumers tax incentives on energy-efficient and renewable energy products, 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 $275 million in investments for research, development, and deployment of clean technologies for residential and commercial buildings in fiscal year 2001 (see Chapter 3).

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

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

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, tax credits for rooftop solar systems, and a change in the depreciable life for distributed power property). 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 tax incentive program has been proposed to accelerate the development and distribution of several energy-efficient technologies, providing a 20-percent credit to the purchasers of energy-efficient equipment from 2001 through 2004. 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
Electric Heat Pump Water Heater	1.7 EF	2001-2004	20% of purchase price up to $500
Natural Gas Heat Pump	Heating GCOP: 1.25 Cooling GCOP: 0.70	2001-2004	20% of purchase price up to $1,000
Fuel Cell[b]	Electricity generation: 35% Minimum capacity: 5 kilowatts	2001-2004	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: EF, Energy Factor; GCOP, Gas 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 2000).

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.[9] 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
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	40%	$3,625 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: 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, *Annual Energy Outlook 2000*, reference case. Installed cost is for a phosphoric acid fuel cell ranging in size from 5 to 250 kilowatts of generating capacity.
Source: 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.

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 natural gas heat pump in an effort to increase sales to a level at which economies of scale can reduce the installed cost.[10] 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 natural 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

[9]U.S. Department of Energy, Office of Building Equipment, *Market Disposition of High-Efficiency Water Heating Equipment* (Washington, DC, November 1996).
[10]Energy Information Administration, *Technology Forecast Updates: Residential and Commercial Building Technologies—Reference Case*, prepared by Arthur D. Little, Inc. (Washington, DC, September 1998).

penetration of natural 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 $3,625 per kilowatt of capacity; the CCTI tax credit would reduce the cost to $3,125 per kilowatt.[11] 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 5 to 7 cents per kilowatthour, depending on regional natural gas prices. That cost is slightly less than the average U.S. commercial electricity price. However, the payback period in this example is 9 to 10 years in most areas of the country, longer than many commercial consumers are willing to accept.[12]

Results

The analysis results indicate that the CCTI tax incentive proposal for energy-efficient building equipment would encourage the penetration of the equipment covered by the proposal (Table 3). The tax credits could reduce projected carbon emissions by 0.14 million metric tons (0.02 percent) and buildings energy use by 6.6 trillion British thermal units (Btu)—0.02 percent of primary energy—in 2005 (Table 4).

Table 3. Projected Purchases of Energy-Efficient Building Equipment Covered by the CCTI Tax Incentive

Projection	Reference Case	CCTI Case	Unintended Beneficiaries (percent)
Residential Heat Pump Water Heaters	1,309	35,899	4
Residential Natural Gas Heat Pumps	81,724	162,738	50
Residential and Commercial Fuel Cells	6	281	2

Source: Energy Information Administration, National Energy Modeling System runs BASE.D022800A and EQPTAX.D022800B.

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. In the years covered by the tax credit (2001-2004), the analysis indicates that a total of 81,724 natural gas heat pumps would be purchased in the reference case,[13] and that an additional 81,014 units would be

[11]Fuel cell costs from Energy Information Administration, *Annual Energy Outlook 2000*, reference case.

[12]Assumed financing terms also include a 20-percent down payment. Natural gas and electricity prices for this example are 2000 prices from Energy Information Administration, *Annual Energy Outlook 2000*, DOE/EIA-0383(2000) (Washington, DC, December 1999).

[13]Reference case results based on assumptions used for the *Annual Energy Outlook 2000* (*AEO2000*). *AEO2000* is available on the EIA web site at www.eia.doe.gov/oiaf/aeo/index.html, and the assumptions for *AEO2000* are available on the EIA web site at www.eia.doe.gov/oiaf/aeo/assumption/index.html.

purchased because of the tax credit in the CCTI case. In the CCTI case, the Treasury would incur a total reduction of $162.7 million in projected tax revenues related to purchases of natural gas heat pumps. Of the $162.7 million, 50 percent of the tax credits paid would go to unintended beneficiaries.

Table 4. Projected Energy Savings and Carbon Emissions Reductions from the CCTI Tax Incentive for Energy-Efficient Building Equipment, 1998, 2005, 2010, and 2020

Projection	1998 Total	2005 Savings	2010 Savings[a]	2020 Savings
Primary Energy (Trillion Btu)	34,149	6.55	5.86	4.10
Energy Bill (Million 1998 Dollars)	227,922	45.4	41.4	32.0
Carbon Emissions (Million Metric Tons)	521.0	0.14	0.09	0.08

[a]By 2010, some of the energy-efficient equipment purchased due to the tax credits needs replacement and is replaced with less efficient equipment, reducing the impact of the credits later in the forecast.

Source: Energy Information Administration, National Energy Modeling System runs BASE.D022800A and EQPTAX.D022800B.

Tax Credits for Energy-Efficient New Homes

Background

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

- In calendar years 2001 through 2003, a credit of $1,000 to the purchasers of 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 2001 through 2005, 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.[14] 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 module 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

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

(PEAR),[15] the MECcheck software,[16] 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 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.[17]

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.[18]

As of the end of 1999, 19 States had adopted MEC95 or better building codes,[19] and 40 States had adopted some form of the MEC or its equivalent.[20] 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. 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 5 and 6 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

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

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

[17]DOE-2 and REM-RATE are two examples of building simulation models that are better equipped to handle some of these issues.

[18]The costs required to meet the efficiency levels specified by the tax credit proposal represent current construction practices, which are not necessarily least-cost methods promoted by other Federal programs such as Building America or the Partnership for Advancing Technology in Housing (PATH). For energy and carbon savings from a fully successful PATH program, see Chapter 3.

[19]Building Code Assistance Project, *The Status of State Energy Codes Report*, January 2000.

[20]Other MEC codes include 1992 and 1993 versions. See Building Codes Assistance Project, web site www.solstice.crest.org/efficiency/bcap.

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 5 and 6 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 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 5. 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 6. 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.[21] For the years 2001 through 2003, during which a $1,000 tax credit applies, it was assumed that Energy Star homes would receive this credit. New homes achieving 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 Energy Star 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.

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

The results are as follows:

- 223,559 additional energy-efficient homes would be built in the CCTI case during the 2001-2005 period. Purchasers of a total of 257,392 homes would receive tax credits averaging nearly $1,800. The total reduction in projected tax revenues would approach $454 million. Unintended beneficiaries, therefore, account for 13 percent (33,833 homes) of the total number of homes qualifying for the credit.
- 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 7.

Table 7. Projected Energy Savings and Carbon Emissions Reductions from the CCTI Tax Incentive for Energy-Efficient New Homes, 1998, 2005, 2010, and 2020

Projection	1998 Total	2005 Savings	2010 Savings	2020 Savings
Delivered Energy (Trillion Btu)	10,237	3.4	3.4	3.4
Energy Bill (Million 1998 Dollars)	131,058	68.6	68.6	68.6
Carbon Emissions (Million Metric Tons)	283.5	0.18	0.14	0.15

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

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 2001 through 2005 are eligible up to a maximum credit of $1,000. Rooftop PV systems placed in service during the 7-year period from 2001 through 2007 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 8.

Table 8. 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 2000). 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.[22] The BETC 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.[23] 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.

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

[23]Energy Information Administration, *Housing Characteristics 1997*, DOE/EIA-0314(97), www.eia.doe.gov/emeu.

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.[24] 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, about 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.[25] 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 2001 through 2005, the period for which revenue impacts are estimated.[26] 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 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.

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[24]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).

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

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

15-Year Depreciable Life for Distributed Power Property

Background

The Administration's CCTI proposal for fiscal year 2001 includes a simplification of current law governing the depreciation recovery period for distributed power property. The objectives of the change are to promote the use of distributed power technologies to reduce both energy use and carbon emissions and to reduce taxpayer uncertainty and controversy. Property used to produce electricity and/or steam for primary use in a taxpayer's industrial manufacturing process or plant activity is generally depreciated using the 150-percent declining balance method over 15 years. Industrial property with a smaller capacity (totaling 500 kilowatts or less of electricity or 12,500 pounds per hour or less of steam) is depreciated in accordance with the class life assigned to the applicable manufacturing equipment class. By contrast, under current law, distributed power property used to produce electricity and/or heat for use in a commercial or residential building is likely to be classified as a building structural component and depreciated using the straight-line method over 39 years if placed in service after 1993.

The CCTI proposal would allow distributed power systems installed to produce energy for buildings use to be depreciated with the same recovery period as that currently used for larger distributed power property in an industrial manufacturing process or plant activity. Specifically, a 15-year depreciation recovery period would be assigned to distributed power property placed in service after the date of enactment that is used in the generation of electricity for primary use in nonresidential real property or residential rental property in the taxpayer's trade or business, and to property with a rated total capacity in excess of 500 kilowatts that is used in the generation of electricity for primary use in a taxpayer's industrial manufacturing process or plant activity.

Assets used to transport primary fuel to the generating facility or to distribute energy within or outside of the taxpayer's facility would not be included in the proposal. Also, no more than 50 percent of the electricity produced from distributed power assets is expected to be sold to, or used by, unrelated persons. If distributed power property is used to produce thermal energy or mechanical power for use in a building, at least 40 percent of the total useful energy produced must consist of electrical power. In an industrial setting, at least 40 percent of the total useful energy produced must consist of electrical power and thermal or mechanical energy used in the taxpayer's industrial manufacturing process or plant activity.

The CCTI proposal for distributed power is expected to have its primary impact on distributed generation and cogeneration in the commercial sector, which is the focus of this analysis. Because the proposal represents no change in the tax treatment of property used in an industrial manufacturing process or plant activity, for the purpose of this analysis it is considered a buildings program although CCTI characterizes this incentive as an industry program. Distributed power in the residential sector is only represented for single-family homes, therefore any potential impacts from the tax initiative on residential rental property are not reflected in these results.

The analysis did not include the potential effects of removing institutional barriers to distributed power and combined heat and power systems (CHP). 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 increase in the adoption of distributed power technologies than is likely with the proposed change in the current depreciation system alone. The Administration currently has in place the Distributed Power Initiative and the CHP Challenge Program, which may address some of these barriers.[27] The analysis also did not include any change in reference case assumptions regarding any research and development programs or voluntary programs.

Methodology

The effects of the proposed change in tax law for distributed power property were assessed by changing the depreciation schedule for modeling distributed electricity generating equipment in the NEMS commercial module for *AEO2000* to the 150-percent declining balance method over 15 years. The results were then compared to the reference case using the depreciation method used for *AEO2000*—straight-line over 39 years.

The NEMS commercial module develops a forecast of distributed generation and cogeneration of electricity based on the economic returns projected for distributed power technologies. Typical generation technologies represented in the NEMS commercial module are depicted in Table 9. The model uses a detailed cash-flow approach to estimate the number of years required to achieve a cumulative positive cash flow. Penetration rates for distributed generation technologies are determined by how quickly an investment in a technology is estimated to recoup its flow of costs—the more quickly costs are recovered, the higher the penetration.

Table 9. Typical Distributed Power Technologies in the NEMS Commercial Module

Technology	Generating Efficiency	Projected Cost in 2001 (1998 dollars per kilowatt installed)
Reciprocating Engine	0.33-0.35	500-900
Combustion Turbine	0.29	900
Fuel Cell	0.40	3625
Microturbine	0.27	800

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

The cash-flow calculations for each potential investment include both costs and returns in an analysis covering 30 years from the date of investment. Costs include down payments, loan payments, maintenance costs, and fuel costs, while returns include tax deductions, tax credits, and energy cost savings. Tax deductions in the reference case include the depreciation of distributed power assets using straight-line depreciation over 39 years, treating the property as a structural component of the

[27] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, www.eren.doe.gov/ee.html.

commercial building. To gauge the effect of the CCTI proposal, the methodology was changed to incorporate the 150-percent declining balance method of depreciation over 15 years as proposed for distributed power assets used to produce electricity for buildings use. All other aspects of the cash-flow analysis were performed as in the reference case.

Results

The analysis results for the Administration's CCTI proposal for distributed power are presented in Tables 10 and 11. About 98 megawatts of new electricity generating capacity in commercial distributed power resources are projected to be added by 2005 in the reference case for this analysis, with 86.7 megawatts of the additional capacity installed during the 2001 through 2005 time frame. An additional 6.1 megawatts of new distributed generating capacity is projected to be installed by 2005 in the CCTI analysis case.

Table 10. Projected Energy Savings and Carbon Emissions Reductions from the CCTI Tax Incentive for Commercial Distributed Power Property, 1998, 2005, 2010, and 2020

Projection	1998 Total	2005 Savings	2010 Savings	2020 Savings
Primary Energy (Trillion Btu)	15,382	0.21	1.67	5.95
Energy Bill (Million 1998 Dollars)	96,865	1.5	11.5	47.1
Carbon Emissions (Million Metric Tons) . . .	237.5	<0.01	0.03	0.14

Source: Energy Information Administration, National Energy Modeling System runs BASE.D022800A and DISTPWR.D030200A.

Table 11. Projected Impacts of the CCTI Tax Incentive for Commercial Distributed Power Property, 1998, 2005, 2010, and 2020

Projection	1998	2005		2010		2020	
		Reference Case	CCTI Case	Reference Case	CCTI Case	Reference Case	CCTI Case
Distributed Generating Capacity (Megawatts) . .	1,647	1,745	1,751	1,956	2,012	2,653	3,023
Commercial Generation (Billion Kilowatthours)	9.40	9.75	9.80	11.04	11.47	17.35	19.67
Tax Revenue Reductions (Million Dollars)	—	—	4.2	—	16.0	—	23.4

Source: Energy Information Administration, National Energy Modeling System runs BASE.D022800A and DISTPWR.D030200A.

The additional capacity prompted by the proposed tax law change results in annual savings of 209 billion Btu in commercial primary energy use by 2005. However, all of the commercial capacity projected to be added in 2005, 27 megawatts, would be eligible to use the proposed depreciation schedule, leading to projected tax revenue losses of $4.2 million. The tax revenue losses for the capacity added because of the tax proposal total $0.1 million for 2005, indicating that 98 percent of the tax benefits would be realized by unintended beneficiaries, capacity that would be added whether or not the proposed change is enacted.

The proposal for distributed power is different from the other CCTI tax revenue proposals in two respects. First, the distributed power proposal affects the depreciation schedule used for equipment, rather than providing a tax credit. Second, the change in tax law under this proposal has no time limit and would apply to any distributed power property for building use placed in service after the date of enactment, whether the equipment was installed in 2002 or 2020. The second aspect allows this CCTI proposal to have a greater effect later in the forecast, as projected costs for more advanced technologies decline. The more favorable depreciation treatment of the CCTI analysis case, combined with the reference case declines in technology costs for newer technologies, results in an additional 370 megawatts (14 percent) of commercial generating capacity in 2020 compared to reference case levels. Primary energy savings are projected to reach almost 6 trillion Btu in 2020, saving commercial consumers $47 million in energy expenditures relative to the reference case.

The increased penetration of distributed power in the CCTI analysis case reduces carbon emissions attributable to the commercial sector marginally compared to reference case levels. Increased use of distributed power technologies reduces purchased power requirements and leads to lower emissions from central-station electricity producers. However, because additional fuel (natural gas in most cases) is required to fuel distributed power systems, higher site emissions result, offsetting some of the reduction in central-station emissions. Annual projected emissions in the CCTI case are 5 thousand metric tons lower by 2005 and 140 thousand metric tons lower by 2020 compared to the reference case, resulting in a cumulative reduction of 1 million metric tons of carbon emissions by 2020. The cumulative estimate for tax revenue losses between 2001 and 2020 as a result of the CCTI proposal reaches $275 million with 77 percent going to unintended beneficiaries.

Transportation

Background

Sales of alternative-fuel vehicles (AFVs) and advanced technology vehicles (ATVs) are expected to total approximately 3.2 percent of all U.S. light-duty vehicle (LDV) sales in 1998.[28,29] About 74 percent of those sales are alcohol-flexible vehicles, which can run on any combination of alternative fuel and gasoline, and 23 percent are AFVs that use either compressed natural gas (CNG) or liquid petroleum gas (LPG). Less than 1 percent are hybrid electric vehicles.

The electric vehicles currently available (Table 12) average 17 to 30 percent higher fuel efficiency than comparable conventional gasoline vehicles.[30] Whereas conventional gasoline vehicles achieve only about 18 to 28 percent efficiency in combustion, electric vehicle motors have almost no loss in thermal

[28]Energy Information Administration, *Annual Energy Outlook 2000*, DOE/EIA-0383(2000) (Washington, DC, December 1999).

[29]AFVs are vehicles that use alternative fuels (other than gasoline or diesel fuel). ATV 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.

[30]The term "electric vehicles" refers to all-electric vehicles, not including hybrid electric vehicles.

efficiency. On the other hand, approximately 66 percent of the primary energy used to produce electricity is lost in production and transmission.

Table 12. Electric, Hybrid Electric, and Fuel Cell Vehicles Currently Available in U.S. Markets and Announced Dates of Production Prototypes

Manufacturer	Currently Available Electric Vehicles	Currently Available Hybrid Electric Vehicles	Production Prototype Availability Dates	
			Hybrid Electric Vehicles	Fuel Cell Vehicles
DaimlerChrysler	Epic minivan	—	ESX3, Durango	Gasoline: 2010 Hydrogen or Methanol: 2004
Ford	Ranger pickup Th!nk	—	Prodigy	2004
GM	EV1 two seater S-10 pickup	—	2001: Precept	2004
Honda	—	Insight	—	2003
Nissan	Altra minivan	—	— [a]	2005
Toyota	RAV 4 sport utility	—	2000[b]	2003

[a]A Nissan hybrid electric vehicle became available in Japan in 1999. There is no date announced for release to the U.S. market.
[b]The Toyota Prius hybrid electric vehicle, already being marketed in Japan, will be available to U.S. buyers in the summer of 2000.
Source: National Alternative-Fuels Hotline, www.afdc.doe.gov/pdfs/my00.pdf.

Hybrid electric vehicles are just beginning to enter the marketplace. For example, the Toyota Prius, scheduled for introduction in the U.S. market in the summer of 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 50 to 55 mpg. The Honda Insight two-seater gasoline-electric hybrid entered the U.S. market in the fall of 1999. The electric motor is used only when the driver needs a power assist during acceleration. Fuel economy for the Insight is approximately 60 mpg in the city and 71 mpg in highway applications. In general, there is about a two-year lag between the availability of a production prototype, which is available in limited quantities, and a commercial prototype, which is available on a larger scale.

Fuel cell vehicle technology is still in the early stages of development. 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, Hybrid Electric, 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 hybrid electric vehicles, tax credits of up to $3,000 are proposed for vehicles purchased from January 1, 2003, through December 31, 2006.

  – $500 if a rechargeable energy storage system provides at least 5 percent but less than 10 percent of the maximum available power

  – $1,000 if a rechargeable energy storage system provides at least 10 percent but less than 20 percent of the maximum available power

  – $1,500 if rechargeable energy storage system provides at least 20 percent but less than 30 percent of the maximum available power

  – $2,000 if rechargeable energy storage system provides at least 30 percent or more of the maximum available power.

  An additional credit of up to $1,000 is available for vehicles with a regenerative braking system.

  – $250 if the regenerative braking system supplies to the rechargeable energy storage system at least 20 percent but less than 40 percent of the energy available from braking in a typical 60 to 0 mph braking event

  – $500 if the regenerative braking system supplies at least 40 percent but less than 60 percent of the available energy

  – $1,000 if the regenerative braking system supplies at least 60 percent or more of the available energy.

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 57 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, hybrid electric (gasoline and diesel) vehicles, and fuel cell vehicles (methanol, hydrogen, and gasoline reformers). Each AFV/ATV 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:[31] (1) vehicle price, (2) cost of driving per mile (fuel price divided by

[31]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.

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 in the future or if some ATVs cannot meet current or future emissions standards, the market penetration rates and carbon emissions reductions projected in this analysis could be lower.

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 net tax incentive was assumed to be approximately $1,600 per hybrid electric vehicle. Each of the current or soon to be available gasoline-electric hybrids and the two diesel-electric hybrid prototypes by Ford and DaimlerChrysler were evaluated according to the percent of maximum available power from the rechargeable energy storage system and the percent of braking energy recaptured by regenerative braking.

Results

Sales of fuel cell vehicles, which are assumed to be available in 2005,[32] are projected to total 37,900 in 2020 in the CCTI case (Table 13). Projected sales of hybrid vehicles—particularly, gasoline-electric hybrids—are significantly higher in both cases than are sales of either electric vehicles or fuel cell vehicles, with sales of gasoline-electric hybrids at about 1,211,300 vehicles in 2020 in the CCTI case. Two 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).[33]

Total AFV/ATV sales in the CCTI case represent 7.4 percent of all LDV sales in 2010. Moreover, most of the projected sales also occur in the reference case. Projected LDV fuel consumption in the CCTI case does not differ significantly from that in the reference case. The difference in 2005 is about 8.6 trillion Btu, consisting almost entirely of a reduction in gasoline consumption. The difference in 2010 is 27.1 trillion Btu and in 2020 it is 65.9 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 about 0.5 million metric tons in 2010—representing 0.08 percent of total carbon emissions for the transportation sector (Table 14). In 2020, the carbon emissions in the CCTI case are lower by 1.2 million metric tons because

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[32]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. DaimlerChrysler has announced that a production prototype will be available by 2004. Inherent in the 2005 date is a 1-year period to convert production prototypes to actual production vehicles and to modify production lines and facilities.

[33]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 hybrid electric vehicles. However, hybrid electric 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, hybrid electric sales could be higher in California.

of the accumulated increased sales of both gasoline-electric and diesel-electric hybrids through 2020. In the CCTI case, the gasoline-electric hybrid vehicles displace some fuel cell vehicles and diesel-electric hybrids, which had slightly higher penetration in the reference case, and some LPG and ethanol vehicle sales are reduced relative to the reference case.

Table 13. Projected Light-Duty Vehicle Sales by Technology from the CCTI Transportation Tax Incentives, 1998-2020
(Thousands)

Vehicle Type	1998	2002 Reference Case	2002 CCTI Case	2005 Reference Case	2005 CCTI Case	2010 Reference Case	2010 CCTI Case	2020 Reference Case	2020 CCTI Case
Electric	1.5	3.1	3.1	106.5	106.6	107.2	107.2	113.3	113.5
Fuel Cell	0.0	0.0	0.0	0.0	0.0	9.1	9.3	38.3	37.9
Diesel-Electric Hybrid	0.0	0.0	0.0	3.2	6.5	11.7	12.1	30.3	29.3
Gasoline-Electric Hybrid	0.0	38.5	50.0	238.9	315.0	626.8	768.0	995.6	1,211.3
Total	**0.0**	**41.6**	**53.1**	**348.6**	**428.1**	**754.8**	**896.6**	**1,177.5**	**1,392.0**
All Light-Duty Vehicles	13,991	13,295	13,295	14,198	14,198	14,341	14,341	15,235	15,235

Source: Energy Information Administration, National Energy Modeling System runs REFCCTI.D033100Q and TAX.D033100C.

Table 14. Projected Transportation Sector Carbon Emissions by Fuel from the CCTI Transportation Tax Incentives, 1998-2020
(Million Metric Tons)

Fuel Type	1998	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	473.4	515.4	515.4	545.6	545.5	592.7	592.2	673.2	672.0
Natural Gas	10.8	12.2	12.2	13.3	13.3	15.8	15.8	18.8	18.8
Electricity	3.4	3.8	3.8	4.9	4.9	6.3	6.3	8.5	8.5
Other	0.0	0.9	0.9	1.3	1.3	2.1	2.1	2.9	2.9
Total	**487.5**	**532.2**	**532.2**	**565.2**	**565.0**	**616.8**	**616.3**	**703.4**	**702.2**

Source: Energy Information Administration, National Energy Modeling System runs REFCCTI.D033100Q and TAX.D033100C.

Projected AFV/ATV vehicle sales and the corresponding reductions in Federal tax revenues in the CCTI analysis case are shown in Table 15. In 2003, the reduction in tax revenues totals just over $392 million, growing to $830 million in 2005 and $973 million in 2006. The total proposed allocation of Treasury funds for the CCTI tax incentives is $2.1 billion for the years 2001 to 2005, as estimated by the Administration in nominal dollars, compared to $1.9 billion in this analysis.

The results suggest that the proposed CCTI tax initiatives for LDVs would not yield many additional AFV/ATV sales above those projected in the reference case with the exception of about 216,000 additional sales of gasoline-electric hybrid vehicles in 2020. Consequently, most of the tax benefits would go toward consumer purchases that would have been made even without the proposed tax incentives (about 84 percent of fuel cell, electric, and hybrid electric vehicle sales over the period of the tax credits)—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.

Table 15. Projected Vehicle Sales and Tax Revenue Reductions by Vehicle Type from the CCTI Transportation Tax Incentives, 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	3.1	3.1	102.2	102.3	104.6	104.7	106.5	106.6	105.9	106.1
Fuel Cell	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gasoline-Electric Hybrid	38.5	50.0	95.2	136.1	156.7	213.8	238.9	315.0	325.8	430.1
Diesel-Electric Hybrid	0.0	0.0	1.3	2.7	2.1	4.3	3.2	6.5	4.5	9.0
Total	**41.6**	**53.1**	**198.7**	**241.1**	**263.4**	**322.8**	**348.6**	**428.1**	**436.2**	**545.2**
Tax Revenue Reductions (Million 1998 Dollars)										
Electric	8.7	11.6	187.9	376.2	94.2	377.3	0.0	376.1	0.0	366.2
Fuel Cell	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gasoline-Electric Hybrid	0.0	75.0	0.0	200.2	0.0	308.2	0.0	444.5	0.0	593.8
Diesel-Electric Hybrid	0.0	0.0	0.0	4.0	0.0	6.2	0.0	9.2	0.0	12.4
Total	**8.7**	**86.6**	**187.9**	**580.3**	**94.2**	**691.7**	**0.0**	**829.6**	**0.0**	**972.5**

Source: Energy Information Administration, National Energy Modeling System runs REFCCTI.D033100Q and TAX.D033100C.

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/ATV 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. CCTI reference case assumptions were updated to the latest available information. Full volume vehicle production levels, which include the maximum level of economies of scale in production, lower the incremental vehicle price above a comparable gasoline vehicle to approximately $4,000 for an hybrid electric vehicle and $6,000 for a fuel cell vehicle by 2020. The full volume production vehicle price is assumed to be currently available for hybrid electric vehicles because the Toyota Prius is currently available in Japan and will be in the United States market by early summer. The Honda Insight hybrid electric is currently available in the United States. The full volume production vehicle price for fuel cells is potentially available if sales were to increase rapidly but is not reached in the reference case until 2020. Several refinement cycles of approximately three to four years each for the fuel cell will be necessary before prototypes achieve the attributes that consumers will demand.

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/ATV purchases if gasoline prices remain low.[34] 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 31.9 cents a gallon (in 1998 dollars) from 1973 to 1974, but by 1978 they were only 14.6 cents above 1973 levels. From 1978 to 1979, prices rose by 47.6 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/ATV 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.[35]

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 ATV 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 three years at a cost of up to $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 ten times that of a lead-acid battery.

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[34]Energy Information Administration, *Annual Energy Outlook 2000*, DOE/EIA-0383(2000) (Washington, DC, December 1999).

[35]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. Toyota has increased the engine size from 1.4 liters in the Japanese Prius to 2.2 liters in the U.S. Prius.

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 12), but their purchase price is approximately $60,000 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/ATV 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/ATV purchases, emissions and environmental issues also pose significant hurdles for the new vehicle technologies. For example, electric vehicles are nearly emission-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 has revised its NO_x and particulate emissions standards through Tier II 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.

In order to assess the impacts of the CCTI transportation tax credits with higher petroleum prices, the tax credits were analyzed using the high world oil price case from *AEO2000*. In that case, world oil prices reached $28.04 per barrel (1998 dollars) in 2020 compared to $22.04 per barrel in the reference case. Using the high world oil prices, the CCTI tax credits result in about 31,000 additional gasoline-electric hybrid vehicle sales in 2020 compared to the additional sales with reference case world oil prices. However, these additional gasoline-electric hybrid vehicles displace some fuel cell, diesel-electric hybrid, and alternative-fuel vehicles, which have higher efficiency and generally lower carbon emissions. As a result, the carbon savings from the CCTI tax credits in 2020 with the high world oil prices are slightly lower than the carbon savings of 1.2 million metric tons with the reference case world oil prices. With the high world oil prices, the tax revenue losses from 2001 through 2005 increase from $1,912 million to $1,940 million.

Renewable Electricity Generation

Background

The proposed CCTI tax initiatives include several provisions aimed at increasing the utilization of renewable technologies in the generation of electricity. It is hoped that the programs will spur the development of these 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.

Wind and Biomass

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. The original production tax credit (PTC) for wind and closed-loop biomass expired on June 30, 1999; however, in late 1999 the credit was extended through December 31, 2001. To qualify, a new wind plant must have come on line between January 1, 1994, and December 31, 2001 (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 PTC, and biomass plants must be closed-loop facilities to qualify.[36] 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.

Through 1999 the REPI and PTC resulted in 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 in addition to the PTC appear to have contributed to the capacity builds during the EPACT PTC period (Table 16). Very little wind capacity was added during the early years of the original PTC. Of the 935 megawatts[37] of new wind generating

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

capacity entering service through 1999, 117 megawatts entered service before 1998, of which 28 megawatts were clearly associated with programs independent of the PTC. Of the remaining 818 megawatts, 494 were also 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, 244 megawatts of which were added in 1998 and 1999. Of the capacity added during 1998 and 1999, 324 megawatts entered service 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, 654 megawatts, entered service in 1999. Some of this capacity probably would have been built in 2000 or later but was brought on earlier to take advantage of the original PTC deadline. The revenue effects of the PTC are fairly limited so far. For wind power, PTC-related revenue losses in 1997 are estimated at less than $4 million, rising to $33.2 million in 1999.

Table 16. New U.S. Wind Generating Capacity Concurrent with the EPACT Tax Credit, 1994-2001
(Megawatts)

Program[a]	Capacity Added 1994-1997	Capacity Added 1998-1999	Projected Capacity Added 2000-2001	Total Capacity Added 1994-2001
Renewable Energy Production Incentive (REPI)	6	11	0	16
State Mandate	22	483	62	567
State Renewable Portfolio Standard (RPS)[b]	0	0	146	146
Other	89	324	50	463
Total	**117**	**818**	**258**	**1,192**

Note: Totals may not 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.

Landfill Gas

The anaerobic decomposition of organic wastes in landfills represents the largest source of methane emissions in the United States and is second only to carbon dioxide as a major contributor to potential greenhouse warming. Gases created during the decomposition process migrate from the depths of the landfill. These gases are composed primarily of methane (50 percent) and carbon dioxide (45 percent). Unless methane is collected and used as a fuel for electricity generation or heat, it is either burned off by flaring the gases without recovering the energy potential of the gas or released into the atmosphere. Over long periods of time, methane is estimated to be 21 times more potent than carbon dioxide as a greenhouse gas. Under current regulations, many landfill owners or operators are required to collect and combust the methane that their landfills produce.

U.S. landfills produced 9.7 million metric tons of methane in 1998, the lowest level of methane emissions since the late 1970s.[38] Although the volume of municipal waste grew by 16 percent between

[38]Energy Information Administration, *Emissions of Greenhouse Gases in the United States 1998*, DOE/EIA-0573(98) (Washington, DC, October 1999), p.31.

1990 and 1997, the amount of the total U.S. waste stream reaching landfills decreased 21 percent. This decrease is the result of the increased use of curbside recycling and composting. Even though the availability of methane production is expected to decrease as a result of increased recycling efforts, the number of landfill-gas-to-energy projects increased from 150 in 1997 to more than 200 in 1998. This increase occurred as producers attempted to complete their projects prior to the expiration, on June 30, 1998, of the Internal Revenue Code Section 29 tax credit that provided a subsidy of about 1.0 cent per kilowatthour for electricity generated using landfill gas.

Climate Change Technology Initiative

The CCTI extends the 1.5-cent PTC for wind and closed-loop biomass for 2.5 years, through June 30, 2004; however, because the proposal allows unfinished plants that are under binding contract or construction as of June 30, 2004, an additional year, the PTC is effectively extended 3.5 years. In addition, the proposal would expand the types of plants qualifying for the biomass subsidy. The definition of eligible biomass sources is broadened from closed-loop biomass only 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). Moreover, biomass facilities that were placed in service before January 1, 2001, would be eligible for a credit of 1.0 cent per kilowatthour, adjusted for inflation from a 2000 base, for electricity generated for 3 years, from 2001 through 2003. EIA projects 1,780 megawatts of biomass capacity would be available on December 31, 2000, and eligible for that credit.

In addition to broadening the definition of eligible biomass, the proposal also provides a 0.5-cent PTC, adjusted for inflation from the 2000 base, for biomass that is co-fired in coal plants to produce electricity during the period January 1, 2001, through December 31, 2005. 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 2001 through 2005. This credit would apply to all facilities that are co-firing biomass with coal, including those that are already doing so.

The CCTI would also institute tax initiatives for further development of landfill-gas-to-energy projects. These incentives would be applied to new landfill-gas-to-energy projects that are placed in service between January 1, 2001, and December 31, 2005. However, facilities would also be eligible for the incentive if the facility is under construction in 2005 and completed in 2006 or a contract for construction is in place in 2005 for a facility to be completed in 2006. The incentives would include a 1-cent-per-kilowatthour PTC for landfills subject to EPA's New Source Performance Standards (NSPS) and a 1.5-cent-per-kilowatthour PTC for landfills not subject to the NSPS. The PTC would be applied to generation over a period of 10 years. The PTC would not apply to existing facilities but effectively extends the incentive to December 31, 2006, if the facility is constructed, reconstructed, or acquired by the taxpayer pursuant to a contract binding on December 31, 2005. In addition, a facility will be eligible for the PTC if the lesser of $1 million or 5 percent of the facility's cost has been incurred or committed by December 31, 2005.

Methodology

For this analysis, the PTC for renewable generation was modeled in the NEMS electricity market and renewable fuels modules, with no feedback from other NEMS modules. The vast majority of biomass-based cogeneration is not eligible for the credit because it uses nonwoody fuels and self-generation does not qualify, so cogeneration was not considered in the analysis. In order to test the potential impacts of the CCTI, it was assumed that the PTC for wind and new biomass would be extended through 2005 and that generation from the existing 2000 biomass capacity would receive the 1.0-cent credit from 2001 through 2003, adjusted for inflation. Based on an analysis of the economics of dispatching, it was also concluded that generation from this capacity would increase in response to the PTC incentive.

For both the reference and the CCTI cases, new biomass technology is not assumed to be commercially available until 2005. Therefore, new biomass generating capacity entering service prior to 2005 is considered to be either demonstration plants or plants using existing technologies.

The model allows coal plants to use biomass for a portion of their fuel if it is economical. It was assumed that a coal plant could use biomass to displace up to 5 percent of the coal it would normally use. Current research has shown that a typical coal-fired boiler can fire as much as 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. However, such modifications are expensive, $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 5 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 4.1 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 5 percent.

To capture costs that may not be fully represented in the biomass supply curves, the model also incorporates a hurdle rate, a minimum savings for displacing coal with biomass. These costs are associated with issues such as developing a reliable fuel supply for a specific plant, testing the fuel in the plant to see what modifications might be necessary, designing and implementing the modifications, applying for any licenses that are needed, and getting air permit changes approved where necessary. Analysts have informed EIA that each of these factors may require some effort to overcome and may slow the penetration of biomass use in coal plants. Therefore, in the reference case, the co-firing shares are phased in between 1999 and 2010, and the hurdle rate is initially 1 cent per kilowatthour in 2000 before declining to 0.1 cent by 2010. In the CCTI biomass co-firing case, it is assumed that the PTC causes the hurdle rate to decline further, reaching 0.05 cents by 2010, essentially assuming that the availability of the biomass co-firing PTC would lead to further reductions in the costs incurred in preparing to use the fuel.

Following observed experience in 1999 of accelerating already mandated new capacity in order to obtain the PTC, extending the PTC for biomass and wind through 2005 would likely accelerate some post-2005 reference case capacity additions resulting from State mandates. As a result, 90 megawatts of mandated new biomass generating capacity and 480 megawatts of mandated new wind generating capacity projected to occur between 2006 and 2008 in the reference case would be built by 2005 in the CCTI case.

Because the *AEO2000* version of NEMS does not allow landfill-gas-to-electricity technologies to economically compete with other generating alternatives, a new reference case was developed along with the CCTI case. In both cases, the amount of new landfill-gas-to-electricity capacity during the projection period competes with other technologies using supply curves that are based on the amount of high, low, and very low methane producing landfills located in each electricity market module region (Figure 1). An average cost of electricity production for each type of landfill yield is calculated using gas collection system and electricity generator costs and characteristics developed by EPA's Energy Project Landfill Gas Utilization Software (E-PLUS).[39]

The amount of methane available by methane yield is calculated by first determining the amounts of total waste generation excluding composting and incineration for the years 1999 through 2020 and applying assumptions regarding the amount of waste that is landfilled against this waste stream. The total waste stream projection is based on a regression model that extrapolates waste from historical values as a function of U. S. population and gross domestic product. Landfill projections are calculated from this total waste stream by assuming that recycling will account for 35 percent of the total waste stream by 2005 and 50 percent by 2020. After projecting the amount of landfill available for 1999 through 2020, the annual landfill amounts are used as supply inputs for a slightly modified EMCON Methane Generation model.[40] The EMCON model characterizes waste by three categories—readily, moderately, and slowly decomposable material—based on the emission characteristics of the each type of waste. It then calculates methane emissions over the decomposition cycle associated with each type. The model and emission parameters used in this analysis are the same as those used in calculating historical methane emissions in EIA's *Emissions of Greenhouse Gases in the United States 1998*[41] but are also applied to the projected landfill amounts calculated as described above. The ratio of high, low,

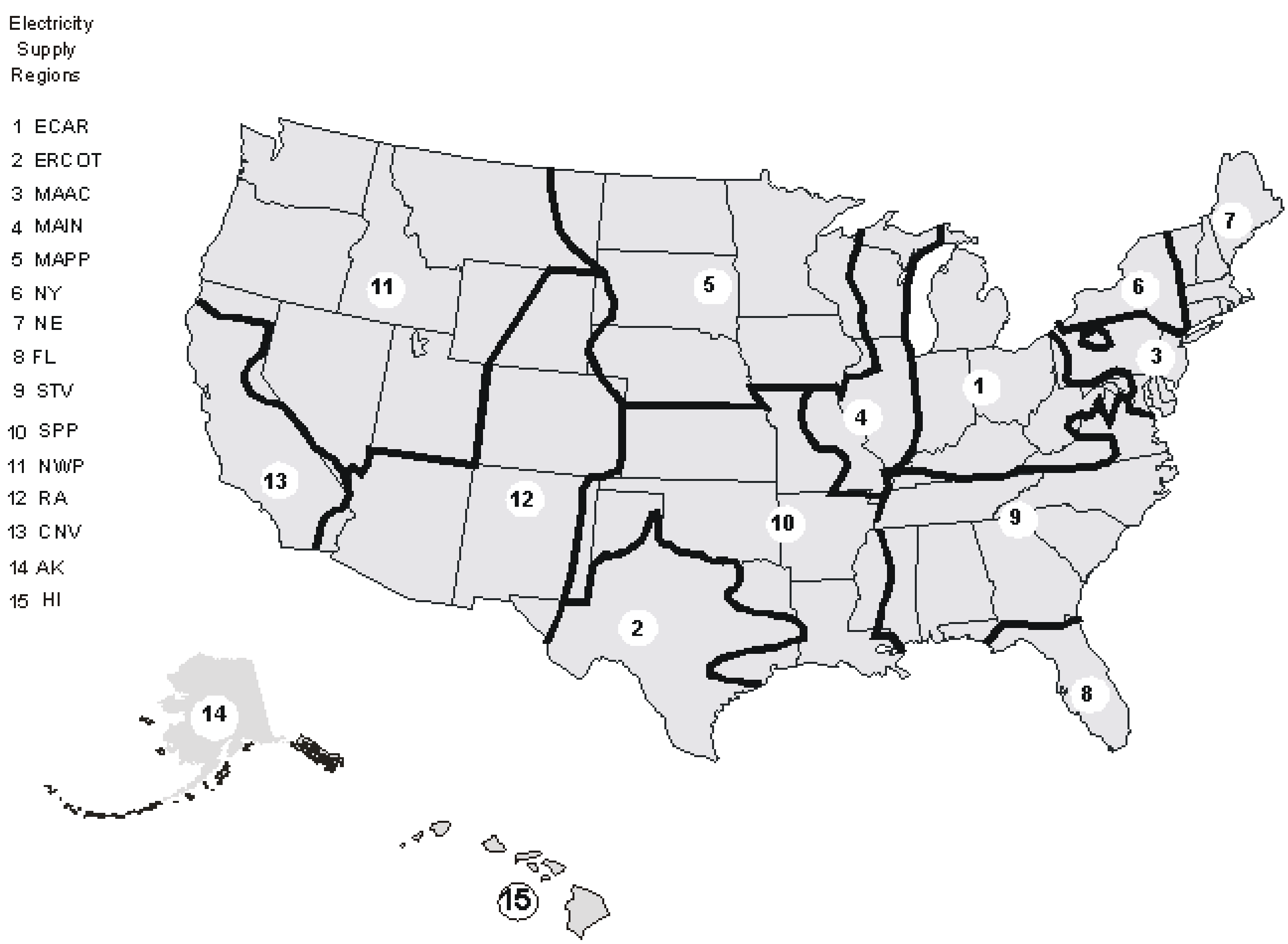
[39]U.S. Environmental Protection Agency, Atmospheric Pollution Prevention Division, *Energy Project Landfill Gas Utilization Software (E-PLUS) Version 1.0*, EPA-430-B-97-006 (Washington, DC, January 1997).

[40]D. Augenstein, "The Greenhouse Effect and U.S. Landfill Methane," *Global Environment Change* (December 1992), pp. 311-328.

[41]Energy Information Administration, *Emissions of Greenhouse Gases in the United States 1998*, DOE/EIA-0573(98)(Washington, DC, October 1999), Appendix A: Estimation Methods, pp. 88-90.

and very low methane production sites to total methane production is calculated by applying the ratios of high, low, and very low methane-yielding sites as calculated from data obtained for 156 operating landfills contained in the Government Advisory Associates' METH2000 database.[42] Finally, because NEMS models landfill-gas-to-electricity technologies as characterized by price and quantity curves rather than site specific data, an analysis was performed using EPA's *State Land Profiles*[43] for 31 states to determine a representative ratio of NSPS to non-NSPS sites. This analysis resulted in an average PTC of 1.41 cents per kilowatthour for new landfill gas capacity construction during the effective PTC period of 2001 through 2006.

Figure 1. Electricity Market Module Regions



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

Similarly, the production cost of electricity for high, low, and very low methane-yielding sites was calculated by constructing a model of a representative 100-acre by 50-foot deep landfill site and by applying methane emission factors for high, low, and very low methane-emitting wastes (Table 17).

[42]Governmental Advisory Associates, Inc., METH2000 Database (Westport, CT, January 25, 2000).
[43]U.S. Environmental Protection Agency, Landfill Methane Outreach Program, *State Landfill Profiles*, February 14, 2000.

Because methane yields for this virtual site are different for each yield assumption, the generator size, number of wells, cost of gas cleanup, piping, and other gas collection and generating parameters lead to different production costs of electricity due to increases in material and losses to economies of scale. In general, high methane yield sites produce electricity at a lower cost per kilowatthour than lower yielding sites. The cost of electricity and the available supply of methane at each yield category for each region is displayed in Table 18.

Table 17. Methane Production Parameters for High, Low, and Very Low Yield Sites

Methane Yield Parameters	High Yield	Low Yield	Very Low Yield
Fraction Readily Decomposable	0.400	0.040	0.040
Fraction Moderately Decomposable	0.450	0.450	0.450
Fraction Slowly Decomposable	0.052	0.052	0.052
Rate of Methane Yield - Readily Decomposable (Cubic Feet per Pound)	4.50	2.75	1.38
Rate of Methane Yield - Moderately Decomposable (Cubic Feet per Pound)	3.55	1.95	0.98
Rate of Methane Yield - Slowly Decomposable (Cubic Feet per Pound)	0.50	0.29	0.16
Lag for Methane Generation from Readily Decomposable Waste (Years)	0	0	0
Lag for Methane Generation from Moderately Decomposable Waste (Years)	2	2	2
Lag for Methane Generation from Slowly Decomposable Waste (Years)	5	5	5
Production Limit of Readily Decomposable Waste (Years)	3	4	4
Production Limit of Moderately Decomposable Waste (Years)	10	20	20
Production Limit of Slowly Decomposable Waste (Years)	20	40	40

Source: Energy Information Administration, *Emissions of Greenhouse Gases in the United States 1998*, DOE/EIA-0573(98) (Washington, DC, October 1999), Appendix A: Estimation Methods. Parameters for very low yield site assumed to be 50 percent of low yield site values.

Table 18. Landfill Gas to Energy Supply and Cost of Electricity Production by Region

Megawatts Equivalent	ECAR	ERCOT	MAAC	MAIN	MAPP	NY	NE	FL	STV	SPP	NWP	RA	CNV	U.S.
High Yield	72	12	93	83	43	54	62	14	68	5	17	-	131	653
Low Yield	30	26	22	92	22	27	6	26	22	-	58	-	250	581
Very Low Yield	539	316	311	495	150	142	51	158	447	185	185	91	749	3,819
Total	**641**	**354**	**427**	**670**	**214**	**222**	**119**	**198**	**537**	**191**	**260**	**91**	**1,130**	**5,053**
Percent of National Capacity														
High Yield	1.43	0.23	1.84	1.64	0.85	1.06	1.23	0.28	1.35	0.11	0.33	0.00	2.59	12.93
Low Yield	0.60	0.51	0.44	1.82	0.43	0.53	0.12	0.52	0.43	0.00	1.16	0.00	4.95	11.50
Very Low Yield	10.66	6.26	6.16	9.79	2.96	2.81	1.00	3.12	8.85	3.66	3.65	1.80	14.83	75.57
Total	**12.69**	**7.01**	**8.44**	**13.26**	**4.23**	**4.39**	**2.36**	**3.92**	**10.63**	**3.77**	**5.14**	**1.80**	**22.36**	**100.00**
1998 Cents per Kilowatthour														Electricity Price
High Yield														3.20
Low Yield														4.10
Very Low Yield														6.45

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

Results

Biomass

As discussed in the methodology section, although new biomass gasification plants are assumed to be commercially available during the final year of the PTC horizon, the extension and broadening of the biomass PTC through 2005 does not lead to more capacity being added solely on an economic basis (Table 19). However, the extension of the PTC may encourage additional demonstration efforts, and it is expected to accelerate construction of about 90 megawatts of mandated new biomass capacity by 2005 in the CCTI case that would have been built after 2005 absent the PTC. In the reference case, 144 megawatts of new biomass capacity come on line within the 2002-2005 PTC period. In the CCTI case, the additional 90 megawatts of accelerated builds bring the total to 234 megawatts expected to be added by 2005. The increase in biomass generation and reduction in carbon emissions because of the 90 additional megawatts added in the CCTI case are small. In 2010, the carbon emissions are unchanged from the reference case; however, the full 234 megawatts added are expected to take the tax credit. In 2010, if all the expected plants took advantage of the PTC, tax collections would be almost $27 million lower than in the reference case. In 2005, approximately 35 percent of the tax savings would go to the 90 megawatts accelerated by the program, and the remaining 65 percent would go to capacity expected to be built even without the program. Over the full life of the proposed CCTI extension for new biomass capacity, 93 percent of the tax revenue is returned to unintended beneficiaries.

Table 19. Projected Impacts of the CCTI Biomass Energy Tax Credit, 1998, 2005, 2010, and 2020

Projection	1998	2005		2010		2020	
		Reference Case	CCTI Case	Reference Case	CCTI Case	Reference Case	CCTI Case
Biomass-Fired Generating Capacity (Gigawatts)	1.8	2.0	2.1	2.4	2.4	2.9	2.9
Biomass-Fired Electricity Generation (Billion Kilowatthours)	6.9	8.4	8.9	11.0	11.0	14.5	14.5
Electricity Sector Carbon Emissions (Million Metric Tons)	550	655	655	692	692	773	773
Tax Revenue Reductions (Million 1998 Dollars)	—	—	26.75	—	26.75	—	0.00

Note: Excludes biomass co-firing at coal plants.
Source: Energy Information Administration, National Energy Modeling System runs CCTIBASJ.D030900B and BIOM.D030900B.

The 1.0-cent PTC (adjusted for inflation from a 2000 base) for existing biomass plants applies to all generation between 2001 and 2003 from the 1,780 megawatts biomass capacity on line in 2000. Because the monetary incentive induces some additional generation from this capacity that would not have occurred otherwise, extending the PTC has the effect of inducing 1.2 billion kilowatthours additional generation by 2003, accounting for 15 percent of all payments to this capacity in 2003. Nevertheless, over the three-year proposed CCTI extension for existing biomass capacity, 86 percent of the tax revenue is returned to unintended beneficiaries.

The biomass co-firing provision of the CCTI has a more significant impact than the PTC for new and existing plants. 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; however, because the co-firing credit expires in 2005, the impact declines somewhat in the later years. In 2005, electricity generation from co-fired biomass is projected to be 14.6 billion kilowatthours in the CCTI case, about three times the reference case level (Table 20). 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 $280 million in tax revenue reductions during the life of the credit, with about 34 percent going to facilities that would have used biomass co-firing without the PTC.

Table 20. Projected Impacts of the CCTI Biomass Energy Co-firing Tax Credit, 1998, 2005, 2010, and 2020

Projection	1998	2005		2010		2020	
		Reference Case	CCTI Case	Reference Case	CCTI Case	Reference Case	CCTI Case
Co-fired Electricity Generation (Billion Kilowatthours)	0.0	4.8	14.6	8.8	9.6	4.3	5.0
Electricity Sector Carbon Emissions (Million Metric Tons)	550	655	652	692	692	773	773
Tax Revenue Reductions (Million 1998 Dollars)	—	—	70.83	—	0.0	—	0.0

Source: Energy Information Administration, National Energy Modeling System runs CCTIBASJ.D030900B and CCTICOFJ.D030900E.

It is assumed in this analysis that the co-firing 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, some 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. Of course, higher capacity factors would increase the tax consequences.

Wind

In the reference case, 991 megawatts of new wind generating capacity is expected to enter service during the 2002-2005 period in response to State mandates, renewable portfolio standards, and other programs. 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 wind PTC through 2005 leads to accelerated construction of 480 megawatts of mandated new wind generating capacity that otherwise would have been built later in response to State renewable portfolio standards (Table 21). No additional wind capacity is expected to be built solely for economic reasons, and analysis indicates that repowering existing older wind facilities would remain economically noncompetitive. As a result, although wind generating capacity and output are increased in 2005 compared with the reference case, by 2010 no differences between the reference and CCTI cases remain.

Table 21. Projected Impacts of the CCTI Wind Energy Tax Credit, 1998, 2005, 2010, and 2020

Projection	1998	2005		2010		2020	
		Reference Case	CCTI Case	Reference Case	CCTI Case	Reference Case	CCTI Case
Wind Generating Capacity (Gigawatts)[a]	2.0	3.9	4.4	5.1	5.1	5.5	5.5
Wind Electricity Generation (Billion Kilowatthours)	3.4	8.2	9.3	11.0	11.0	12.1	12.1
Electricity Sector Carbon Emissions (Million Metric Tons)	550	655	655	692	692	773	773
Tax Revenue Reductions (Million 1998 Dollars)	—	—	55.38	—	55.38	—	0.00

Source: Energy Information Administration, National Energy Modeling System runs CCTIBASJ.D030900B and WIND.D030900B.

The tax revenue consequences of the CCTI are similarly modest for wind power when applied only to the CCTI-induced additional capacity, totaling $18 million in 2005. The total tax revenue effects of the PTC extension are much greater, however, because the 991 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 $55.4 million in 2005. Over the full life of the extension for wind power, 94 percent of the tax revenues are returned to unintended beneficiaries. Because little new wind capacity is expected to be encouraged by the extended PTC, carbon emissions are virtually unchanged.

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 original PTC time frame appear to have been encouraged by the combination of the PTC, State mandates, and other incentive programs, the combined stimulus could again 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. 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.

It is also possible, however, that utility testing, green power, and other wind technology demands are satisfied by capacity additions through 2001 and that additional capacity for those reasons is unlikely despite the PTC. 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 penetrate 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.

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 Competition Act proposed by DOE in 1999 included a 7.5-percent renewable portfolio standard. The analysis of this proposal in *AEO2000* found that it could lead to a reduction in carbon emissions of almost 20 million metric tons in 2010 at minimal cost to consumers.[44]

Landfill Gas

In the reference case, 374 megawatts of new landfill gas capacity are projected to come online between 2001 and 2006. However, this new capacity is the result of State initiatives or mandates, such as renewable portfolio standards or green power initiatives, and are unintended beneficiaries of the tax incentives. An additional 381 megawatts of State initiatives or mandates are planned for the period 2007 through 2010 in the reference case. Since implementation of the PTC is likely to encourage accelerated development of some plants currently planned for the post-PTC period, it is assumed that 143 megawatts of this capacity would be accelerated to begin operation by 2006 in the CCTI case. The remaining 238 megawatts are completed during 2007 through 2010, as currently planned. Consequently, a total of 517 megawatts due to State initiatives and mandates are projected to be built during the PTC period. However, all generation from the 374 megawatts scheduled to be completed before 2007 in the reference case and that portion of the generation that occurs after 2006 from the accelerated 143 megawatts are considered to be unintended beneficiaries.

The PTC in the CCTI case results in an additional 570 megawatts of landfill gas capacity during the period 2001 through 2006 over and above the mandated capacity additions. Tax revenues returned in 2005 equal $77 million, of which $30 million, or 38 percent, would be returned to unintended beneficiaries (Table 22). Total revenues returned over the life of the tax incentive are $900 million, of which $491 million, or 55 percent, would be returned to unintended beneficiaries.

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[44]Energy Information Administration, *Annual Energy Outlook 2000*, DOE/EIA-0383(2000) (Washington, DC, December 1999).

Table 22. Projected Impacts of the CCTI Landfill Gas Tax Credit, 1998, 2005, 2010, and 2020

Projection	1998	2005		2010		2020	
		Reference Case	CCTI Case	Reference Case	CCTI Case	Reference Case	CCTI Case
Landfill Gas Generating Capacity (Gigawatts)	2.5	2.9	3.3	3.4	4.0	3.5	4.1
Landfill Gas Electricity Generation (Billion Kilowatthours)	17.8	20.0	23.4	23.7	28.7	25.5	29.8
Electricity Sector Carbon Emissions (Million Metric Tons)[a]	550	655	654	692	691	773	772
Tax Revenue Reductions (Million 1998 Dollars)	—	—	77.3	—	58.4	—	0.00

[a]Direct emissions of carbon only. Does not include the carbon equivalent emissions of methane.
Source: Energy Information Administration, National Energy Modeling System runs CCTIBASJ.D030900B and CCTIMSWJ.D030900A.

Due to the displacement of fossil-fired generation by new landfill gas capacity, direct carbon emissions are reduced by about 1 million metric tons in 2005. However, the additional 570 megawatts projected in the CCTI case due to the PTC result in an additional 3.4 million metric tons reduction in carbon equivalent emissions in 2005 when the methane emissions avoided are converted to carbon equivalent, assuming that the methane would otherwise have been emitted into the atmosphere.

Although generation by landfill gas facilities is projected to be small relative to total U.S. generation (less than 0.6 percent in 2020 in the reference case), the PTC in the CCTI could have significant impact within the landfill-gas-to-energy industry itself. This analysis demonstrates that the proposed PTC could lead to a near tripling of landfill gas generating capacity additions during the years 2001 through 2006. This amount could be increased if plans for the remaining State-mandated 238 megawatts of new landfill gas generators for the period 2007 through 2010 are accelerated to take advantage of the credit. However, offsetting the benefits of the PTC are the tax revenues that will be returned to the 374 megawatts of currently planned facilities during this period.

In order to assess the impacts of extending the PTC beyond the proposed CCTI expiration date of 2006, a case was developed which extended the PTC for landfill gas technologies through 2020. The landfill gas PTC was selected because it has the largest impacts of all the renewable generation tax incentives. Extending the PTC results in an increase of 733 megawatts of landfill gas capacity compared to the reference case through 2020, 186 megawatts more than in the CCTI case.

The same schedule is used for the State-mandated capacity additions as in the reference case, so all reported State-mandated additions through 2020 become unintended beneficiaries of the extended PTC. In the case extending the PTC, unintended beneficiaries account for tax revenue reductions of $911 million through 2020, or 55 percent of the total revenue reductions of $1,644 million. In the CCTI case, unintended beneficiaries account for revenue reductions of $491 million, also 55 percent of the total revenue reductions of $900 million.

Summary

In general, the estimated impacts of the proposed tax incentives in CCTI are relatively small. In 2005, the tax incentives for the buildings and transportation sectors are projected to reduce total primary energy consumption by 25.2 trillion Btu, or 0.02 percent, relative to the reference case projection of 105 quadrillion Btu (Table 23). The impact in 2010 is 44.2 trillion Btu (0.04 percent). In the *AEO2000* reference case, carbon emissions are projected to reach 1,683 million metric tons in 2005 and 1,787 million metric tons in 2010. (Note that the EIA model only tracks the carbon equivalent of carbon dioxide emissions from the combustion of energy.) These tax incentives lower the projected carbon emissions by 0.5 million metric tons (0.03 percent) and 0.7 million metric tons (0.04 percent) in 2005 and 2010, respectively, relative to the *AEO2000* reference case (Table 24). The renewable generation tax incentives are projected to reduce fossil energy consumption for electricity generation by 150.9 trillion Btu in 2005 and by 48.7 trillion Btu in 2010, reducing carbon emissions by 3.2 million metric tons (0.19 percent) in 2005 and by 0.6 million metric tons (0.03 percent) in 2010, relative to the *AEO2000* reference case. An additional 3.4 million metric tons carbon equivalent of methane emissions are avoided in 2005 due to the landfill gas tax incentive.

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

CCTI Initiative	2002	2003	2004	2005	2010
Buildings					
- Energy-Efficient Equipment	3.1	4.8	6.7	6.6	5.9
- Energy-Efficient New Homes	0.8	2.1	5.1	9.8	9.5
- Rooftop Solar Equipment	<0.01	<0.01	<0.01	<0.01	<0.01
- Distributed Power	<0.05	0.1	0.1	0.2	1.7
Transportation					
- Electric, Fuel Cell, and Hybrid Electric Vehicles	0.5	2.5	5.2	8.6	27.1
Renewable Generation[a]	91.4	103.5	127.5	150.9	48.7
Total	**95.8**	**113.0**	**144.6**	**176.1**	**92.9**

[a]For the renewable generation tax credits, the change represents the reduction in fossil energy use for electricity generation.
Note: Estimated reductions are relative to the CCTI reference case, which is similar to that in Energy Information Administration, *Annual Energy Outlook 2000*, DOE/EIA-0383(2000) (Washington, DC, December 1999).

In 2005, total carbon emissions are projected to be reduced by 3.7 million metric tons, or 0.22 percent of the *AEO2000* reference case projection, as a total of the individual impacts of the tax incentives. The reduction reflects lower projected energy consumption and a shift in the mix of energy fuels. In 2010, the tax incentives reduce projected carbon emissions by 1.3 million metric tons, or 0.07 percent of the *AEO2000* reference case projection.

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

CCTI Initiative	2002	2003	2004	2005	2010
Buildings					
- Energy-Efficient Equipment	0.1	0.1	0.2	0.1	0.1
- Energy-Efficient New Homes	<0.05	<0.05	0.1	0.2	0.1
- Rooftop Solar Equipment	<0.01	<0.01	<0.01	<0.01	<0.01
- Distributed Power	<0.01	<0.01	<0.01	<0.01	<0.05
Transportation					
- Electric, Fuel Cell, and Hybrid Electric Vehicles	<0.05	0.1	0.1	0.2	0.5
Renewable Generation	2.0	2.2	2.7	3.2	0.6
Total	**2.1**	**2.4**	**3.1**	**3.7**	**1.3**

Note: Estimated reductions are relative to the CCTI reference case, which is similar to that in Energy Information Administration, *Annual Energy Outlook 2000*, DOE/EIA-0383(2000) (Washington, DC, December 1999). Estimated reductions in carbon emissions from electricity are calculated from the estimated emissions of marginal generating plants.

For all the tax incentives, with the exception of the buildings equipment credit, the impacts increase from 2002 to 2005, because the more advanced technologies become available and gradually penetrate the market. As the buildings equipment tax credits expire in 2004, the impact of the tax credits is reduced, because some of the new, more efficient equipment begins to need replacement and is replaced by less efficient equipment. The more efficient equipment is no longer economical without the tax credit. As most other tax credits expire in 2005, their incremental impacts are subsequently reduced. Since the initiative for distributed power is a change in the depreciation schedule without a time limit, rather than a credit, this proposal has a greater impact later in the projection period. The proposed transportation tax credits also have more sustained impacts by encouraging the penetration of advanced technology vehicles.

Although the CCTI tax initiatives lower carbon emissions, there is a loss to the Federal government resulting from the lower tax revenues. In Table 25, the revenue reduction per ton of carbon reduced or avoided is presented for each of the tax initiatives, using two different methods. In the first method, the tax revenue losses through 2020 are discounted, and in the second method, both the tax revenue losses and the emissions reductions are discounted. Both methods are calculated because there is some disagreement about discounting nonmonetary values. Discount rates of 7 and 15 percent are used, along with no discounting.

With no discounting, the cost of carbon reductions ranges from $44 to $267 per ton across the various tax initiatives. For a 7-percent discount rate, the cost ranges from $54 to $460 per ton if carbon emissions are discounted and from $24 to $157 per ton if emissions are not discounted, and, for a 15-percent discount rate, the cost ranges from $55 to $813 per ton if carbon emissions are discounted and from $14 to $98 per ton if emissions are not discounted. The cost per ton of carbon emissions reduction increases with higher discount rates if the carbon emissions are discounted because the revenue reductions occur earlier in the period while the carbon emissions are reduced over the life of the equipment. As requested by the Subcommittee, it is noted that only the landfill gas tax initiative has a cost in the range of the $14 to $23 dollars per ton estimated as the cost of implementing the Kyoto Protocol.

Table 25. Projected Tax Revenue Reductions per Ton of Carbon Emissions Reduced
(1998 Dollars)

CCTI Initiative	Discount Rate				
		7 Percent		15 Percent	
	0 Percent	Emissions Discounted	Emissions Not Discounted	Emissions Discounted	Emissions Not Discounted
Buildings					
- Energy-Efficient Equipment	100	158	84	228	70
- Energy-Efficient New Homes	171	256	130	353	98
- Distributed Power	267	303	109	362	46
Transportation					
- Electric, Fuel Cell, and Hybrid Electric Vehicles	247	460	157	813	97
Renewable Generation	74	94	46	108	30
- Wind	142	198	79	275	44
- Biomass Co-firing	51	54	38	55	28
- Landfill Gas	44	61	24	80	14

Note: Calculated through 2020. Does not include the rooftop solar equipment and biomass tax credits, which have tax revenue reductions but relatively small carbon emissions reductions.
Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

The investment tax credits lower the initial cost of purchasing more efficient 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 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 incentives 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 incentives are critical. For example, the fuel cell vehicle tax credit extends through 2006, and EIA assumes that fuel cell vehicles will first become commercially available in 2005.

Although tax incentives have benefits in encouraging some incremental investments, there may be some unintended consequences. Some of the technologies covered by the incentives would likely penetrate even without the incentives, which can be seen by comparing the tax incentive cases with the reference case. Those units would receive the tax incentives in addition to those units added incrementally as a result of the incentives. Such unintended beneficiaries may be a significant portion of the total units, nearly all of the rooftop solar equipment and 70 percent or more for the distributed power, transportation, wind, and biomass tax initiatives (Table 26). Another unintended result could be a shifting of planned investments to fall within the time period of the incentives by purchasers either delaying until the incentives begin or accelerating their investments.

Table 26. Projected Unintended Beneficiaries of CCTI Tax Initiatives
(Percent of Revenue Reductions)

CCTI Initiative	Unintended Beneficiaries
Buildings	
- Energy-Efficient Equipment	42
- Natural Gas Heat Pump (Residential Only)	50
- Electric Heat Pump Water Heater (Residential Only)	4
- Fuel Cell	2
- Energy-Efficient New Homes	13
- Rooftop Solar Equipment	Almost 100
- Distributed Power	77
Transportation	
- Electric, Fuel Cell, and Hybrid Electric Vehicles	84
Renewable Generation	70
- Wind	94
- Biomass	90
- Biomass Co-firing	34
- Landfill Gas	55

Note: Unintended beneficiaries are calculated over the life of the tax incentives, except for distributed power which is calculated from 2001 to 2020.
Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

As discussed earlier in this report, there are a number of uncertainties in key assumptions that could affect the specific results of this analysis. Changes in energy prices from those in the *AEO2000* reference case could alter the underlying economics of technology penetration. Also, unforeseen changes in the costs and performance characteristics of new or more advanced technologies or fundamental shifts in consumer behavior and consumer valuation of more energy-efficient or lower-emission technologies could impact the results. Given these assumptions, the impacts of these incentives on energy consumption and emissions appear small.

Comparison to the Fiscal Year 2000 Climate Change Technology Initiative

The Administration's fiscal year 2000 budget request included $383 million in tax incentives, compared to $201 million in the fiscal year 2001 budget request, all in nominal dollars. Over a five-year period, the tax incentives in the fiscal year 2000 request totaled $3.6 billion from fiscal years 2000 through 2004, and the incentives in the fiscal year 2001 request total $4.0 billion from fiscal years 2001 through 2005. Although many of the proposed tax incentives are similar, there are some significant deletions, additions, and modifications to the proposals. The impacts of the fiscal year 2000 CCTI were analyzed by EIA at the request of the U.S. House of Representatives Committee on Science.[45]

Buildings

Tax Credits for Energy-Efficient Homes

The fiscal year 2001 CCTI tax credit for energy-efficient new homes proposes a credit of $1,000 for purchasers of new homes built between 2001 and 2003 that are at least 30 percent more efficient and a credit of $2,000 for homes built between 2001 and 2005 that are at least 50 percent more efficient than the IECC standard. The fiscal year 2000 CCTI included a credit of $1,000 for new homes built between 2000 and 2001 that are at least 30 percent more efficient, a credit of $1,500 for new homes built from 2000 through 2002 that are at least 40 percent more efficient, and a credit of $2,000 for new homes built from 2000 through 2004 that are at least 50 percent more efficient than the IECC Standard. By removing the 40-percent category, the energy savings in 2010 are reduced from 11.6 to 9.5 trillion Btu and the savings in carbon emissions from 0.2 to 0.1 million metric tons (Table 27). The estimated impact on tax revenues over the five-year period decreases from $537 million to $454 million.

Table 27. Summary of Projected Impacts for Climate Change Technology Tax Initiatives, 2010

	Reduction[a] in Primary Energy Use[b] (Trillion Btu)		Reduction[a] in Carbon Emissions[c] (Million Metric Tons)	
CCTI Initiative	Fiscal Year 2001	Fiscal Year 2000	Fiscal Year 2001	Fiscal Year 2000
Buildings				
- Energy-Efficient Equipment	5.9	24.4	0.1	1.2
- Energy-Efficient New Homes . . .	9.5	11.6	0.1	0.2
- Rooftop Solar Equipment	<0.01	<0.01	<0.01	<0.01
- Distributed Power	1.7	—	<0.05	—
Industrial				
- Combined Heat and Power	—	—	—	0.2
Transportation				
- Electric, Fuel Cell, and Hybrid Electric Vehicles	27.1	0.8	0.5	<0.01
Renewable Generation	48.7	71.9	0.6	1.5
Total	**92.9**	**108.7**	**1.3**	**3.1**

[a]Estimated reductions are relative to the CCTI reference cases which are similar to those in Energy Information Administration, *Annual Energy Outlook 2000*, DOE/EIA-0383(2000) (Washington, DC, December 1999) and *Annual Energy Outlook 1999*, DOE/EIA-0383(99)(Washington, DC, December 1998).
[b]For the renewable generation tax credits, the change represents the reduction in fossil energy use for electricity generation.
[c]Reductions in carbon emissions from electricity are calculated from the estimated emissions of marginal generating plants.

[45]Energy Information Administration, *Analysis of the Climate Change Technology Initiative*, SR/OIAF/99-01 (Washington, DC, April 1999).

Tax Credits for Energy-Efficient Equipment in Homes and Buildings

The fiscal year 2001 CCTI includes a 20-percent tax credit, subject to caps, for purchasers of electric heat pump water heaters, natural gas heat pumps, and fuel cells, meeting specified efficiency levels, from 2001 through 2004. In the fiscal year 2000 CCTI, tax credits of 10 percent were proposed for specified equipment and efficiency levels purchased between 2000 and 2001 and tax credits of 20 percent for specified equipment and efficiency levels purchased between 2000 and 2003, all subject to caps. However, the fiscal year 2000 CCTI also included central air conditioners, natural gas water heaters, and electric heat pumps. By reducing the number of eligible technologies, the energy savings in 2010 are reduced from 24.4 to 5.9 trillion Btu and the savings in carbon emissions from 1.2 to 0.1 million metric tons.

Tax Credits for Rooftop Solar Systems

The CCTI for fiscal year 2001 proposes a 15-percent tax credit, subject to a cap, for rooftop photovoltaic systems installed between 2001 and 2007 and solar water heating systems installed from 2001 and 2005 but not applicable to solar-heated swimming pools. This is identical to the credit proposed in the fiscal year 2000 CCTI although the applicable time period was shifted by one year. The impact of the proposed credit is negligible, and, for the most part, the credit would apply to equipment already completed under the Million Solar Roofs program.

Tax Incentives for Distributed Power Property

The fiscal year 2001 CCTI includes tax incentives for distributed power property for use in commercial or residential rental buildings by proposing a 15-year depreciation recovery period for these systems, making their tax treatment consistent with that currently used by industrial generation facilities. Distributed generation facilities in buildings currently have a 39-year depreciation recovery period if placed in service after 1993. The estimated energy savings from the distributed power property tax incentive in 2010 are 1.7 trillion Btu, with 0.03 million metric tons of carbon emissions reductions. The tax revenue losses are estimated at $8 million for the distributed power property tax incentive.

Industrial

Tax Credit for Combined Heat and Power Systems

The fiscal year 2000 CCTI included a tax credit of 8 percent for qualified combined heat and power systems larger than 50 kilowatts, installed between 2000 and 2002. This credit is not included in the fiscal year 2001 CCTI. In 2010, the energy savings from this tax credit were essentially negligible because reductions in purchased electricity were offset by increases in natural gas consumption for cogeneration; however, carbon emissions were reduced by 0.15 million metric tons. The tax revenue losses were estimated to be between $85 million and $125 million, with the range resulting from the possibility that systems planned for 1999 or 2003 would be moved to take advantage of the credit.

Transportation

Tax Credits for Electric Vehicles and Fuel Cell Vehicles

The fiscal year 2001 CCTI proposes extending the current 10-percent tax credit, subject to a cap, for qualified electric and fuel cell vehicles. This credit is currently scheduled to begin to phase down in 2002, phasing out in 2005, and the proposal would extend it at its full level through 2006. This is identical to the proposal for electric and fuel cell vehicles in the fiscal year 2000 CCTI.

Tax Credits for Hybrid Vehicles

The fiscal year 2000 CCTI proposed graduated tax credits from $1,000 to $4,000 for qualifying hybrid vehicles. The level of the credit was based upon the efficiency improvement relative to the average efficiency of comparable vehicles in the same size class. This has been changed to a proposed tax credit for qualifying hybrid electric vehicles purchased from 2003 through 2006, ranging from $500 to $3,000 depending on the design performance. The level of the tax credit is based upon the percent of the maximum available power provided by the energy storage system and the percent of the energy used in braking that is recaptured and stored into the battery.

Hybrid electric vehicles can have two different designs in which the electric motor either assists the gasoline engine when more performance is needed or is used at low speeds while the gasoline engine is used at high speeds to optimize the engine efficiency. The revised incentive may be intended to achieve the latter design of optimizing the engine efficiency rather than using the electric motor as a power assist. The fiscal year 2001 tax credit proposal may lead to the earlier development of advanced regenerative braking technology and the optimization of the engineering efficiency of the combined hybrid electric motor and engine.

In 2010, the tax credits proposed in the fiscal year 2001 CCTI for transportation are projected to save 27.1 trillion Btu of energy and 0.5 million metric tons of carbon emissions, compared with 0.8 trillion Btu of energy and a negligible amount of carbon emissions with the tax credits in the fiscal year 2000 CCTI. The five-year tax revenue loss is estimated at $1,912 million for the fiscal year 2001 proposal, compared to $1,960 million for the fiscal year 2000 proposal.

Renewable Energy Electricity Generation

Tax Credits for Wind Generation

An existing tax credit for wind generation provides a credit of 1.5 cents per kilowatthour, adjusted for inflation from a 1992 base, for systems placed in service after December 31, 1993, and before January 1, 2002. In the fiscal year 2001 CCTI, this credit would be extended to systems placed in service before July 1, 2004, or, if unfinished by that date but under firm contract or under construction, eligibility is extended through June 30, 2005, one year beyond the date proposed in the fiscal year 2000 CCTI. Under both proposals, the savings in carbon emissions in 2010 are negligible. The tax credits are not large enough to stimulate significant new capacity additions. In the current analysis, additional wind capacity is expected in 2005, even without the tax credit, due to additional State mandates. Because of the higher planned wind capacity additions relative to the previous analysis and the accelerated construction of post-2005 planned wind capacity to obtain the benefits of the tax credit, the tax revenue losses in 2005 are about double those in the analysis of the fiscal year 2000 CCTI and are more than double in 2010.

Tax Credits for Biomass Generation

Currently, closed-loop biomass generation systems placed in service after December 31, 1992, and before January 1, 2002, receive a tax credit of 1.5 cents per kilowatthour, which is adjusted for inflation from a 1992 base. In the fiscal year 2001 CCTI, this tax credit would be extended to systems placed in service before July 1, 2004, or, if unfinished by that date but under firm contract or under construction, through June 30, 2005, one year beyond the date proposed in the fiscal year 2000 CCTI. Under both proposals, the definition of biomass systems eligible for the credit would be extended to certain open-loop systems, and the proposed credit in the fiscal year 2001 CCTI would be extended one year beyond the date proposed in the fiscal year 2000 CCTI. In addition, the fiscal year 2001 CCTI proposes a 1.0-cent-per-kilowatthour credit, adjusted for inflation from a 2000 base, for electricity produced from 2001 to 2003 from open-loop biomass facilities placed in service prior to January 1, 2001. The credit for existing open-loop biomass systems was not proposed in the fiscal year 2000 CCTI. In 2010, the revenue losses as a result of the tax credit for new biomass capacity are similar to those in the analysis of the fiscal year 2000 CCTI, but the revenue losses are lower in 2005, as accelerated construction of State-mandated capacity is offset by less new capacity in the reference case, compared to last year's analysis. The credit for existing open-loop biomass systems provides tax revenue reductions of about $235 million from 2001 through 2003. The tax credits for both existing and new biomass capacity are not expected to have a significant impact on carbon emissions.

The fiscal year 2001 CCTI proposes a 0.5-cent-per-kilowatthour tax credit, adjusted for inflation from a 2000 base, for biomass-fired electricity generated by coal plants using biomass co-firing from January 1, 2001, through December 31, 2005. The proposal shifts the biomass co-firing tax credit in the fiscal year 2000 CCTI by one year and reduces the proposed credit from 1.0 cents per kilowatthour to 0.5 cents per kilowatthour. Because the lower tax credit reduces the economic incentive, co-firing is reduced from 19 to 12 billion kilowatthours in 2004, and revenue losses are about one-third of those estimated under the fiscal year 2000 proposal. In addition, the fiscal year 2001 proposal extends this credit through 2005, generating additional tax revenue reductions of about $70 million for the additional year.

Tax Credits for Landfill Gas Generation

The fiscal year 2001 CCTI provides a tax credit of 1.0 cent per kilowatthour for landfills subject to EPA's NSPS and a 1.5-cent-per-kilowatthour tax credit for landfills not subject to the NSPS. This applies to systems placed in service between January 1, 2001, and December 31, 2005, but is extended through December 31, 2006, if the facility is constructed, reconstructed, or acquired by the taxpayer under a contract binding on December 31, 2005. The fiscal year 2000 CCTI did not include a tax credit for landfill gas generation. As a result of this proposed credit, about 600 megawatts of new landfill gas generating capacity are constructed with reductions in carbon emissions of about one million metric tons annually with revenue losses of $900 million through 2015.

Total Renewable Energy Electricity Generation

In total, the renewable energy generation tax credits proposed in the fiscal year 2001 CCTI are projected to reduced carbon emissions in 2010 by 0.6 million metric tons compared to 1.5 million metric tons estimated for the fiscal year 2000 CCTI. The lower estimated savings result from the lower impact of the biomass co-firing tax proposal. The five-year tax revenue losses are increased from $816 million to $944 million under the fiscal year 2001 CCTI.

Across all programs, the savings in carbon emissions as a result of the fiscal year 2001 CCTI total 1.3 million metric tons in 2010. This is lower than the 3.1 million metric tons estimated as the impact of the fiscal year 2000 CCTI, due to smaller impacts from the energy-efficient buildings equipment tax credit, the renewable generation tax credits, and the distributed power tax incentive when compared to the CHP tax credit. The lower carbon savings from these proposals, and to a lesser extent the energy-efficient new homes tax credit, are partially offset by higher carbon savings from the proposed transportation tax credits.

3. Research, Development, and Deployment

Introduction

The Administration's Climate Change Technology Initiative (CCTI) proposes fiscal year 2001 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 $1.4 billion, an increase of $337 million over the fiscal year 2000 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 2000* (*AEO2000*), 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 2000, and new building shell efficiencies are fixed at 2000 levels. In the industrial sector, the efficiencies of new plants and equipment are constant at 2000 levels. New equipment is fixed at 2000 efficiencies for all transportation modes, and the cost and performance characteristics of all electricity generation technologies are held to 1999 levels.

- Second, for most of the 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 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 *AEO2000* 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; the Partnership for a New Generation of Vehicles (PNGV) in the transportation 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, performance, costs, 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 $275 million in funding for buildings technology research, development, and deployment. CCTI funding for DOE, EPA, and HUD programs in fiscal year 2001 represents a 42-percent increase over fiscal year 2000 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 *AEO2000* 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 2000 levels. The comparison shows that, in 2010, projected energy consumption in the buildings sector is 700 trillion

British thermal units (Btu), or 2 percent, lower in the reference case than in the frozen technology case, and projected carbon emissions from the sector are 12 million metric tons (1.8 percent) lower.[46]

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 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 single-family homes constructed were assumed to be 50 percent more energy-efficient in heating and cooling than today's new homes. (It should be noted that any homes built under the PATH program during 2001-2004 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 28 shows the energy, carbon, and energy bill savings projected to come from meeting the goals of the PATH program as described above. In 2010, annual energy savings relative to the reference case are projected at 96 trillion Btu (0.8 percent), saving Americans $898 million and reducing carbon emissions by 1.9 million metric tons (0.6 percent). In 2020, the projected savings are 278 trillion Btu (2.2 percent of the reference case projection), $2.5 billion in consumer energy bills, and 5.7 million metric tons of carbon emissions (1.5 percent).

Table 28. Projected Energy Savings and Carbon Emissions Reductions for Successful PATH Program Goals in New Housing, 1998, 2005, 2010, and 2020

Projection	1998 Total	2005 Savings	2010 Savings	2020 Savings
Delivered Energy (Trillion Btu)	10,237	35.4	96.0	278.2
Energy Expenditures (Million 1998 Dollars)	131,058	337.7	897.7	2,473.5
Carbon Emissions (Million Metric Tons)	283.5	0.8	1.9	5.7

Source: Energy Information Administration, National Energy Modeling System runs BASE.D022800A and RSPATH.D022900B.

[46]Energy Information Administration, *Annual Energy Outlook 2000*, DOE/EIA-0383(2000) (Washington, DC, December 1999), Table F5.

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 2001 budget calls for new funding to support the launch of new Energy Star product lines and promote the Energy Star labeling program in 6 to 10 export markets.[47] Possible candidates for the Energy Star label include commercial ice makers, ventilation fans, and water coolers. 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.[48] EPA plans to strengthen the MOU to a 1 watt restriction within the next several years. The *AEO2000* 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 97 trillion Btu of electricity will be saved (cumulatively), accumulating $2.1 billion dollars of energy bill savings, and abating 5.0 million metric tons of carbon emissions cumulatively. In 2010, the program is projected to save 17.5 trillion Btu of delivered electricity (0.4 percent of residential electricity use) and to reduce carbon emissions by 0.8 million metric tons (0.2 percent) relative to the reference case projections (Table 29). These estimates of savings are about half those in last year's analysis of the CCTI for fiscal year 2000 because more recent data from EIA's Residential Energy Consumption Survey 1997 show that TVs use less electricity than previously assumed.

Table 29. Projected Residential Electricity Savings and Carbon Emissions Reductions for the Energy Star TV/VCR Program in the *AEO2000* Reference Case, 1998, 2005, 2010, and 2020

Projection	1998 Total	2005 Savings	2010 Savings	2020 Savings
Delivered Electricity (Trillion Btu)	3,835	8.6	17.5	30.3
Electricity Expenditures (Million 1998 Dollars)	90,444	188.8	378.3	645.3
Carbon Emissions (Million Metric Tons)	283.5	0.5	0.8	1.5

Source: Energy Information Administration, National Energy Modeling System runs BASE.D022800A and RSESTAR.D022800C.

[47]"Report to Congress on Federal Climate Change Expenditures," p. 12.

[48]Personal communication with the Energy Star program manager, April 5, 1999.

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.[49] 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.[50]

Table 30 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

[49]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.

[50]See the Million Solar Roof web site, www.eren.doe.gov/millionroofs/ as of March 2000.

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 30.

Table 30. Projected Energy Savings and Carbon Emissions Reductions for Successful Million Solar Roofs Program, 1998, 2005, 2010, and 2020

Projection	1998 Total	2005 Savings	2010 Savings	2020 Savings
Primary Energy (Trillion Btu)	34,149	5.4	40.5	37.9
Energy Expenditures (Million 1998 Dollars)	227,922	38.9	354.3	347.7
Carbon Emissions (Million Metric Tons)	521.0	0.1	0.8	0.9

Source: Energy Information Administration, National Energy Modeling System runs NOMSR.D022900A and FULLMSR.D030100A.

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 September 30, 1999, the program reported 3,037 organizations participating in the partnership. The program focuses first on energy-efficient lighting upgrades, typically the most cost-effective improvement for commercial buildings. EPA reports 44.1 billion pounds of carbon dioxide emissions prevented and $1.4 billion in energy costs saved, cumulatively, from the completed upgrades.[51] The NEMS commercial module includes the effects of this program in its reference case assumptions.

Energy Smart Schools is a campaign of DOE's Rebuild America 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 help cut schools' energy bills by up to 25 percent, 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 Clean Cities, 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

[51] See the Energy Star Buildings and Green Lights Partnership web site, www.epa.gov/buildings/esbhome/.

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.

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 Energy Policy Act of 1992 (EPACT) and Executive Order 13123 in 1999. 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 13123 requires agencies to achieve a 30-percent reduction by fiscal year 2005, and a 35-percent reduction by 2010 relative to the 1985 baseline. Under the executive order, each Federal agency also has the goal to reduce greenhouse gas emissions attributed to facility energy use by 30 percent by 2010 compared to 1990 levels.

FEMP activities to help agencies meet their energy goals include creation of partnerships, resource leveraging, technology transfer, and training and support. The fiscal year 2001 budget request includes an increase in funding of $6 million (23 percent) over the 2000 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. Preliminary numbers from FEMP's forthcoming *Annual Report to Congress* for fiscal year 1998 indicate that:

- By the end of fiscal year 1998, the Government had decreased energy consumption in buildings by 18.7 percent per square foot since 1985—more than halfway to its goal of achieving a 30-percent reduction by 2005.
- Energy efficiency efforts have contributed significantly to a 17-percent decrease in the cost for energy in buildings compared to a 1985 baseline.
- Carbon emissions from energy used in buildings have decreased by 15.8 percent since 1990.

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; addressing Federal energy opportunities arising from utility restructuring and green power; and other FEMP activities.[52]

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

Energy-Efficient Buildings Technologies

The CCTI budget proposes an increase of $33 million (29 percent) over the 2000 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 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 for industry and has recently reported that its programs reduced 1999 consumption in the industrial sector by 176 trillion Btu.[53] 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. The proposed budget is $184 million, an increase of $9 million over 2000.[54] The DOE funding request for industrial programs in CCTI is summarized in Table 31.

One indication of the possible impacts of these programs is provided by the *AEO2000* projections. A frozen technology case for the industrial sector projects 860 trillion Btu (2 percent) more energy

[53]U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Office of Industrial Technologies, Budget Materials, February 2000, www.cfo.doe.gov/budget/00budget/ec/industry.pdf, p. 14.

[54]For comparability purposes, $13.5 million for black liquor gasification is included in the fiscal year 2000 total. However, this funding was included in the Office of Fossil Energy budget for fiscal year 2000.

consumption in 2010 than in the reference case,[55] and a portion of the difference is due to inclusion of the energy effects of the DOE programs.

Table 31. Department of Energy Industrial Programs

Program Area	Fiscal Year 2000 Appropriation (million dollars)	Fiscal Year 2001 Request (million dollars)
Industries of the Future (specific industries)	66.0	83.9
Industries of the Future (cross cutting)		
Distributed Generation	27.3	17.3
Financial Assistance	11.4	12.0
Technical Assistance	19.8	25.8
Management and Planning	8.9	9.3
Cooperative Programs	2.0	0.0
Science Initiative	3.9	0.0
Total	**175.2**	**184.0**

Note: Fiscal year 2000 total includes $13.5 million for black liquor gasification that previously was in the Fossil Energy budget.
Source: U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Office of Industrial Technologies, *Budget Materials*, February 2000.

This analysis does not attempt to quantify the energy or emissions impacts of DOE research, development, and deployment programs; however, the *AEO2000* 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 estimated that the programs included in the Climate Change Action Plan could reduce annual electricity consumption by 25 billion kilowatthours and annual fossil fuel consumption by 65 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.[56] 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

[55]Energy Information Administration, *Annual Energy Outlook 2000*, DOE/EIA-0383(2000) (Washington, DC, December 1999), Table F3.

[56]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.

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 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 reduce energy intensity by 25 percent in 2010 compared with 1990.[57] The *AEO2000* forecast for industrial energy consumption in 2010 is 39.1 quadrillion Btu.[58] In *AEO2000*, EIA projected energy intensity to decline by 2 percent to 23 percent for selected Industries of the Future.[59] Consequently, the 25-percent reduction goal, while ambitious, could be achievable.

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 *AEO2000* projections, the CHP Challenge goal appears to be quite ambitious. For example, over the 1998 to 2010 period, projected CHP additions total 6.5 gigawatts in the reference case.[60] 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.

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[57]U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Office of Industrial Technologies, Budget Materials, February 2000, p. 4, www.eia.cfo.doe.gov/budget/01budget/ec/industry.pdf.

[58]Energy Information Administration, *Annual Energy Outlook 2000*, DOE/EIA-0383(2000) (Washington, DC, December 1999), p. 118.

[59]Energy Information Administration, *Energy Consumption Projections for Selected Industries of the Future*, SR/OIAF/99-5 (Washington, DC, November 1999).

[60]Energy Information Administration, *Annual Energy Outlook 2000*, DOE/EIA-0383(2000) (Washington, DC, December 1999), p. 130.

Other Programs

The proposed budget for EPA's industry programs is $63 million, an increase of $41 million from fiscal year 2000. 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.[61] As with any other voluntary deployment program, it is not clear to what extent the projected savings can be attributed to the Climate Wise program.

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 $378 million, an increase of $68 million over the 2000 budget. In the *AEO2000* 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 6 percent higher than the 1998 level, and fuel efficiency for new heavy trucks in 2010 is approximately 7.9 percent above the 1998 level. In comparison with the frozen technology case, transportation energy consumption in the reference case is 0.7 quadrillion Btu (2.1 percent) lower in 2010.[62]

Partnership for a New Generation of Vehicles

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[63] 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.

The CCTI research and development initiatives for fiscal year 2001 include a proposed funding increase of $30 million for the PNGV program, which was funded at $225 million in fiscal year 2000. The National Research Council (NRC), which evaluates the PNGV program each year, has recommended that additional funding be provided. This appears particularly important because the PNGV diesel technologies can not meet Tier II emissions standards as currently formulated. Research on advanced catalysts and other exhaust after-treatment technologies combined with advanced high quality fuels needs funding. The NRC summarizes some of the most important reasons for increased funding: "U.S.

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[61] U.S. Environmental Protection Agency, *Climate Wise Progress Report*, EPA 231-R-98-015 (Washington, DC, October 1998), p. 4.

[62] Energy Information Administration, *Annual Energy Outlook 2000*, DOE/EIA-0383(2000) (Washington, DC, December 1999), Table F4.

[63] Including maintenance and operating costs and purchase price.

government and industry investments in research and development (of fuel cells) should, therefore, be continued at current levels or even be increased for an extended period. The government should significantly expand its support for the development of long-term PNGV technologies that have the potential to improve fuel economy, lower emissions, and be commercially viable."[64]

Through the PNGV technology selection process, two of the most promising technologies are hybrid electric vehicles and fuel cell vehicles. Hybrid electric vehicles may use either a gasoline or diesel engine in combination with an electric motor, and fuel cell vehicles are currently designed to operate using hydrogen stored on the vehicle or processed with a gasoline or methanol reformer on board.

The National Alternative-Fuel Vehicle Survey, funded by DOE's Office of Transportation Technologies, revealed that consumers of advanced technology vehicles, such as the PNGV technology vehicles, make purchasing decisions on the following criteria: vehicle price, cost of driving per mile, vehicle range, availability of refueling stations, luggage space, vehicle maintenance costs, and vehicle acceleration or performance measured in seconds from 0 to 60 mph. Other factors that may limit vehicle purchases are the commercial availability dates and the availability of vehicle technologies in various sizes and vehicle types. Some technologies are limited in their application due to size requirements, and others are constrained by cost considerations, such as electric vehicles with the size of a cargo van.

With the benefit of economies of scale, the incremental cost of the hybrid electric and fuel cell vehicles above a gasoline vehicle at full market production may be approximately $4,000 and $6,000, respectively. The hybrid electric full production vehicle price is based on current production levels of the gasoline-electric hybrid vehicles that are offered or soon to be offered in the United States. The fuel cell vehicle full production vehicle price is achieved in 2020 because there are no plans for a production prototype fuel cell vehicle until 2004. Shortly after 2004, manufacturers would be able to produce reasonable quantities of fuel cell vehicles if demanded; however, reaching the full production volumes that correspond to the incremental vehicle price of $6,000 would require very large sales volumes and some significant breakthroughs in the deployment of fuel cell vehicles. Both hybrid electric and fuel cell vehicles will require approximately two to three refinement cycles of three to four years each before these vehicles are expected to have the consumer attributes that are needed to reach full production volumes.

In addition to the initial vehicle price, there are other obstacles to the penetration of these vehicles. For example, fuel cells have achieved considerable size and weight reductions, but they have not been enough to completely eliminate the luggage space and interior volume displacement from the fuel cell, the hydrogen storage tanks, and the reformers. In addition, the infrastructure for the production and distribution of hydrogen and methanol do not currently exist on a national level. Other infrastructure issues, including vehicle parts, trained mechanics, and safety issues associated with hydrogen, methanol, and methyl tertiary butyl ether (MTBE) storage will also need to be resolved. EPA has

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[64]National Research Council of the National Academy of Sciences, *Review of the Research Program of the Partnership for a New Generation of Vehicles: Fifth Report* (Washington, DC: National Academy Press, 1999), pp. 96-98.

recently announced its intention to ban MTBE as a gasoline additive because of the past experiences with contamination of groundwater in many states; MTBE is made from methanol and a decline in MTBE used for blending in gasoline could negatively impact methanol production and fuel availability in the future when fuel cell methanol vehicles may be available.

It is likely that the fuel economy of the hybrid electric and fuel cell vehicles offered to the public will not achieve the PNGV goal of three times the gasoline vehicle fuel economy, which represents the upper range of technological feasibility. Consumer demand for higher performance will lower the fuel economy of the vehicles offered. When the actual fuel economy levels are combined with much higher projected prices for hydrogen and methanol relative to gasoline, the cost of driving these vehicles will not be competitive compared to gasoline vehicles. Maintenance costs on the hybrid electric may also be considerably higher, compared to a gasoline vehicle, due to battery replacement. Replacement can cost from $2,000 to $10,000, lasting three to five years, depending on the percentage of the driving time that the vehicle uses the electric motor and battery.

For hybrid vehicles, there are difficulties with emissions standards. American manufacturers, who have not yet made their versions of the hybrid electric available, all use diesel fuel. At this time, Tier II emissions regulations set by EPA cannot be met by diesel-electric hybrids. In the future, engine redesign, high-quality, low-sulfur fuel, and after-treatment with advanced catalysts may lead to advanced diesels compliant with the Tier II standards, but at a higher cost.

There are additional technical issues associated with fuel cell vehicles. Engine startup times currently approach three minutes although the goal is one minute. Water loss in the self-enclosed fuel cells has been a problem and can also lead to operational problems in freezing outdoor temperatures. As noted above, the weight and size of fuel cells need further improvement, and technological breakthroughs are also needed for the gasoline and methanol on-board reformers because of the complexity of refining these fuels into hydrogen. Finally, safety issues are a concern with hydrogen storage due to the flammability and potential leakage from the embrittlement of the storage tanks, and methanol is highly toxic even in very small quantities, is very corrosive, and has an invisible flame during combustion.

If the cost, efficiency, and performance goals of the PNGV program are realized, it is likely that these vehicles will begin to capture a significant portion of the market. However, continued additional funding will be necessary for the success of the program in order to overcome the technical and consumer acceptance obstacles.

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 0.04 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 developing a new direct injection diesel automobile (the Lupo) with a fuel efficiency goal of 78 mpg. For model year 2000, Volkswagen is again offering the turbo direct injection engine in the Golf, Jetta, and Beetle.

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.[65] On average, a heavy truck travels 37,600 to 86,500 miles each year.[66] 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 1998.

The stated goal of the CCTI proposal for light trucks is a 35-percent improvement in fuel efficiency above conventional gasoline vehicles by 2003 while meeting strict emissions standards. For heavy trucks the goal is to achieve a fuel efficiency of 10 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.[67] 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 2003 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

The results for the CCTI analysis case show that diesel direct injection light truck sales in 2010 total approximately 162,000 vehicles, an increase of about 47,000 sales above the reference case (Table 32). Projected carbon emissions from light-duty vehicles in the CCTI case are reduced by 0.4 million metric

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

[66]U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Office of Transportation Technologies, *Program Analysis Methodology* (Washington, DC, January 15, 1999), p. 21.

[67]For a more detailed description of the transportation module, see Chapter 2.

tons in 2005 and 0.6 million metric tons in 2010 from reference case levels. Carbon emissions in the CCTI case are slightly higher than in the reference case in 2020 because diesel fuel consumption displaces gasoline and alternative fuels. Since diesel fuel has a higher carbon emissions factor than gasoline and alternative fuels, the carbon emissions rise slightly above the reference case in 2020.

Table 32. Projected Impacts on Light-Duty Vehicles from the Advanced Diesel Program, 1998-2020

Projection	1998	2003		2005		2010		2020	
		Reference Case	CCTI Case	Reference Case	CCTI Case	Reference Case	CCTI Case	Reference Case	CCTI Case
Diesel Direct Injection Light Trucks (Thousands)	0.0	0.0	82.6	105.4	130.7	114.9	162.3	147.3	151.6
Total Light-Duty Vehicle Sales (Thousands)	13,991	13,575	13,575	14,197	14,197	14,338	14,338	15,232	15,232
Carbon Emissions (Million Metric Tons)	280.2	310.4	310.2	323.1	322.7	351.8	351.2	395.4	395.6

Source: Energy Information Administration, National Energy Modeling System runs REFCCTI.D031600F and TDI.D032300C.

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 has revised the NO_x and particulate emissions standards via Tier II regulations 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 DaimlerChrysler 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 low volume of sales for direct injection diesel vehicles from Volkswagen and the current low level of sales for diesel light-duty vehicles, which made up 0.04 percent of all light-duty vehicle sales in 1998.

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 1 to 4-year payback period, depending on the technology, 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 2009. 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,[68] 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.

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

- **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. There is a plan to reduce cab drag by replacing the mirrors with video cameras, but 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.

Results

The heavy-duty truck technology characteristics in Tables 33 and 34 are 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.

In Tables 33 and 34, 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.

Table 33. 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)
Advanced Transmission	2001	2,500	40	1
Lightweight Materials	2002	3,000	30	1
Synthetic Gear Lube	2001	60	60	2
Advanced Tires: Low Resistance . . .	2001	900	70	4
Advanced Drag Reduction	2002	1,200	65	7
Electronic Engine Control	2001	1,000	95	4
Advanced Engine	2009	1,000	90	9
Turbocompounding	2001	2,000	90	5

Source: Energy Information Administration, *Assumptions for the Annual Energy Outlook 2000*, www.eia.doe.gov/oiaf/aeo/assumption/index.html.

Table 34. Heavy Truck Diesel Technology Characteristics in the Advanced Diesel Program

Technology	Commercial Availability Date	Capital Costs (1998 Dollars)	Maximum Potential Market Share (Percent)	Fuel Economy Improvement (Percent)
Advanced Transmission	2001	1,500	40	4
Lightweight Materials	2002	2,000	30	2
Synthetic Gear Lube	2001	40	60	3
Advanced Tires: Low Resistance . . .	2001	900	70	6
Advanced Drag Reduction	2002	600	65	10
Electronic Engine Control	2001	800	95	4
Advanced Engine	2009	800	90	10
Turbocompounding	2001	1,700	90	5

Source: Energy Information Administration, *Assumptions for the Annual Energy Outlook 2000*, www.eia.doe.gov/oiaf/aeo/assumption/index.html.

In 2010, the heavy truck diesel stock fuel efficiency improvement in the CCTI case relative to the reference case is approximately 0.18 mpg, which results in a reduction of 120 trillion Btu of heavy truck diesel fuel use and a carbon emissions reduction of 2.6 million metric tons (Table 35). Reductions in fuel use and carbon emissions both 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 the late commercial availability date (Table 34), one of the most promising technologies, advanced engines, is projected to have limited market penetration—1.0 percent—by 2010 (Table 36). 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 6.54 mpg in the CCTI case, compared with 6.02 mpg in the reference case (a 9-percent improvement). The difference has the effect of reducing heavy diesel fuel consumption from 4,125 trillion Btu in the reference case to 3,791 trillion Btu in the CCTI case, for a net fuel savings of 334 trillion Btu and carbon emissions reductions of 7.4 million metric tons, or 1.0 percent of the total for the transportation sector.

Table 35. Projected Impacts on Heavy Trucks from the Advanced Diesel Program, 1998-2020

Projection	1998	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)	5.67	5.76	5.91	6.12	6.71	6.72	7.53
Heavy Truck Diesel Fuel Stock Efficiency (Gasoline Equivalent Miles per Gallon)	5.10	5.39	5.43	5.56	5.74	6.02	6.54
Heavy Truck Diesel Fuel Consumption (Trillion Btu)	3,236	3,794	3,768	3,951	3,831	4,125	3,791
Freight Truck Carbon Emissions (Million Metric Tons)	81.4	91.2	90.6	94.3	91.7	99.0	91.6

Source: Energy Information Administration, National Energy Modeling System runs REFCCTI.D031600F and TDI.D032300C.

Table 36. Projected Penetration of Heavy Truck Technologies in New Trucks from the Advanced Diesel Program, 2005, 2010, and 2020
(Percent)

Technology	2005	2010	2020
Advanced Transmission	1	20	40
Lightweight Materials	0	0	0
Synthetic Gear Lube	24	60	60
Advanced Tires: Low Resistance	21	64	70
Advanced Drag Reduction	3	65	65
Electronic Engine Control	7	71	95
Advanced Engine	0	1	90
Turbocompounding	16	67	90

Source: Energy Information Administration, National Energy Modeling System run TDI.D032300C.

Fuel efficiency in Table 35 refers to both the on-road stock average under real driving conditions and the new fuel efficiency average. In the CCTI analysis case, the fuel efficiency of new heavy trucks is projected to be 5.91 mpg in 2005 and 6.71 mpg in 2010. With the exception of lightweight materials, all heavy truck technologies are expected to reach their maximum potential by 2020. Partly due to new emissions standards, electronic engine controls are projected to achieve a penetration of 71 percent by 2010.[69] The advanced engine is a low-emission, high-efficiency, heavy-duty diesel engine, with technical targets developed by DOE with industry input. Since the initial introduction date is expected to be 2009,

[69]Browning, "Technologies and Costs for On-Road Heavy-Duty Engines Meeting 2004 Emissions Standards," Society of Automotive Engineers technical paper no. 973256 (Society of Automotive Engineers: Warrendale, PA, 1997).

this engine will not have a significant penetration and impact on fuel economy until later in the forecast.[70]

Table 37 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 37. Projected Impacts on Light and Heavy Trucks from the Advanced Diesel Program, 2005, 2010, and 2020

Projection	2005	2010	2020
Fuel Savings (Quadrillion Btu)	0.05	0.17	0.38
Carbon Emissions Reduction (Million Metric Tons)	0.9	3.3	7.3

Source: Energy Information Administration, National Energy Modeling System runs REFCCTI.D031600F and TDI.D032300C.

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.[71] 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 1998, 58,000 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.[72]

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

[70]U.S. Department of Energy, Office of Transportation Technologies, *OHVT Technology Roadmap*, DOE/OSTI-11690 (Washington, DC, October 1997).

[71]Ethanol blended into gasoline in 1998 represented 0.9 percent of net petroleum imports and 1.1 percent of motor gasoline product supplied.

[72]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.

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 January 2000, for example, the subsidy lowered the price of ethanol by almost half, from $1.22 per gallon to 68 cents per gallon, compared to the methyl tertiary butyl ether (MTBE) spot price of 90 cents per gallon.[73] 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. Because the ethanol tax exemption has been extended several times since its introduction in 1979, most recently to 2007, extensions of the tax exemption through 2020 are assumed in the reference case for this analysis.[74] Without the subsidy, ethanol's share of the market would likely be much smaller.[75]

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 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 (USDA), 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.

Several projects are currently being developed in partnership with DOE. BC International is building a facility in Louisiana that is designed to convert sugarcane residue to ethanol. BC International is also involved in two projects in California. One is slated to use wood waste as feedstock while the other will use rice straw. Arkenol is also working to establish a commercial facility in Sacramento, California, to convert rice straw to ethanol. Masada Resource group is planning a municipal solid waste-to-ethanol plant in New York. Sealaska Corporation, with support from both DOE and the State of Alaska, is exploring the possibility of using low-value wood resources to produce ethanol in Southeast Alaska. In addition, DOE is working with the traditional corn-based ethanol industry to define the technical and economic issues involved in using corn stover as a primary feedstock along with corn starch in ethanol production.

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[73] *Oxy-Fuel News Monthly Market Update* (February 21, 2000).

[74] See also Energy Information Administration, *Outlook for Biomass Ethanol Production and Demand*, www.eia.doe.gov/oiaf/analysis.html (Washington, DC, forthcoming).

[75] California has enacted legislation to restrict the use of MTBE and other States are considering similar legislation. If the use of MTBE were restricted and oxygen content requirements for gasoline remained in place, the use of ethanol would likely increase considerably.

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. Some additional funding for the ethanol program is expected, which will contribute to the development of advanced technologies for more cost-effective biomass production and harvesting and improved pretreatment and enzymes for hydrolyzing biomass to various sugars that can be converted to ethanol fuel. 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 38 percent from current levels by 2020.[76]

Ethanol production from corn is projected to increase slowly in the early years of the reference case projections, then level off at 127,000 barrels per day after 2010. Cellulose ethanol, on the other hand, rises steadily through the forecast, reaching 17,000 barrels per day by 2010 and 54,000 barrels per day by 2020 (Table 38). 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 5 percent per year from 2001 to 2005, 10 percent per year from 2006 to 2010, and 15 percent per year after 2010.[77]

Table 38. Projected Ethanol Consumption and Resulting Carbon Emissions Reductions in the Reference Case, 1998, 2005, 2010, and 2020

Projection	1998	2005	2010	2020
Ethanol Consumption (Thousand Barrels per Day)				
Corn-Based Ethanol	90	117	125	127
Cellulose Ethanol	0	9	17	54
Total	**90**	**126**	**142**	**180**
Carbon Emissions Reductions from Displacement of Gasoline by Cellulose Ethanol (Million Metric Tons)	0.0	0.2	0.4	1.2

Sources: 1998: Energy Information Administration (EIA), *Petroleum Supply Annual 1998*, DOE/EIA-0340(98/1) (Washington, DC, June 1999). Projections: EIA, AEO2000 National Energy Modeling System run AEO2K.D100199A.

Carbon emissions reductions resulting from the displacement of gasoline by cellulose ethanol are projected at 0.2 million metric tons in 2005 (0.04 percent of transportation petroleum carbon emissions), 0.4 million metric tons in 2010 (0.07 percent of transportation petroleum carbon emissions), and 1.2 million metric tons in 2020 (0.2 percent of transportation petroleum carbon emissions).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.

[76]This is based on the 1999 study *Bioethanol Multi-Year Technical Plan* by the National Renewable Energy Laboratory. An earlier study by the National Biomass Ethanol Program estimated a 50-percent cost reduction by 2020.

[77]The cellulose ethanol production capacity growth estimates are lower in *AEO2000* than in the *Annual Energy Outlook 1999*. The capacity expansion rates in *AEO2000* are based on an algorithm derived from the Mansfield and Blackman statistical models of new technology market penetration as described in Energy Information Administration, *Outlook for Biomass Ethanol Production and Demand*, www.eia.doe.gov/oiaf/analysis.html (Washington, DC, forthcoming).

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 rises slowly to 107,000 barrels per day in 2010, increasing to 131,000 barrels per day by 2020 (Table 39). Ethanol for E85 also increases throughout the forecast, rising to 35,000 barrels per day in 2010 and 49,000 barrels per day in 2020.[78]

Table 39. Projected Uses of Ethanol in the Reference Case, 1998, 2005, 2010, and 2020
(Thousand Barrels per Day)

Ethanol Use	1998	2005	2010	2020
Direct Blending	90	106	107	131
E85	0	20	35	49
Total	**90**	**126**	**142**	**180**

Sources: 1998: Energy Information Administration (EIA), *Petroleum Supply Annual 1998*, DOE/EIA-0340(98/1) (Washington, DC, June 1999). Projections: EIA, AEO2000 National Energy Modeling System run AEO2K.D100199A.

In an analysis of cellulose ethanol, a high technology case was developed in which the conversion cost of cellulose ethanol was assumed to decline 66 percent based on the successful development of an advanced conversion process.[79] It was also assumed that market penetration would occur at a more rapid pace than in the reference case. With these assumptions, cellulose ethanol consumption is projected to increase to 22,000 barrels per day in 2010 and 185,000 barrels per day in 2020. In contrast to the reference case, however, cellulose ethanol takes market share from corn ethanol in this case. Corn ethanol consumption declines over the last ten years of the forecast period, falling to 89,000 barrels per day in 2020. In the high technology case, carbon emission reductions resulting from the displacement of gasoline by cellulose ethanol amount to 0.5 million metric tons in 2010 (0.08 percent of transportation petroleum carbon emissions) and 4.1 million metric tons in 2020 (0.6 percent of transportation petroleum carbon emissions).

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

[78]In the *Annual Energy Outlook 1999*, ethanol was also used to produce ETBE, primarily in Petroleum Administration for Defense District V (California). In *AEO2000*, however, a ban on MTBE use in California was assumed to discourage the use of ETBE as well, therefore, this blending component was not produced.

[79]Energy Information Administration, *Outlook for Biomass Ethanol Production and Demand*, www.eia.doe.gov/oiaf/analysis.html (Washington, DC, forthcoming).

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 *AEO2000* 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 fossil generating technologies would stay at 1999 levels, projected fossil fuel use in the electricity sector was 1 percent higher in 2010 and 2 percent higher in 2020 than in the reference case. Similarly, electricity sector carbon emissions were 2 million metric tons higher in 2010 and 12 million metric tons 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) requested $38 million in 2000 and $56 million for 2001 for climate change funding (Table 40). Significant increases are requested for research on efficient generating technologies—including coal integrated combined-cycle, coal pressurized fluidized bed, fuel cells, gas turbines, and Vision 21 power facilities—and carbon control and sequestration technologies.

Efficient Electricity Generating Technologies

Background

The proposed 2001 CCTI budget requests for research on more efficient coal-fired generating technologies is very similar to the 2000 budget. However, the proposed budget for coal technology research and development is slightly less than the 2000 budget. In the 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.

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)."

Table 40. Office of Fossil Energy CCTI Funding, 1999, 2000, and 2001
(Thousand Dollars)

Research Area	Fiscal Year 1999 Enacted	Fiscal Year 2000 Enacted	Fiscal Year 2001 Request
Coal			
Advanced Clean/Efficient Power Systems			
Indirect Fired Cycle	$1,000	$1,000	$2,000
High-Efficiency Integrated Gasification Combined-Cycle	$14,000	$12,806	$12,410
High-Efficiency Pressurized Fluidized Bed			
Pressurized Fluidized Bed Combustion	0	$1,600	$200
Advanced Research and Environmental Technology			
CO_2 Control/Sequestration	$5,825	$9,217	$19,500
Advanced Research and Technology Development			
Coal Utilization Science	$2,000	$2,000	$2,000
Material & Components	$1,000	$1,000	$1,000
Innovations for Existing Plants	0	0	$990
Gas			
Natural Gas Research			
Turbines			
Vision 21	0	$800	$3,000
Fuel Cells	0	$10,015	$15,000
Total	**$23,825**	**$38,438**	**$56,100**

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

For gas-fired generating technologies, the proposed 2001 CCTI budget includes $15 million for research on fuel cells and $3 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 *AEO2000* 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 natural gas prices widens.[80]

[80]Energy Information Administration, *Annual Energy Outlook 2000*, DOE/EIA-0383(2000) (Washington, DC, December 1999) 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. This fact is recognized in the 2001 CCTI request which more than doubles the budget for carbon sequestration research. 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 41). 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. The efficiency goals for the DOE Vision 21 program are 60 percent for new coal plants and 75 percent for new natural gas plants by 2015. Carbon emissions from these advanced technologies would be 323 pounds per megawatthour for coal and 145 pounds per megawatthour for natural gas. However, there would be no significant penetration of these advanced plants by 2020, the time frame of this analysis.

Table 41. Carbon Emissions for Fossil Generating Technologies

Technology	Carbon Emissions		Efficiency (Percent) (Illustrative)
	Pounds per Million Btu Consumed	Pounds per Megawatthour Generated	
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.[81] 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-fired 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

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

strategy to reduce global carbon emissions. In addition, in the longer run, if domestic natural 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 natural gas-fired technologies, EIA expects new power plant additions to be dominated by relatively efficient natural gas plants. In *AEO2000*, new advanced natural gas-fired generating plants are expected to reach efficiencies of nearly 54 percent. As with the new generation of coal plants, Vision 21 natural gas plants are not expected to play much of a role 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 produced by U.S. power plants (mostly as CO_2).

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 2001 DOE coal technology research and development budget request calls for spending approximately $19.5 million on carbon sequestration research and development. In addition, the DOE basic science program, EPA, and USDA have requested funding increases for CO_2 removal and sequestration programs.

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 finding 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 1998 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 8 cents per kilowatthour through 2020, while the costs for more traditional electricity supplies from natural gas-fired power plants remain close to 3.5 cents per kilowatthour or less.

Consumer costs for electricity from small-scale photovoltaic modules, especially if they are installed 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 less expensive and 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, DOE plans to increase the efficiency of thin-film modules in multi-megawatt production from 7 percent to 12 percent and to reduce module manufacturing costs from $2.50 to $1.50 per watt. The DOE goal for 2001 is to have module efficiency reach 14 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. In 1997, DOE estimated 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.[82] 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 long-term goal for dish/Stirling (concentrating) solar thermal energy systems is to achieve commercial maturity by 2010. 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 not commercially viable 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,[83] and possible beginning penetration of U.S. green power markets.

The dish/Stirling technology faces large challenges in contributing to U.S. electricity supply before 2010. The technology remains far from published 2000 goals, 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 essential rural 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 and biobased products and bioenergy by 2010. This would result in 3,000 megawatts of new biomass capacity by 2010. The EIA reference case projections indicate that roughly one-third of the new capacity goal is likely to be achieved.

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

[83]Electric Power Research Institute and U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, *Renewable Energy Technology Characterizations*, EPRI TR-109496 (December 1997), p. 5-57.

The CCTI budget request for fiscal year 2001 includes $48 million for the Biomass Power Systems research, development, and deployment program. 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.[84]

The Salix Consortium project in New York supports commercial development of willows for generating electricity. The fast-growing willows will be co-fired with coal in existing power plants. Led by Niagara Mohawk Power Corporation, the Salix Consortium's objectives are to establish willow as a commercial biomass energy crop in the Northeast and Upper Midwest (the Consortium will attempt to develop a reliable market for willow at a cost of less than $2 per million Btu by 2001) and to demonstrate and quantify the environmental and economic benefits of co-firing willow with coal in existing electric power plants. Test burns of willow have been conducted at New York State Electric and Gas Company's (NYSEG) Greenridge Station, now owned by AES Corporation of Arlington, Virginia. This plant is capable of co-firing up to 5,000 tons of willow per year grown on 400 acres of land near the plant. Co-firing tests at Niagara Mohawk's Dunkirk Station are planned for 2001. Willows will be grown on 400 acres near the 600-megawatt plant. The energy input from biomass is expected to provide about 10 to 20 percent of the total energy requirement for this plant.

DOE is supporting another co-firing project in partnership with Chariton Valley Resource Conservation and Development, Inc. (RC&D) in Centerville, Iowa. This project is aimed at developing switchgrass as an energy crop. The Chariton Valley Project's goal is to develop enough switchgrass to generate 35 megawatts of power by co-firing with coal at the Alliant Power Company's Ottumwa generating station. This represents 5 percent of the total capacity of the power plant, rated at 650 megawatts, and will require 200,000 tons of biomass harvested from 40,000 to 50,000 acres of switchgrass. It is anticipated that eventually as many as 500 local farmers will have the opportunity to raise and sell energy crops for power production. Modifications at the power plant to accommodate co-firing are scheduled for late 1999 through early 2000.

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 *AEO2000*, EIA projects an expansion of biomass systems in the industrial sector, where biomass cogeneration capacity increases from 6.0 gigawatts in 1998 to 8.5 gigawatts in 2020.

In the Vermont project, DOE is developing a demonstration-scale biomass gasifier that will be connected to an existing power station, the McNeil generating station in Burlington, Vermont. The gasifier will consume 200 tons of wood chips per day and will generate a fuel gas which will be combusted in a boiler

[84]U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Web site www.eren.doe.gov/biopower.

at the McNeil station. In the future, a gas turbine will be added to the system. The gasifier start-up and shake-down testing began in 1998 and continued through 1999. To date, the gasifier has supplied fuel for generation of 100,000 kilowatthours of electricity. Design of the gas turbine began in 1999 and installation of the gas turbine is scheduled for 2000. Following installation, long-term trials of the integrated system will begin.

The Minnesota AgriPower project is designed to demonstrate the feasibility of electric power production fueled by alfalfa stems. The Minnesota Valley Alfalfa Producers (MnVAP) is a farmers cooperative that manages this project and plans to enlist as many as 2,000 farmers to grow 680,000 tons of alfalfa annually on 180,000 acres of farmland. MnVAP will collect alfalfa grown by member farmers and separate the alfalfa leaves from the stems. The leaves will be used as a high-quality animal feed product that will be marketed by MnVAP. The stems will be utilized as a fuel for a biomass gasifier and combined-cycle gas turbine facility. The integrated gasifier and gas turbine process will be capable of generating 75 megawatts of electricity. A power purchase agreement between MnVAP and Northern States Power Company of Minneapolis, Minnesota, has been signed guaranteeing the long-term sale of electricity starting December 31, 2001. The City of Granite Falls, Minnesota, has donated 100 acres of land for the power facility. The State of Minnesota has allocated $200,000 to support alfalfa production and processing facilities. The State has also approved regulatory changes and tax exemptions worth more than $3 million per year to support the alfalfa producers role in this project. Ground was broken in 1999 and power plant construction has begun.

The EIA analysis described in Chapter 2 characterizes the biomass gasification technology incorporated in *AEO2000*. For this analysis, EIA accelerated 90 megawatts of mandated new biomass-fired capacity that would have entered service after 2005 to begin service earlier in order to obtain the proposed production tax credit in the CCTI. In addition, biomass generating capacity growth from 2002 through 2005 already includes 144 megawatts of new construction.

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.

The feedstock development program overlaps with other Biomass Power Systems programs in that feedstocks are an important part of the economics of biomass utilization. NEMS 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.

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 and providing 5 percent of the Nation's electricity needs by 2020.[85] 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.[86] 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 1999, 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 2000.

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.[87] Cost estimates assuming investor financing raise levelized costs to as much as 3.2 cents per kilowatthour.

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

[86] Electric Power Research Institute and U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, *Renewable Energy Technology Characterizations*, EPRI TR-109496 (December 1997), pp. 7-3.

[87] Based on discussions with Department of Energy, Office of Energy Efficiency and Renewable Energy.

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 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 with a levelized cost less than 3.5 cents per kilowatthour in good steam resources. A new initiative, GeoPowering the West, seeks to focus national, regional, State, and local efforts to supply at least 10 percent of electricity needs of the West with 20,000 megawatts of geothermal power installed by 2020. 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.

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 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 energy conversion program has two principal elements. The first would initiate a cost-shared project to construct and test a Kalina-cycle 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.

Opportunities for U.S. geothermal development are limited to the Western states, where current capacity totals less than 3,000 megawatts. The *AEO2000* reference case projects 3,750 megawatts by 2020 and notes that in some instances geothermal power may be competitive by 2020 with costs at or below the 3.5-cent goal anticipated by the proposal. However, because there are few very low-cost sites available, it is unlikely that geothermal could provide a very large fraction of the proposed amount below the 3.5-cent goal by 2020. Even in the *AEO2000* high renewables case, in which capital costs for geothermal are 33 percent below the reference case costs in 2020, resource constraints limit total geothermal capacity to less than 6 gigawatts in 2020.[88]

Hydropower

DOE is supporting the development of a new generation of hydropower turbines that would reduce dangers to fish and would also maintain higher levels of dissolved oxygen in the water to keep river ecosystems healthier. 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, there are real prospects for stalled or even declining U.S. hydroelectric output. Almost no new generating capacity is projected through 2020, and restrictions are reducing output from existing hydroelectric facilities.

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 2001 on its Nuclear Energy Plant Optimization (NEPO) program. The goal of the NEPO program is to ensure that current nuclear plants can continue to deliver adequate and affordable energy supplies up to and beyond their initial 40-year license period by resolving open issues related to plant aging and by applying new technologies to improve plant economics, reliability, and productivity. Overall, NEPO aims to achieve and sustain an increase of average plant capacity factor from an average of 71 percent in 1997 to 85 percent in 2010. EIA has incorporated similar capacity factor assumptions in recent analyses. In fact, in the *AEO2000* reference case, the capacity factor for nuclear plants is assumed to be slightly higher than 85 percent in 2010.

Without license renewal a large number of existing nuclear plants will reach the end of their current operating licenses by 2020. In *AEO2000*, about 13 percent of the existing U.S. nuclear capacity is

[88]Energy Information Administration, *Annual Energy Outlook 2000*, DOE/EIA-0383(2000)(Washington, DC, December 1999), p. 217.

projected to be retired by 2010 and about 41 percent by 2020. Some 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. In general, the plants that were recently retired had specific reasons for being decommissioned, and all preceded the recent deregulation trends that are currently resulting in increased consolidation of the industry through the buying and selling of plants. The impact of these retirements has been counterbalanced by the improving performance of the remaining nuclear plants. In fact, nuclear generation had a record year in 1999, exceeding 700 billion kilowatthours for the first time. In the future, it is impossible to predict when or if other plants might face the need for expensive maintenance or upgrades. However, in *AEO2000*, about 40 gigawatts of nuclear capacity are expected to retire by 2020, with thirteen plants retiring before their licenses would have expired and twelve units continuing to operate beyond their original licenses.

AEO2000 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 5 million metric tons lower in 2010 and 14 million metric tons lower in 2020 than projected in the reference case.

In total, all existing nuclear plants operating today are displacing between 113 and 165 million metric tons of carbon. The range depends on whether the plants are assumed to displace the average carbon emissions for all generation or the average for fossil generation. In evaluating the future impact on carbon emissions, the replacement fuel for retiring nuclear plants is of key importance. Given the technology costs and fuel prices expected over the next 20 years, they would most likely be replaced by natural gas-fired, combined-cycle plants that have relatively low carbon emissions. If all current nuclear plants were replaced by new natural gas-fired, combined-cycle plants, annual carbon emissions would be about 62 million metric tons higher.

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 the National Renewable Energy Laboratory, "Unfortunately, the widespread use of hydrogen energy is not currently feasible because of economic and technological barriers."[89] 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 just over $2.00 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.

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.

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

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°F, whereas in recent years materials with superconductive properties at temperatures near -200°F have been developed. Although temperatures of -300 to -200°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."[90] 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."[91] 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.

Summary

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 programs, partnerships, and similar initiatives to encourage the penetration and adoption of improved technologies, some of which appear to have

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

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

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 performance, costs, 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 1.9 and 5.7 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, 0.8 and 0.9 million metric tons in 2010 and 2020, respectively.

In the transportation sector, EIA 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 0.5 percent of total transportation energy in 2010 and 1.0 percent in 2020, reducing transportation carbon emissions by 3.3 million metric tons (0.5

percent) in 2010 and 7.3 million metric tons (1.0 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 with current funding levels, 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 6.7 to 7.5 miles per gallon in 2020, raising the average stock efficiency from 6.0 to 6.5 miles per gallon, but that would still be short of the stated efficiency goal of 10 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 42 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 42. 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		

Source: Energy Information Administration, *Annual Energy Outlook 2000*, DOE/EIA-0383(2000) (Washington, DC, December 1999).

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 2000* (*AEO2000*) projects a 31-percent decline in electricity use for refrigerators in 2020 from the 1997 level, despite a projected 23-percent increase in the stock of refrigerators. Table 43 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 43. 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.[92] 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 Climate Change Technology Initiative (CCTI), a portion of the $275 million included in the proposed initiative for buildings technology would be used to accelerate the lighting and energy efficiency standards program.[93] 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, *AEO2000* included scenarios that assumed additional appliance standards for various products. Given the uncertainty surrounding the effective dates of appliance efficiency standards, the reference case forecasts include only the standards that have been officially promulgated by DOE. In the accelerated standards case presented here, it is assumed that standards are revised every 8 years and the efficiency levels increased by 10 percent when technologically feasible. In general, both the schedule and level of the assumed efficiency improvements are aggressive when compared to the history of standards enactment. Because of the timing of these assumed standards, some technologies may have two cycles of

[92]The time line discussed here is the one given for central air conditioners by U.S. Department of Energy, Office of Codes and Standards.
[93]"President Clinton's FY 2001 Climate Change Budget," p. 6, and "Report to Congress on Federal Climate Change Expenditures," p. 11.

improvement in the forecast horizon. 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 44 shows the assumed efficiency levels and effective dates of the accelerated standards for each appliance in the CCTI analysis case.

Table 44. 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
Electric Clothes Dryers	3.01 EF	3.21 EF	2009
Natural Gas Clothes Dryers	2.67 EF	2.84 EF	2009
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	2009
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	2009
Dishwasher	0.48 EF	0.62 EF	2009
Natural Gas Ranges and Ovens	—	No Pilot	2009
Commercial Packaged Air Conditioner[b]	8.9 EER	10.3 EER	2008
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.

[b]Effective date changed from that given in source reference. Timetable adjusted from 2001 to 2008 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: Energy Information Administration, *Annual Energy Outlook 2000,* DOE/EIA-0383(2000) (Washington, DC, December 1999).

Analysis and Results

Table 45 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 44.

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 about 195 trillion British thermal units (Btu), or 0.9 percent, of delivered energy in the buildings sector could be saved by 2010, reducing buildings sector carbon emissions by 7.1 million metric tons (1.1 percent) in 2010.

Table 45. Projected Buildings Sector Energy Consumption and Carbon Emissions for the Accelerated Standards Case, 1998, 2005, 2010, and 2020

Projection	1998	2005		2010		2020	
		Reference Case	Accelerated Case	Reference Case	Accelerated Case	Reference Case	Accelerated Case
Delivered Energy Use (Trillion Btu)	17,692	19,684	19,642	20,648	20,453	22,029	21,436
Carbon Emissions (Million Metric Tons)	521.0	602.7	601.0	632.5	625.4	685.1	664.8
Energy Bill (Million 1998 Dollars)	227,922	243,918	243,292	255,187	252,151	271,479	263,394

Source: Energy Information Administration, National Energy Modeling System runs BASE.D022800A and STNDS.D022800B.

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 delivered energy use in the buildings sector in the accelerated standards case is 593 trillion Btu (2.7 percent) lower, and carbon emissions are 20.3 million metric tons (3.0 percent) lower, than in the reference case. The projected annual savings in energy expenditures for residential and commercial consumers exceed $8 billion in 2020.

Appendix A

Letter from the Committee on Government Reform, Subcommittee on National Economic Growth, Natural Resources, and Regulatory Affairs

ONE HUNDRED SIXTH CONGRESS

Congress of the United States

House of Representatives

COMMITTEE ON GOVERNMENT REFORM

2157 RAYBURN HOUSE OFFICE BUILDING

WASHINGTON, DC 20515–6143

[illegible]

March 21, 2000

BY FACSIMILE

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

Dear Mr. Hakes:

I am writing to request that the Energy Information Administration (EIA) update its April 14, 1999 report entitled "Analysis of the Climate Change Technology Initiative," to take into account any proposed changes in the President's Fiscal Year (FY) 2001 Budget to the tax credit component of the Climate Change Technology Initiative (CCTI).

The President's FY 2001 Budget requests a five-year $4.0 billion package of tax incentives to help reduce greenhouse gas emissions, a significant increase over the Clinton-Gore Administration's $3.6 billion request in FY 2000. I am concerned that the Administration has learned nothing from EIA's analysis of the FY 2000 CCTI tax credits, commissioned by House Science Committee Chairman James Sensenbrenner and former Ranking Minority Member George Brown on March 2, 1999, nor from EIA's September 1, 1999 elaboration of certain aspects of that analysis, requested by me on June 8th.

I am particularly interested in EIA's analysis of the cost, feasibility, and equity of the CCTI tax credit proposals. Pursuant to the Constitution and Rules X and XI of the United States House of Representatives, I request that EIA address the following questions in the updated report:

- For each of the proposed CCTI tax credits, what is the average cost (revenue loss) per ton of carbon reduced or avoided?
- Which, if any, of the CCTI tax credits costs less, in lost revenue, than $14 to $23 per ton of carbon reduced or avoided -- the Council of Economic Advisors' estimate of the per-ton cost of implementing the Kyoto Protocol?

- What percentage of each CCTI tax credit would go to "free riders" people or businesses who would have purchased the energy efficient product or made the energy efficiency investment anyway, without a special tax preference or inducement?

- Compared to EIA's Annual Energy Outlook 2000 (AEO2000) baseline, what are the likely impacts of the CCTI tax credit proposals on energy efficiency and carbon emission trends?

Finally, although the CCTI nuclear energy program is a spending program rather than a tax credit, please assess the Administration's claim that the proposed $5 million nuclear energy expenditure will "help offset carbon emissions of more than 150 million metric tons of carbon equivalent per year by helping to ensure the continued safe operation of nuclear power plants." As you may recall, last year, using EIA and Nuclear Regulatory Commission data, I challenged that 150 million metric ton figure as a huge overestimate in two letters to the Department of Energy (August 18th and December 14th). Since the nuclear program is the only element of the CCTI that appears to deliver substantial bang for the buck, EIA's updated analysis should include an assessment of that particular proposal.

Please complete EIA's updated analysis of the CCTI tax credit proposals by April 10, 2000. The updated analysis should be delivered to the majority and minority staffs of the House Government Reform Subcommittee on National Economic Growth, Natural Resources, and Regulatory Affairs in Rayburn House Office Building, rooms B-377 and B-350A, respectively. Please also deliver copies to the House Science Committee majority staff in Rayburn House Office Building, room 2320, and minority staff, in HI-822. If you have any questions about this request, please call Subcommittee Staff Director Marlo Lewis at 225-1962.

Sincerely,

David McIntosh

David M. McIntosh
Chairman
Subcommittee on National Economic Growth,
Natural Resources, and Regulatory Affairs

cc: The Honorable Dan Burton
The Honorable Dennis Kucinich
The Honorable Don Nickles
The Honorable F. James Sensenbrenner, Jr.
The Honorable Ralph Hall
The Honorable Larry Craig