# **Assessing Tax Incentives for Clean Energy Technologies:**

- A Survey of Experts Approach -

J. Andrew Hoerner and Avery P. Gilbert

**CENTER FOR A SUSTAINABLE ECONOMY** 

Washington, DC November 12, 1999 Revised: April, 2000



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## 1. Abstract

Some analysts regard tax incentives for environmentally beneficial technologies as necessary to jumpstart new clean technologies; others see them as wasteful subsidies to the benefited industries. The magnitude of public benefits from a particular tax incentive provision depends on the nature of the market, the impact of the provision on the process of technological change, and the value of the environmental harm averted. Whether public benefits are greater or less than the revenue cost of a given tax subsidy is an empirical question that must be decided on a case-by-case basis.

This paper uses a survey-of-experts (single-round Delphi Analysis) approach to estimating the impact of the tax incentive portion of the Climate Change Technology Initiative (CCTI) proposed by the Administration as part of the fiscal 2000 budget. Based on the responses of a panel of 81 experts (at least ten per technology) drawn roughly equally from industry, government, academia and the non-governmental organization (NGO) community, we provide mean forecasts for quantity and price of each of the technologies covered by the CCTI tax incentives with and without the tax package. These price and quantity estimates are then used to calculate the increase in consumer surplus in the market for that technology. We also asked the panel to estimate any spillover benefits from credit-induced technological progress on the efficiency of products not receiving the credit.

To be effective the tax credits cannot be enacted alone. Instead they must be part of a larger policy effort to stimulate the targeted technologies. Because this is true we did not attempt to estimate the impact of the credit absent additional policies that help counter other types of barriers to the penetration of the technologies. Instead, we assumed that a host of measures and policies to facilitate the market penetration of the technologies would be introduced and then asked our panel of experts what the additional penetration might be with a tax credit.

We conclude first that the credits are likely to have a revenue cost about 13 percent less than estimated by the U.S. Congress's Joint Committee on Taxation (JCT). This modest change disguises much greater disagreement on a provision-by-provision basis, with our estimates of the cost of the solar and the wind and biomass credits being more than double JCT's estimates and all other provisions costing significantly less. Four of the six proposed credits would provide *non-environmental* economic benefits to the public more than sufficient to offset the cost of the credits: the credits for fuel-efficient vehicles, energy-efficient homes, energy-efficient building equipment, and combined heat and power systems. The credits for wind and biomass power and for rooftop solar systems have estimated non-environmental economic benefits to consumers comparable to their revenue cost.

Based on the expert forecasts of the quantity of each technology adopted we then estimated the energy savings attributable to each credit for each fuel type. The environmental value of these fuel savings was then monetized based on the high, medium and low estimates from a literature search and assessment by Viscusi, et al. (1994). These are local U.S. environmental benefits and do not include any benefit from reductions in impacts on the global climate. We conclude that, based on non-environmental benefits and local environmental benefits alone, the benefit/cost ratio is greater than one for all six credits, ranging from 1.5 to 1 (solar) to 75 to 1 (vehicles). These estimates use market-rate discounting. If lower social discount rates are used, the benefit is even higher.

However, it should be observed that in every case the precise level of public benefit is highly uncertain. Moreover, most of the benefits from accelerated technology development accrue from the continued use of that technology after the credits expire. In some cases, especially the vehicles credit, other energy policies need to be adjusted to prevent the benefits of the credit from being undermined. Finally, the value of the local environmental benefit from the electricity-oriented technologies (CHP, wind and biomass, PV's, and some heating and cooling equipment) is greatly reduced if the

technologies are presumed to displace new natural gas fired generating plants rather than the average fuel mix.

We estimate the CCTI tax incentive package would reduce carbon emissions by 116 million metric tons over the forecast period 2000-2018. Estimates of the value of this reduction are provided on a credit-by-credit basis for a range of alternative carbon emission damage values. The cost of credit-induced carbon savings averages eleven dollars per ton of carbon saved over the lifetime of the equipment, a value that compares favorably with the cost of abatement through international trading as estimated by the President's Council of Economic Advisors.

The following table summarizes the present value of the costs and benefits of the CCTI tax incentives. It assumes that a package of low-cost technology promotion measures is enacted along with the CCTI incentives.

	Value of Non-Environmental and Environmental Benefits from the Tax Credits, 2000-2018 (1999 dollars in millions)										
		Environ s and B		Environmental Benefits*							
		S	*	Local Envi				Climate R	elated Ben	efits	
	Expenditure	Consumer Surplus	Spillover Benefits**	Local Environmental Benefit	Local Environmental Benefits (Spillover)	\$5/ton Direct Carbon Benefit	\$5/ton spillover Carbon Benefit	\$20/ton Direct Carbon Benefit	\$20/ton Spillover Carbon Benefit	\$100ton Direct Carbon Benefit	\$100ton Spillover Carbon Benefit
Vehicles	1,181	20,197	67,232	550	517	43	40	172	161	859	807
Homes	35	115	728	33/7	0.05/0	0.8/.6	0.0/0.0	3/2	0.02/0.01	17/14	0.1/0.0
Building Equipment	108	146	N/A	190/18	N/A	6/5	N/A	24/19	N/A	120/96	N/A
CHP	208	4,674	N/A	5,016/46	N/A	92/58	N/A	366/229	N/A	1831/1144	N/A
Solar	358	406	N/A	132/8	N/A	9/7	N/A	38/30	N/A	189/151	N/A
Wind & Biomass	3,718	2,014	5,962	5,800/53	N/A	106/66	N/A	422/264	N/A	2112/1320	N/A
Total	5,608	27,552	73,921	11,721/682	517	256/180	40	1,025/716	161	5,127/3,584	807

<sup>\*</sup>The second figure in each cell is the value of the benefit when we assume that electricity savings displace emissions only from natural gas combustion rather than the forecast average fuel mix.

<sup>\*\*</sup> Only the economic value of the spillover benefits from hybrid vehicles, energy efficient homes, and biomass are included in this table Spillovers from wind and solar technologies are not included because of the difficulty of distinguishing social benefits from mere redistribution of income.

# 2. Overview of Methods and Findings

#### 2.1 Introduction

The Administration's fiscal year 2000 budget request contains a series of tax incentives aimed at improving the efficiency of our nation's vehicles, homes, and building equipment, as well as encouraging electricity generation from renewable energy sources. Also contained in the budget are a number of research and development spending proposals and related programs such as Million Solar Roofs, Energy Star Homes and the Partnership for a New Generation of Vehicles. These research and development provisions are intended to provide a stock of new or improved technologies from which the private sector can draw, while the tax incentives are intended to foster more rapid commercial development and market penetration for those technologies.

Expenditures on poorly constructed or ineffective tax incentives can waste our tax dollars while heightening the complexity of the tax code. On the other hand, a well-designed tax incentive may be an effective market-based approach to encouraging the private sector to provide a public or quasipublic benefit. Whether the benefit to the public from those incentives justifies the cost of providing them is a matter for empirical investigation.

It can be argued that tax incentives for environmental technology offer two public benefits that justify the public expenditure required to support them. First, they can accelerate the introduction of new technologies, thereby driving down the cost of providing essential services (such as lighting, space heat, transportation, and electric power) to the public. For this benefit to justify a public expenditure, it is not enough that the cost be lowered by the amount of the incentive payment. The incentive must also stimulate a productivity improvement that would not have otherwise occurred. This is unlikely unless the technology in question is either relatively new or currently in low production volume. In a mature industry, little productivity improvement from a production or investment incentive can be expected. In addition, only a portion of the value of the incentive will be passed on to the consumer, with the remainder constituting a subsidy to the producer.

Second, the incentive can cause the reduction of pollution emissions by stimulating lower-emissions alternatives to conventional technologies. Where pollution emissions lead to significant economic costs, the avoided cost from the avoided emissions is a public benefit from the enactment of the incentive. However, the benefit of the incentive derives entirely from the increase in the use of the low-emission technology stimulated by the incentive. To the extent that the incentive merely subsidizes pollution-reduction activities that would otherwise have occurred, it is merely a transfer payment. To justify an environmental technology tax incentive, the sum of the value of the induced productivity improvement (if any) and the value of the reduced pollution emissions (if any) must exceed the social cost of the incentive, as measured by the social cost of raising the foregone revenue from other taxpayers.

This report provides a case study of the use of an approach to estimating the benefit/cost ratio for environmental technology incentives based on a survey of experts. It is well-known that consensus

forecasts typically outperform the overwhelming majority of individual forecasters<sup>1</sup>. These consensus form forecasts the basis for important indicators, such as the Blue Chip Consensus Forecast of Economic Indicators widely used by the Federal Reserve and others as a basis for economic projections used to make major public policy decisions.

This study relied on responses to questionnaires from experts in each of the technology areas. One hundred and eighty questionnaires were distributed among a pool of experts evenly divided among industry experts, relevant non-governmental agencies, government officials, and academics (30 questionnaires per technology). We received 81 usable responses (at least 10 per technology). Respondents were offered the choice of anonymity; most who preferred anonymity were from the private sector. Those who did not request anonymity are listed in Appendix A.

Respondents were asked to indicate the effect of three different policy scenarios: 1) business-as-usual, under current climate and energy policy; 2) when a package of policies is enacted to encourage the technology; and 3) when the package of policies and the tax credits are both in place. In each scenario they were asked to forecast the price of each technology and the quantity produced over the 2000-2018 forecast period. For some technologies they were also asked to project the impact of the credit on closely related products not receiving the credit, such as the impact of the energy-efficient homes credit on the efficiency of non-eligible homes. The questionnaire provided a business-as-usual projection (drawn from the EIA's Annual Energy Outlook where possible) as a reference point, but experts were asked to provide their own business-as-usual forecasts and nearly all the experts gave baselines that differed from the reference baseline we provided. From the responses to these questionnaires we established a business-as-usual baseline for production of the technology or energy from the renewable energy source, and then calculated the avoided fossil fuel combustion that would be achieved from the increased proliferation of the technologies under each of the other two policy scenarios. These fuel savings in turn were used to estimate the local environmental benefits and carbon emission reductions from the incentives. Our methodology is described in more detail in the next section, with additional details in the sections discussing each specific technology.

For comparison, we analyzed the CCTI package under the assumption that the revenue effects of the tax credits estimated by the Joint Committee on Taxation (JCT) are accurate. We used these projections to estimate the rate of adoption of each technology and the implied fuel savings under the JCT assumptions, and estimated the carbon emissions savings based on those fuel savings estimates. For purposes of this analysis, we assumed that all the purchases of equipment or production of energy induced by the tax credits are reflected by the JCT budgetary projections. The effect of the tax credits on technology purchases after the incentives expire was, therefore, not quantified in the JCT constrained analysis, nor does the JCT-based estimate distinguish between purchases that would have occurred in the absence of the credit and credit-induced purchases. No consumer surplus analysis was possible because the JCT does not publish forecasted market prices for the technologies receiving the credit. The JCT-derived findings were used for comparative purposes only.

<sup>&</sup>lt;sup>1</sup> See, e.g., Ryoto Ono and Dan Wedemeyer, "Assessing the Validity of the Delphi Technique," Futures, v. 26, no. 4, pp. 289-304 (1994); Zarnowitz, Victor and Philip Braun, "Twenty-Two Years of the NBER-ASSA Quarterly Economic Outlook Surveys: Aspects and Comparisons of Forecasting Performance," Business Cycles, Indicators, and Forecasting. James H. and Mark W. Watson, eds. Chicago, IL:University of Chicago Press, 1993; U.S. Department of Energy, "Combined Heat and Power: The Potential to Reduce Emissions of Greenhouse Gases," Unpublished Monograph, Washington DC, U.S. DOE. Office of Energy Efficiency and Renewable Energy, 1997. See also, Neal Elliot and Mark Spur, "Combined Heat and Power: Capturing Wasted Energy, American Council for an Energy Efficient Economy"; Washington DC, May 1999.

# 2.2 Methodology

## 2.2.1 The Problem of Forecasting Technological Progress

The CCTI tax incentives are novel in that their purpose is to promote technological progress in energy efficiency and non-fossil renewable energy sources in order to reduce cost and increase market share of these technologies. Thus it is inappropriate to analyze the credits using approaches that assume that the rate of technological progress is fixed. Economics, engineering and business administration have developed a wide range of approaches to forecasting technological progress, ranging from the experience curves of learning-by-doing models to the "stock of technology" approach of endogenous technology models, to the detailed, technology-specific approach of engineering models, and many others. Technology forecasting is a relatively young discipline, and there is no consensus on what approach is best suited to forecasting energy efficiency and renewable energy. We therefore adopted a survey of experts approach to forecasting.

# 2.2.2 Delphi Analysis

SURVEY METHODOLOGY

The Delphi analysis of the tax credits for renewable energy and energy-efficient technologies began by assembling a list of experts in each relevant field drawn equally from the industry, academic, government, and non-profit sectors. Lists of experts were assembled primarily through literature search, presenters at major conferences, and consultation with industry. Questionnaires were mailed to a list of 180 experts, 30 per technology. Eighty-one usable responses were received, ten to 14 per technology (treating wind and biomass as separate technologies). We had a higher response rate from government and industry sources than from non-governmental organizations and academics. For a breakdown of responses by technology and sector, please see Appendix B.

Separate questionnaires for each technology targeted by the tax credits were devised to elicit from these experts production quantity, price, and spillover benefit projections under three different policy scenarios: business-as-usual; a package of low-cost policies designed to encourage the technology described by the credit; and the same policy package plus the investment or production tax credit. All information was sought for each year from 2000 to 2018.

The questionnaires were pre-tested through review by two to four individuals familiar with the technologies. Most of the questionnaires underwent revision as a result. Reviewers and respondents differed as to whether they preferred to do projections of the quantity of each technology purchased in terms of number of units, market share, or growth rate. Regardless of the form of the question or response, the responses were converted to number of units before further analysis was undertaken.

The experts were each asked to specify the components of a package of low-cost policies to promote each technology. It seemed clear that any tax incentive package would be accompanied by other policies designed to promote renewables and energy efficiency, and that uncertainty about this policy environment is an important part of the uncertainty about the effectiveness of the credits themselves. The components of the policy packages and the benefits of those packages are discussed in the sections of this report addressing each technology. Given the wide diversity of policy packages that resulted, it should be no surprise that the variance in the incremental benefit from the CCTI tax incentives was much smaller than the variance in the benefit from the related policy package. Only this incremental benefit is reported in this summary.

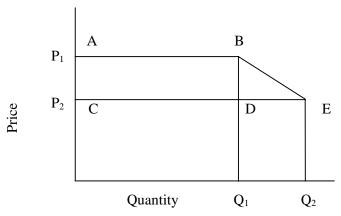
Although we report the average consumer surplus and carbon savings from the policy package in the technology-specific sections, it should be noted that no single policy package exists. Rather, each respondent was asked to assume that the package would consist of the low-cost policy measures s/he recommended.

## **Consumer Surplus**

Projected variation from business-as-usual in the rate of price decline under each policy scenario was used to determine the change in consumer surplus brought about by the policy package. The graph below shows the basic approach. For each year, the business-as-usual forecast provides a price ( $P_1$  in the graph below) and the production volume ( $Q_1$ ) (e.g., number of efficient homes, kWh of electricity, number of installed CHP systems, etc.) in the absence of any new technology promotion policy. This status quo forecast is represented by the point labeled B on the graph. As a result of the package of technology policies, the price falls to  $P_2$  and quantity increases to  $Q_2$ , shifting the economy to the new point E.

The shift from business-as-usual to the policy case (from point B to E) provides two benefits, which can be weighed against the cost of the incentive provision. First, persons who would have purchased the technology under the business-as-usual case benefit from the lower price. This benefit is equal to the product of the business-as-usual quantity and the difference in price, and is represented by the rectangle ABCD in the graph below. The second benefit is the benefit to new purchasers who buy because of the new lower price. The segment BE represents a portion of the demand curve, and the difference between what these

consumers were willing to pay and what they actually pay is the vertical distance between that demand curve (BE) and the price (DE). The benefit to incremental purchasers is represented by the area of the triangle DBE. For each technology, after the change in consumer surplus from the policy package was estimated, the additional increment in consumer surplus from the tax credits was calculated using a precisely identical approach, treating the policy scenario as point B and the



policy-plus-credit scenario as point E. These increments to consumer surplus are reported in the Findings section below.

Note that we estimate only increases in consumer surplus and not increases in producer surplus. As a result, if the value of a credit is retained by producers and not passed through to consumers, it is not covered in our analysis. This understates the benefit of the credits, especially the solar and the wind and biomass credits, which are partially retained by producers according to the price and quantity changes estimated by our panel of respondents. Note also that the consumer surplus estimate includes only benefits from reduced purchase price of the equipment or energy production receiving the credit. Other benefits are estimated separately.

#### **Spillover Benefits**

In addition to consumer surplus from investment in the technologies, our study attempted to identify the benefits that could accrue from credit-induced improvements in the technology used by producers or consumers who do not receive the credit. These benefits result from the "public good" aspect of technology, in which efficiency improvements in one area can spill over to the benefit of other,

closely related areas. For example, if the general improvement of fuel economy technology caused by the credit for super-efficient vehicles results in higher gasoline mileage for vehicles that are not eligible for the credit, this is considered a spillover benefit. These benefits are listed below:

Provision	Spillover Benefit
Hybrid and Electric Vehicles	Improvement in light duty fleet fuel economy for vehicles not receiving the credit
Energy Efficient Building Equipment	Improvement in the efficiency of HVAC equipment not receiving the credit
Energy Efficient Homes	Improvement in national average home energy consumption per square foot for homes not receiving the credit
Rooftop Solar	Increase in revenue from exports*
Combined Heat and Power	None identified
Wind and Biomass	Increase in wind turbine exports;* increase in revenue to forest products industries, saved landfill space, etc.**

<sup>\*</sup>The value of increased exports is reported in the text but not included in the cost-benefit analysis because of difficulties in assessing the dollar value of public benefit per dollar of exports.

Spillover benefits were estimated using the same survey approach used to calculate the direct benefits. Our panel was asked to forecast efficiency improvements in homes, vehicles, etc., under the business-as-usual case and each of our policy scenarios. The spillover benefits from each credit are the incremental improvement between the policy package without the credit and the same package with the credit.

These spillover benefits were calculated in terms of fuel savings in the affected sectors. Fuel savings were then converted into dollar savings using EIA fuel price forecasts. The reductions in fuel use were also used to calculate reductions in local environmental damages and in greenhouse gas emissions, as described below.

#### **Economic Benefits from Reduced Domestic Air Pollution**

The reduction of fossil fuel consumption can produce a number of benefits that flow primarily to society as a whole, rather than to the purchaser of the fuels, electricity, or fuel-saving capacity. These include improved balance of trade, reduced national security risks associated with the need to maintain uninterrupted oil flow, reduced environmental impacts in the U.S. from local air pollution, and reduced risk of climate change from greenhouse gas emissions. For purposes of this analysis we have attempted to measure the value of only two of these: local environmental benefits and the greenhouse gas emission reductions.

A recent and fairly complete survey of the economic value of the health and environmental costs of local air pollution from fossil fuel consumption can be found in Viscusi, et al.<sup>2</sup> A considerably wider array of energy-related social costs were captured by Hall<sup>3</sup>; however, we believe the Viscusi results

<sup>2</sup> Viscusi, Kip., et al., "Environmentally Responsible Energy Pricing," Energy Journal. International Association for Energy Economics. Vol. 15; No2; pg.23 April 1994.

<sup>3</sup> Hall, Darwin C., "Preliminary Estimates of Cumulative Private and External Costs of Energy," Contemporary Policy Issues. Vol VIII, pg. 283. July 1990.

<sup>\*\*</sup>We did not include other possible benefits such as land lease income for farmers because it is too difficult to estimate if such income is an aggregate benefit to the economy or merely a redistribution of capital.

are more reliable because his cost estimates are drawn primarily from EPA regulatory benefit analyses, which must undergo extensive public review. These values are further supported by a November 1999 study completed by the EPA Office of Air and Radiation, *The Benefits and Costs of the Clean Air Act.*<sup>4</sup>

The local benefits from investments in energy efficiency and renewable energy described in this study were drawn primarily from the estimates of the cost of fossil fuel combustion detailed in the Viscusi paper. We therefore did not include environmental costs associated with nuclear or hydroelectric power. The covered costs consist of the economic value of damage to health and property caused by air pollution. The following table details the dollar cost per unit of energy attributed to each pollution category.

Unit Value of Benefits of Emission Reduction (Given Compliance with Federal Standards as of 1994)								
Pollution Category	Gasoline (\$/gallon)	Diesel (\$/gallon)	Aircraft fuel (\$/ gallon)	Heating Oils (\$/gallon)	Natural Gas (\$/1,000 cu. ft.)	Coal (\$/short ton)		
Lead in gasoline	0.0108							
Particulates	0.0831	0.2156	0.0679	0.0432	0.0181	8.4069		
Sulfur Oxides	0.0169	0.1044	0.0091	0.3653	0.0026	154.51		
Ground-level Ozone	0.0214	0.0176	0.0055	0.0021	0.0228	1.0579		
Visibility	8000.0	0.0051	0.0005	0.0178	0.0001	7.54		
Air Toxics	0.0223	0.1281						
Total	0.1553	0.4708	0.083	0.4284	0.0436	171.5148		

Source: Viscusi, et al., 1994, "Environmentally Responsible Energy Pricing," <u>Energy Journal</u>, International Association for Energy Economics, Vol. 15; No2; pg.23 April 1994.

These dollar values reported in the table above are the midpoint of the estimated social cost range. The large amount of uncertainty and the difficulty of measuring social costs demand that the estimates be reported as ranges of value. The tables contained in this report include the benefit from each technology using the low, middle, and high values for the cost of local pollutants from fossil energy sources. For purposes of comparison we converted these costs into like units for each of the energy sources offset by the technologies included in the Climate Change Technology Initiative. The table below shows the high, medium, and low estimate costs estimate for each fuel.

Average Economic Value of Avoided Domestic Health & Environmental Costs (\$ per million Btu)										
	Gasoline Diesel Heating Oils (distillate) Heating Oils (residual) Gas Coal LPG									
High	0.186	0.436	0.126	0.116	0.0039	0.320	0.262			
Medium         1.25         3.49         3.09         2.86         0.042         8.06         2.12							2.12			
Low	<b>Low</b> 2.32 6.54 6.05 5.61 0.081 15.8 3.98									

<sup>&</sup>lt;sup>4</sup> The Benefits and Costs of the Clean Air Act 1990-2010, EPA report to Congress, EPA-410-R-99-001, November 1999.

For electricity savings, including the electricity displaced as a result of the wind and biomass production credits, the per-kWh environmental cost is estimated by applying the fuel-specific costs given above to the national electricity fuel mix in the year in question (as forecast in the Energy Information Administration's *Annual Energy Outlook*) and dividing the total national cost by the forecast number of kWh generated (for the production credits) or delivered (for energy efficiency savings).

The largest social cost for gasoline and diesel comes from health hazards from emitted particulates. Coal has the largest cost per unit of energy owing largely to the combustion-related emission of sulfate particles and sulfur oxide that result in mortality. Natural gas is the cleanest of all conventional energy sources although some social costs accrue from ground level ozone. The air toxics category accounts for the emissions-related cancer cases from motor vehicles. Because most of the technologies targeted by the initiative (other than hybrid vehicles and some building equipment types) offset electricity to a varying extent, the composition of the average electricity fuel mix critically affects the results of our study. Specifically, coal imposes almost three times the social cost of any other energy source, making the percent of coal energy used in the fuel mix each technology is offsetting an important determinant of the social benefit from each technology.

It should be observed that there are several reasons to believe the range of cost estimates used here are conservative, in the sense of being lower than the true costs. First, only the fossil-related environmental costs of electricity are covered by this analysis. Thus, the economic benefit from reduced environmental impacts as a result of decreasing nuclear or hydroelectric generation is not included. These costs may be substantial.5 Second, a recent EPA review of the health impact of particulate emissions suggests that those impacts are substantially higher than formerly believed. This that implies the health-related costs from fuel combustion should be adjusted upward. In addition, the costs shown are the average costs associated with total fossil fuel emissions, i.e., the per-unit savings from complete elimination of the pollutant emissions associated with each fuel. However, most health and environmental costs are non-linear -- they increase with increasing emissions. This implies that the marginal value of emissions reductions is greater than the average value. We used average cost estimates because no good comprehensive marginal cost estimates have yet been done. Since the CCTI would result in only a modest reduction in fuel use over the forecast period, use of marginal rather than average costs is theoretically more appropriate and would result in increasing all three estimates (low, medium, and high). On the other hand, the estimates used here may be too high to the extent that future improvements in emissions control technology unrelated to the CCTI reduce the emissions per unit of fuel consumed. In addition, if it is assumed that the technologies reduced demand for electricity from the marginal generating unit rather than the average generating unit, and, if we assume that this marginal generating unit is natural gas combustion, the local environmental benefit is reduced substantially.

#### Carbon Savings

The carbon savings from the policy package and the incremental increase in carbon savings from the tax credit were determined from the variation in the market penetration of the technologies in each of the policy scenarios. Savings by fuel were converted to carbon savings using appropriate carbon coefficients. In the case of electricity savings, carbon savings under two different assumptions are provided. The first assumes that the electricity saved or displaced is generated using the forecast national average fuel mix. The second assumes that the electricity saved would have been generated from the last unit brought on line, or the marginal generating unit. To estimate the lower bound of the environmental benefit, we treat these marginal units as 100 percent gas turbines. in this case natural

<sup>5</sup> Hall, Darwin C., "Preliminary Estimates of Cumulative Private and External Costs of Energy," Contemporary Policy Issues. Vol VIII, pg. 283. July 1990.

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gas combustion. Carbon emissions savings were monetized using a range of values (low, middle and high; \$5/ton, \$20/ton, and \$100/ton) representative of typical values used in the literature.<sup>6</sup> The metric ton is used as the standard unit for carbon emissions offsets throughout the study. The monetized carbon emissions values would therefore increase to \$5.50/ton, \$22/ton and \$110/ton, respectively, if carbon emissions were calculated as short tons.

#### **Benefit/Cost Analysis**

The benefit/cost ratio is calculated for consumer surplus alone; consumer surplus plus ancillary spillover benefits; and when consumer surplus, spillover benefits, and environmental benefits are summed. For U.S. local environmental benefits, we estimated high, medium and low environmental values based on the range of plausible valuations reported in the literature; the same was done for valuing greenhouse gas reduction benefits.

It should be observed that the cost estimates used in this analysis include only the loss of public revenues. A fuller cost accounting would include the cost, not only of the revenues themselves, but also of the economic distortion caused when those lost revenues are raised from other taxpavers. Estimates of this distortion vary widely for the federal tax system as a whole, but mainly fall in the range of ten cents to a dollar per dollar of revenue raised. Thus it may be appropriate to divide the benefit/cost ratios reported here by 1.1 to 2, where the use of the 1.1 value represents the belief that the federal tax system is mildly distorting and the use of the 2 value represents the conviction that the federal tax system is very strongly distorting.

## 2.2.3 **JCT Constrained Analysis**

For comparison purposes, we derived the carbon savings from each tax incentive consistent with the revenue estimate prepared by the Joint Committee on Taxation.

#### **EXPENDITURES**

Expenditures on the tax credit in the JCT constrained study were taken directly from the Joint Committee on Taxation's Estimated Budgetary Effects of the President's Fiscal Year 2000 Budget.

<sup>&</sup>lt;sup>6</sup> See, e.g., Bruce, James P., Hoesung Lee and Erik F. Haites, (editors), Climate Change 1995: Economic and Social Dimensions of Climate Change. Contribution of Working Group III to the Second Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press (1996); Ayers, R. and J. Walter, "The Greenhouse Effect: Damages, Costs, and Abatement," Environmental Resource Economics, Vol.1 (1991); 237-270; Nordhaus, W.D., Managing the Global Commons: The Economics of Climate Change. MIT Press, Cambridge, MA: 1994; Cline, W.R., "Optimal Carbon Emissions Over Time: Experiments with the Nordhaus DICE Model," Institute for International Economics, Washington, DC: 1992; Cline, W.R., "Modeling Economically Efficient Abatement of Greenhouse Gases," Paper Presented at the United Nations University Conference on Global Environment, Energy and Economic Development. Tokyo (1993); Peck, S.C., and T.J Teisberg, "CETA: A Model for Carbon Emissions Trajectory Assessment," Energy Journal 13 (1) (1992) 55-77; Fankhauser, S., Social Costs of Greenhouse Gas Emissions: An Expected Value Approach," Energy Journal 15 (2), pp. 157-184 (1994); Maddison, D.J., "The Shadow Price of Greenhouse Gases and Aerosols," mimeo, Center for Social and Economic Research on the Global Environment (CSERGE), University College London and University of East Anglia, Norwich (1994). Koomey, Jonathan G., R. Cooper Richey, Skip Laitner, Robert Marketl, and Chris Marnay, *Technology and Greenhouse Gas Emissions:* and Integrated Scenario Analysis Using the LBNL-NEMS Model, EPA 430-R-021, U.S. Environmental Protection Agency, Washington, DC, September 1998. Laitner, Skip. "WYMIMWYG (What You Measure is What You Get): The Benefits of Technology Investment as a Climate Change Policy." A paper given to the 18th Annual North American conference of the USAEE/IAEE, San Francisco, CA. September 7-10.

See, e.g., Ballard, Charles, John Shoven, and John Walley, "General Equilibrium Computations of the Marginal Welfare Cost of Taxes in the United States." American Economic Review 75 No. 1 (March 1985): 128-38; Browning, Edgar, "On the Marginal Welfare Cost of Taxation." American Economic Review 77 No.1 (March 1987):11-23; Harberger, Arnold, "Taxation, Resource Allocation, and Welfare." In The Role of Direct and Indirect Taxes in the Federal Reserve System, edited by John Due, Princeton: Princeton University Press, 1964; Slemrod, Joel and Shlomo Yitzhaki. "The Costs of Taxation and the Marginal Cost of Funds," International Monetary Fund Staff Papers 43 No.1 (March, 1996):172-98; Stuart, Charles, "Welfare Cost per Dollar of Additional Tax Revenue in the United States," American Economic Review 74 No.3 (June 1984): 352-62.

#### FUEL SAVINGS

Fossil fuel savings from the tax incentives were derived in the JCT constrained analysis by dividing the amount spent on the credit in each year by the credit amount available for each purchase of energy-efficient equipment or structures. The number of purchases expected to receive the credit in each year was multiplied by the carbon savings each efficient product would achieve relative to reference case technology efficiency to determine the carbon savings from new purchases in each year of the credit. The carbon savings from investments made during the credit period were assumed to accrue over the lifetime of the equipment credited.

In the case of the production credits, the amount spent on the credit in each year was divided by the inflation-adjusted value of the production credit in that year to determine the amount of electricity produced from these renewable sources in each year. The electricity produced from renewables (kWh) in each year was multiplied by the carbon content of the average electricity fuel mix per kWh to determine the carbon emissions displaced by wind and biomass in each year.

# 2.3 Findings

# 2.3.1 JCT and CSE Cost and Carbon Savings Compared

Using market impact estimates derived from JCT budgetary estimates, we find that an expenditure of \$6.4 billion dollars on the tax credits would result in carbon emissions savings from eligible equipment of 33 million metric tons over the lifetime of the technologies (25 MtC assuming electricity savings displaces electricity produced from the marginal generating unit). In contrast, based on the results of our survey of experts, an expenditure of \$5.6 billion dollars on the tax credits would result in 116 million metric tons of carbon (81 MtC if electricity from gas-fired generating units is displaced) saved between 2000-2018 and a consumer surplus of almost \$27 billion spread over 19 years. In addition to these direct benefits from the package of policies and tax credits, spillover effects from the advancement of the technologies could result in additional carbon savings of 14.3 million metric tons and \$77 billion of savings.

All dollar figures reported in this findings section are present values, discounted at a five percent real interest rate and presented in millions of constant 1999 dollars. The five percent real interest rate is used because it is the official discount rate used by the federal government for cost-benefit analysis. Undiscounted values and values using a lower social discount rate are reported in the sections on individual technologies; these alternatives consistently show higher total benefits and benefit/cost ratios than those reported here.

Assuming the package of policies is cheap or free (with the exception of research and development funding parallel to that proposed in the President's fiscal year 2000 budget), this study finds that every forty-eight dollars (sixty-nine dollars under gas fired generating unit electricity assumption) of investment in the tax incentives will save a metric ton of carbon over the 2000-2018 forecast period (\$11 per metric ton saved over the lifetime of the equipment receiving the credit. In the JCT constrained study it would cost \$195 dollars to save a ton of carbon emissions. The following table compares the findings of the study under each set of assumptions: the JCT budget effects-constrained study (JCT) and the expanded study (CSE).

<sup>8</sup> White House Office of Management and Budget, *OMB Circular No. A-94*. Appendix C, Washington, DC., January 1999.

Revenue Effects and Carbon Savings from CCTI Tax Credits: JCT and CSE, 2000-2018							
Provision		nditure s 1999 \$)	Carbon Emissions Savings (million metric tons)				
	JCT	CSE	JCT	CSE			
Hybrid and Electric Vehicles	3,901	1,181	5	33.5			
Energy Efficient Homes	369	35	4/3.6*	1.9/ <i>1.7</i> *			
Energy Efficient Building Equipment	996	108	2.1/1.8	3.0/2.7			
Combined Heat and Power	232	208	13/ <i>8.3</i>	32.3/20.2			
Rooftop Solar Equipment	148	358	0.8/0.5	3.9/1.4			
Wind and Biomass Energy	795	3,718	8.1/ <i>5.1</i>	42.5/35.4			
Total	6,441	5,608	33/25	116/ <i>95</i>			

<sup>\*</sup>When electricity avoided by the technologies displaces natural gas-fired electricity rather than the forecast average electricity fuel mix

The JCT-derived estimates were more optimistic than those of the respondents to our survey about the future of electric vehicles, advanced natural gas heat pumps, the introduction date of fuel cells for building applications, and about the rate of penetration for energy efficient homes. The expenditure estimates in the CSE case reflect this difference. The respondents to our survey were slightly more optimistic than JCT about the impact if the credit on the number of rooftop solar equipment and combined heat and power systems and much more optimistic about wind and biomass facilities, given the implementation of a package of policies to promote the technologies.

# 2.3.2 CSE and EIA Studies Briefly Compared

In April 1999 the Energy Information Administration (EIA) published a report analyzing the CCTI initiative. We will not attempt to do a detailed, credit-by-credit comparison here. However, it is interesting to note certain broad similarities and differences. First, over the 2000-2018 forecast horizon, the EIA projects carbon savings from the CCTI credit package of approximately 70 million metric tons (MtC). This is fairly close to our estimate of 102 MtC of direct savings over the same period. Given the high variance inherent in long-term technology forecasting, this thirty percent difference is unsurprising. Moreover, our estimates assume that a package of related technology-promotion policies is enacted in tandem with the CCTI, and this alone could easily account for the difference. The broad similarity between the EIA results and ours despite very different methodologies lends credence to both.

Our study, however, estimates a number of benefits from the credit that are not included in the EIA study. These include:

- The value of reduced equipment costs to consumers or purchasers;
- The economic value of local environmental improvements and greenhouse gas emission reductions:
- The benefits of technology spillover in the form of improved efficiency of cars, homes, and equipment not receiving the credits; and

<sup>&</sup>lt;sup>9</sup> Energy Information Administration, *Analysis of the Climate Change Technology Initiative*, SR/OIAF/99-01, Washington DC, April 1999.

• The continued benefit of emissions reductions installed during the forecast period over the life of the equipment.

Our generally more positive results on the CCTI credit package does not reflect any deep disagreement with the EIA report's conclusions, but rather our own finding that these additional benefits are quantitatively significant.

## 2.3.3 Most Credit-Induced Benefits Accrue After the Credits Expire

The primary reason the incremental carbon savings from the tax incentives in the CSE case exceed those in the JCT case is that the CSE case quantifies the emissions savings from technological progress induced by the credit, savings which continue after the credit itself expires. The following table compares our estimates of the carbon savings benefits and consumer surplus that accrue during the years the credits are available to total savings from the tax credit between 2000-2018. (See also the section on carbon emissions below for longer-term equipment life carbon savings.)

Ratio of Credit Effect During the Years the Credits are Available* to Total Effect from 2000-2018								
	Carbon	Emissions (MtC)	Avoided	Consumer Surplus (1999 dollars in millions)**				
Provision	2000- end of credit period  total carbon saved, 2000- 2018  Ratio (total/ credit period)			2000- end of credit	total consumer surplus	Ratio(total /credit period)		
Hybrid and Electric Vehicles	0.16	33.5	209	1,116	20,196	18		
Energy-Efficient Building Equipment	0.02	2.7	130	4	225	56		
Energy-Efficient New Homes***	0.005	1.9	380	3	106	35		
Combined Heat and Power	5.52	32.3	6	700	4,935	7		
Rooftop Solar	0.07	3.9	33	29	202	7		
Wind and Biomass	25	42.5	1.7	850	2014	2		
Combined	31	116	3.7	2,702	27,678	10		

<sup>\*</sup>The credit period varies according to the description of the proposal for each technology.

These figures assume that technologies that save electricity displace the average electricity fuel mix, the carbon savings would be adjusted downward similarly to the previous table if electricity saved displaces the gas-fired generation. The ratios remain the same, however, whether the average electricity fuel mix emissions rate or the marginal generating unit emissions rate is used.

#### 2.3.4 Most of the Credits Have Substantial Non-Environmental Benefits

The following table details the non-environmental economic benefits from enactment of the credits. Ancillary benefits are the benefits listed in the methodology section. Although the value of increased exports of wind turbines is reported here, it is not included in the cost-benefit analysis below because of the difficulty of estimating the ratio of the value of public benefit to the value of exports.

<sup>\*\*</sup>Discounted to 1999 at a market discount rate of 5%

	Value of Non-environmental and Environmental Benefits from the Tax Credits, 2000-2018 (millions 1999\$)										
	Non-Environmental Costs and Benefits					Environmental Benefits*					
		sn	* *	Local Enviro Benef		Climate Related Benefits					
	Expenditure	Consumer Surplus	Spillover Benefits**	Local Environmental Benefit	Local Environmental Benefits (Spillover)	\$5/ton Direct Carbon Benefit	\$5/ton spillover Carbon Benefit	\$20/ton Direct Carbon Benefit	\$20/ton Spillover Carbon Benefit	\$100/ton Direct Carbon Benefit	\$100/ton Spillover Carbon Benefit
Vehicles	1,181	20,197	67,232	550	517	43	40	172	161	859	807
Homes	35	115	728	33/7	0.05/0	0.8/.6	0.0/0.0	3/2	0.02/0.01	17/14	0.1/0.0
Building Eqpmt	108	146	N/A	190/18	N/A	6/ <i>5</i>	N/A	24/19	N/A	120/96	N/A
CHP	208	4,674	N/A	5,016/ <i>46</i>	N/A	92/58	N/A	366/229	N/A	1831/1144	N/A
Solar	358	406	N/A	132/8	N/A	9/7	N/A	38/30	N/A	189/ <i>151</i>	N/A
Wind & Biomass	3,718	2,014	5,962	5,800/ <i>53</i>	N/A	106/66	N/A	422/264	N/A	2112/1320	N/A
Total	5,608	27,552	73,921	11,721/682	517	256/180	40	1,025/ <i>716</i>	161	5,127/ <i>3,584</i>	807

<sup>\*</sup>The second figure in each cell is the value of the benefit when we assume that electricity savings displaces emissions only from natural gas combustion rather than the forecast average fuel mix.

The analysis suggests that the largest non-environmental benefits in dollar terms come from the vehicles credit, followed by the CHP and the wind and biomass credits, with the homes and solar credits pulling in third. For the vehicles and homes credits, most of the benefit comes from efficiency improvements in units that do not themselves receive the credit, but rather benefit from spillover technology improvements. These improvements are quite small in percentage terms, but are quantitatively large because the relatively large number of new ineligible vehicles and homes offsets the small percentage of improvement. The dollar value of the carbon savings for the technologies that displace electricity (wind and biomass, CHP, pv's, central air conditioners, and some heating equipment) would be adjusted downward under the assumption that electricity saved displaces gasfired rather than the average generating unit. For instance, the total \$5/ton direct carbon savings for the package would be adjusted from \$256 million to \$180 million.

## 2.3.5 The Value of Environmental Benefits Is Significant

The table above also shows the estimated value of local environmental benefits, using the midrange value from Viscusi, et al. (High and low values are reported in the technology-specific sections.) The principle lesson of this analysis is that local environmental benefits are substantial. For three of the six credits – building equipment, CHP, and wind and biomass -- local environmental benefits exceed direct non-economic benefits. In aggregate, the economic value of local benefits and environmental benefits is approximately double the revenue cost of the credits.

Greenhouse gas damage valuation is potentially very large but even more uncertain than valuation of local environmental damages. Savings from avoided climate change damages are estimated for three values of damage per ton of emitted carbon: \$5, \$20 and \$100 (see Methodology section). Except at

<sup>\*\*</sup> Only the economic value of the spillover benefits from hybrid vehicles, energy efficient homes, and biomass are included in this table Spillovers from wind and solar technologies are not included because of the difficulty of distinguishing social benefits from mere redistribution of income.

the \$100/ton level, greenhouse gas damages are small relative to local environmental damages. Thus the "Climate Change Technology Initiative" is something of a misnomer, at least with regard to the tax incentive portion. If economic valuation is the measure used, it would be more accurate to regard the package as a device to reduce the impact of air pollution in the U.S., rather than to reduce the economic impact of climate change.

# 2.3.6 The Economic Benefit of the CCTI Credit Package Exceeds its Cost

The table below details the benefit/cost ratio for each of the tax incentives. Each figure describes the ratio of the specified benefit to the revenue cost of the provision. The benefit values shown are cumulative, i.e., the Spillover value includes direct Consumer Surplus, and the Local Environmental Benefits (midrange estimate) value includes the sum of the non-environmental benefits. The three Carbon Value columns include the non-environmental and midrange local environmental values, plus the value of greenhouse gas reduction at the stated valuation rate.

We conclude that, with the exception of the Solar and the Wind and Biomass credits, these credits are justified based on non-environmental values alone, even when one assumes that the distortion cost of federal taxation is very high. For the package as a whole, and considering only direct effects, the benefit/cost ratio is nearly five to one. When spillover effects are included, that ratio climbs to seventeen to one.

Hybrid and electric vehicles have the highest benefit/cost ratio because the tax credits are expected to have a significant effect on the rate of price decline as well as on the fuel economy of standard vehicles. The energy-efficient homes and CHP credits also show extremely high benefit/cost ratios. When the local environmental health value is included, the Wind and Biomass credit achieves a respectable 3.7 benefit/cost ratio, but the solar credit remains marginal at 1.5 to 1.

Benefit/Cost Ratios								
Provision	Non-Environmental Benefits			Environmental and Non-environmental Benefits (includes spillover benefits)*				
	Expenditure (millions 1999\$)	Consumer Surplus	Consumer Surplus plus Spillover	Local Environmental Benefit	\$5/ton Carbon value	\$20/ton Carbon Value	\$100/ton Carbon Value	
Vehicles	1,181	17.1	74.0	74.9	75.0	75.2	76.3	
Homes	35	3.3	24.1	25.1/ <i>24.2</i>	25.0/ <i>24.3</i>	25.1/ <i>24.3</i>	25.5/24.7	
Building Equipment	108	2.1	2.1	3.8/1.5	3.9/1.6	4.1/1.7	5.3/2.4	
CHP	208	22.5	22.5	46.6/ <i>22.7</i>	47.0/23	48.3/23.8	55.4/28.2	
Solar	358	1.1	1.1	1.5/ <i>1.2</i>	1.5/1.2	1.6/ <i>1.2</i>	2.0/1.6	
Wind and Biomass	3,718	0.5	2.1	3.7/2.2	3.7/2.2	3.8/2.2	4.2/2.5	
Total	5608	4.9	17.0	19.2/18.2	19.3/ <i>18.2</i>	19.4/18.3	20.2/18.9	

<sup>\*</sup>The second figure in each cell describes the benefit-cost ratio when electricity generation avoided is natural gas combustion rather than the average electricity fuel mix.

As mentioned above, the local environmental benefits from the CCTI tax credit package are approximately twice the revenue cost of the package. Thus the CCTI can be justified on the basis of either the environmental or the non-environmental value alone.

## 2.3.7 The CCTI Tax Credit Package is Cost-effective in Reducing Carbon Emissions

We found that the climate change tax incentive package is cost-effective at reducing emissions of carbon dioxide. The costs per ton of emissions reduction range from six dollars to eighteen dollars, with an average cost for the entire package of eleven dollars a ton. This cost compares favorably with the cost of carbon abatement through international emissions trading as estimated by the President's Council of Economic Advisors (\$14 to \$23 per ton of carbon-equivalent).<sup>10</sup>

The following table details the findings and includes carbon savings attributable to investments made during the forecast period but does not include carbon savings from policies put in place during the forecast that influence investments after the forecast period.

Greenhouse Gas Benefit/Cost Comparison of the Climate Change Tax Incentive Package								
Provision	Expenditure (Millions	Carbon Emiss (m/l		Cost Effectiveness	Benefit/Cost Ratio Using Three Carbon Values			
	1999\$)	2000-2018	Lifetime of Equipment	(\$/ton)	\$5/ton	\$20/ton	\$100/ton	
Energy-Efficient Hybrid and Electric Vehicles	1181.0	33.5	191.2	6.2	0.4	1.8	8.8	
Energy-Efficient Homes	35.0	1.9	3.9	9.1	0.3	1.1	5.5	
Building Equipment	107.8	2.7	15.8	6.8	0.2	0.9	4.4	
Combined Heat and Power	208.0	32.2	36.9	5.6	0.6	2.3	11.7	
Solar Equipment	431.1	3.9	73.4	5.9	0.4	1.7	8.3	
Wind and Biomass	3718.0	42.5	201.4	18.5	0.1	0.6	2.9	
Total Package	5680.9	116.0	522.6	10.9	0.3	1.0	4.9	

If electricity avoided by the technologies is natural gas combustion instead of the average fuel mix the benefit/cost ratios are shifted for CHP from 2.3 under the \$20/ton carbon value to 1.4 and for wind and biomass from 0.6 to 0.4. The vehicles benefit to cost ratio would not be affected while the ratios for homes, building equipment, and solar equipment would be shifted downward very slightly.

The benefit-to-cost ratio exceeds one in all technology cases with the exceptions of wind and biomass and efficient building equipment when the carbon emissions avoided over the lifetime of the various equipment types are valued at 20 dollars per ton. Note that these ratios are for greenhouse gas valuations alone and include neither non-environmental nor local environmental benefits. When the value of carbon is increased to one hundred dollars per metric ton the ratio of monetized benefit from emissions reductions to expenditure on the credit ranges from eleven dollars of benefit for every dollar of expenditure for combined heat and power systems to less than three dollars of benefit for every dollar of expenditure on wind and biomass electricity production. The package as a whole achieves a balance of a dollar of benefit for every dollar of expenditure when carbon is valued at twenty dollars per ton and market discounting is applied on both the cost and the benefit side.

# 2.3.8 Results Are Highly Uncertain

Although the point estimate from the benefits of the tax credits suggests that the benefit/cost ratio is large, it should be observed that the variance in these estimates is substantial. The table below provides the mean and standard deviation for the consumer surplus and carbon savings for each

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<sup>&</sup>lt;sup>10</sup> Council of Economic Advisors, The Kyoto Protocol and the President's Policies to Address Climate Change: Administration Economic Analysis. Washington, DC. July 1998.

provision. The ratio of standard deviation to cost savings is the same for local environmental benefits.<sup>11</sup>

Uncertainties 2000-2018								
Provision	Mean Consumer Surplus Estimate	Standard Deviation	Mean Carbon Savings Estimates	Standard Deviation				
Hybrid and Electric Vehicles	20,196	16,271	20	15				
Energy-Efficient Homes	115	101	0.27	0.24				
High Efficiency Building Equipment	145	73	2.6	1.8				
Combined Heat and Power	4674	4227	25	13				
Solar Systems	406	197	2.26	2.1				
Wind and Biomass	1641	826	56	30				

An examination of estimate histograms suggests that the distribution of estimates around the mean was roughly symmetrical, i.e., the variance was not a function of a handful of consistently optimistic or pessimistic respondents. In part, this variance reflects uncertainty in the current policy climate for each of the technologies targeted by the proposed tax credits. Although our study revealed that there is a large amount of variation in the projections for market penetration of the technologies, that variation reflects the political reality that there is a wide range of policy conditions each technology could face and that these policy factors play a crucial role in determining the rapidity of market acceptance. The relative proportion of carbon savings from the tax credit to carbon savings from the policy package varied much less across respondents.

#### 2.3.9 Non-Tax Policies Must Be Enacted to Make The Credits Effective

Although our results suggest that the CCTI tax incentives are justified from a benefit/cost perspective, the use of tax credits has certain limitations. Some of these are inherent in the credit approach, some are related to the details of the credits in the CCTI package, and some relate to the need to imbed the credits in a larger suite of technology promotion policies if they are to function as intended. These limitations, and summaries of the recommendations of our panel about how to remedy them, are discussed in more detail in the technology-specific sections.

With the exception of the wind and biomass production tax credits, all of the incentives are tax credits against the income of the purchaser of the equipment. If the purchaser of the equipment does not file tax returns or have taxable income, h/she will not benefit from the incentive. This means that large sectors of our economy -- governments, schools, and non-profits -- will not be able to take advantage of the credits. Most of the credits are intended to stimulate demand for efficient products. However, because consumers would not be able to claim the tax credit until they filed tax returns, the incentive to purchase efficient equipment may not be apparent in the immediate sticker-price decision process. Thus public education programs will be required to bolster the effectiveness of these credits.

For some of the credits, the short duration of credit availability is problematic. For example, combined heat and power facilities take at least three years to plan but the credit is only available for three years. The effect of the credit in this instance is to accelerate the construction of already-planned

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<sup>&</sup>lt;sup>11</sup> For each individual credit, the fuel mix of the energy savings is the same for the calculation of local environmental benefits as it is for calculation of carbon savings. As a result, for a specified credit the carbon saving and local environmental benefit are linearly related.

installations. Also, some of the credits may not be big enough to stimulate substantial new investments. Many of our respondents suggested that the solar credit was too small to have a major effect on the market. However, even a small credit may be effective if enacted with other policies that make solar technologies more competitive with existing technologies, such as removing barriers to grid interconnection for PV applications.

The most serious limitation of a credit-only approach derives from non-tax barriers to the adoption of new technologies and destructive interactions between tax policies and other policies. To be effective, tax incentives must be part of a larger suite of policies to provide fundamental research, educate the public, eliminate market and regulatory barriers, and the like. The most vivid example of destructive interaction is in the way the vehicles credit interacts with corporate average fuel economy (CAFE) standards.

Auto companies are required to meet minimum average fuel economy standards for the cars they sell. These limits are binding, i.e., car companies are normally at the standard and would produce more low-efficiency vehicles if the standard were not in place. As a result, in the absence of appropriate policies to harmonize the tax incentive and CAFE approach, the credit for super-efficient vehicles may have no impact on aggregate emissions. The existence of some super-efficient vehicles would be offset by the sale of other, low-efficiency vehicles so that the average efficiency would remain unchanged. Therefore, we recommend that any vehicles receiving the credit be excluded from the CAFE calculation. The CAFE standard would then apply only to the remainder of the fleet. In the same way, the vehicle efficiency spillover effects predicted by our expert panel (in which creditinduced efficiency improvements are copied in cars that are not eligible for the credit) can be nullified if the efficiency gains are offset by making cars bigger, heavier, or otherwise less fuel efficient. Thus the credit approach would have to be accompanied by a slight tightening in CAFE standards on the non-credit vehicles to achieve the predicted efficiency gains.

A variety of policies in addition to the credit are required if tax policies are to be effective in stimulating technological change. In the cases of efficiency investments, such as hybrid and electric vehicles and energy-efficient homes, policies that increase the price of fossil fuels were thought to be most effective. In cases that involve electricity generation, such as wind and biomass electricity, solar systems, and CHP, policies that enable non-utility generators of electricity to sell excess electricity back to the grid and to receive back-up power at competitive rates without the tacking on of prohibitive exit fees are most effective. In all cases, policies that reconfigure the energy marketplace to make efficient clean power a priority both for the consumer and the manufacturer are successful in stimulating real improvement in both the efficiency of technologies and the cleanliness of fuel sources.

# 3. Detailed Analysis of the CCTI Credits

# 3.1 Fuel Efficient Hybrid and Electric Vehicle Tax Incentives

## 3.1.1 Background

#### PROPOSAL12

The tax credit proposal would extend the present credit for qualified electric vehicles and provide temporary tax credits for fuel-efficient hybrid vehicles. A qualifying hybrid vehicle is a vehicle powered by on-board fuel and that uses regenerative braking and an energy storage system that will recover at least 60 percent of the energy in a typical 70 to 0 braking event. A qualifying vehicle would have to meet all emission requirements applicable to gasoline-powered automobiles. These credits would be available to all qualifying light duty vehicles. The details of the credit are as follows:

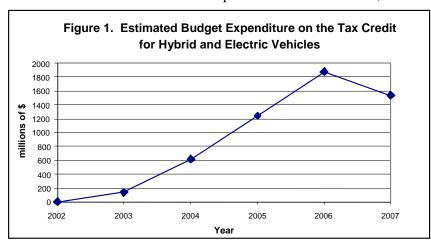
<u>Credit for electric vehicles</u>. The currently scheduled phase-down of the credit for electric vehicles would be eliminated and the credit extended through 2006. Thus, the maximum \$4,000 credit would be available for purchases before January 1, 2007.

# <u>Credit for fuel-efficient hybrid vehicles</u>. The credit would provide:

- (a) \$1,000 for each vehicle that is one-third more fuel efficient than a comparable vehicle in its class, effective for purchases of qualifying vehicles after December 31, 2002 and before January 1, 2005;
- (b) \$2,000 for each vehicle that is two-thirds more fuel efficient than a comparable vehicle in its class, effective for purchases of qualifying vehicles after December 31, 2002 and before January 1, 2007;
- (c) \$3000 for each vehicle that is twice as fuel efficient as a comparable vehicle in its class, effective for purchases of qualifying vehicles after December 31, 2003 and before January 1, 2007; and
- (d) \$4000 for each vehicle that is three times as fuel efficient as a comparable vehicle in its class,

effective for purchases of qualifying vehicles after December 31, 2003 and before January 1, 2007.

The Joint Committee on Taxation (JCT) estimated that the expenditure on the credit for hybrid and electric vehicles will total \$5.4 billion between 2002 and 2009, 74 percent of the total expenditure on the climate change tax incentive package. <sup>13</sup> JCT expects that



this expenditure will be distributed over the credit period as illustrated by Figure 1.

<sup>12</sup> Department of the Treasury, Description of the Revenue Proposals Contained in the President's Fiscal Year 2000 Budget, Washington, DC; February, 1999.

<sup>13</sup> Joint Committee on Taxation, Estimated Budget Effects of the Revenue Proposals Contained in the President's Budget for Fiscal Year 2000, February, 1999.

The first year of expenditure represents only credits to electric vehicles because the credits for hybrid vehicles do not come into effect until 2003. Year 2003 expenditures are for electric vehicles and hybrid vehicles that are 1/3 or 2/3 more efficient than conventional vehicles. In year 2004 all the credit types are available. In years 2005 and 2006 all but the credit for vehicles that are 1/3 more efficient than conventional vehicles are available. The expenditure in fiscal year 2007 indicates purchases only in the last quarter of calendar year 2006.

#### **HISTORY**

The tax credit for qualified electric vehicles, established by the Energy Policy Act of 1992, provides a credit of ten percent of the cost of a qualified electric vehicle against a taxpayer's income tax. A qualified electric vehicle is any motor vehicle that is powered primarily by an electric motor that draws its current from rechargeable batteries, fuel cells, or other portable sources of electrical current. The credit is effective for property placed in service after June 10, 1993 and before December 31, 2004. The maximum credit allowable is \$4,000, and the credit is scheduled to phase out after December 31, 2001 by \$1000 per year. No credit is available after 2004.<sup>14</sup>

#### **CONTEXT**

Transportation in the U.S. is the largest single source of carbon dioxide in the world, accounting for 4-5% of the CO<sub>2</sub> emitted annually as a result of human activity.<sup>15</sup> It accounts for 35 percent of all U.S. carbon emissions and 36 percent of all energy use. 16 The sector's emissions are forecasted by the Energy Information Administration (EIA) to grow at an average annual rate of 1.7 percent, faster than all other sectors. Stagnation of vehicle fuel economy improvements coupled with a 1.6 percent average annual increase in vehicle miles traveled intensifies the serious climate change threat and health hazard the transportation sector poses.<sup>17,18</sup>

The light duty vehicle sector consumes 60.7 percent of all energy used in U.S. transportation and is forecasted to continue growing by 1.3 percent annually into 2010. 19 Carbon emissions from light duty vehicles are expected to increase 24 percent over 1997 levels, a slightly slower rate than the 26 percent increase expected from the whole transportation sector.<sup>20</sup>

Although the fuel economy of new vehicles increased dramatically during the oil embargo of the late 1970's there has been little increase in the fuel efficiency of new vehicles in the past decade (Figure 2). The stagnation of vehicle fuel economy improvements is thought to be a response to falling oil prices, nearly unchanged Corporate Average Fuel Economy (CAFE) standards, and consumer preference for larger, more powerful, and less fuel efficient luxury and sport utility vehicles.<sup>21</sup>

Technologies exist that could dramatically increase vehicle fuel economy, but manufacturers have little incentive to invest in these new and expensive manufacturing techniques. The postponement of the California zero-emissions electric vehicles mandate revealed that more than a mandate strategy is

<sup>&</sup>lt;sup>14</sup> Joint Committee on Taxation, List of Expiring Tax Provisions, 1998-2007. July 1998. JCX-53R-98.

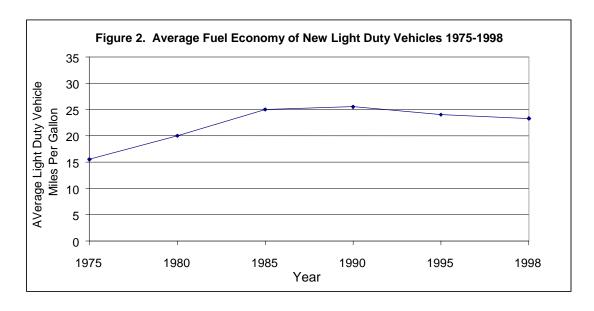
<sup>&</sup>lt;sup>15</sup> National Research Council, Effects of Transportation on Energy and Air Quality, National Academy Press; Washington DC, 1997.

<sup>&</sup>lt;sup>16</sup> Energy Information Administration, *Annual Energy Outlook 1999*, Figure 7, Washington, D.C. December, 1998. <sup>17</sup> Transportation Research Board, National Research Council, Toward A Sustainable Future: Addressing the Long-Term Effects of Motor Vehicle Transportation on Climate and Ecology, Washington, D.C.: National Academy Press,

<sup>&</sup>lt;sup>3</sup> Ibid. pg. 84.

<sup>&</sup>lt;sup>19</sup> U.S. Department of Energy, *Transportation Energy Data Book 18*, Table 2.8 Washington D.C., September 1998. <sup>20</sup> Department of Energy, Scenarios of U.S. Carbon Reductions: Potential Impacts of Energy Technologies by 2010 and Beyond. Table 5.5 Washington, DC., September, 1997.

<sup>&</sup>lt;sup>21</sup> Bernow, S., W. Dougherty, M. Duckworth, S. Kartha, M. Lazarus, and M. Ruth, *Policies and Measures to Reduce* CO2 Emissions in the United States: An Analysis of Options through 2010, Washington, DC; World Wildlife Fund, March, 1998.



Source: American Council for an Energy Efficient Economy, adapted from Environmental Protection Agency, Washington DC, October, 1998., http://aceee.org/briefs/emb\_71.gif.

needed to begin to replace the nation's inefficient light duty vehicle fleet with vehicles that reduce transportation emissions, improve air quality, and help the U.S. fulfill its obligation to reduce greenhouse gas emissions. The absence of market signals, such as significantly higher oil and gas prices, to encourage the production of fuel efficient and alternative fuel vehicles necessitates a federal policy to create incentives that would help eliminate the barriers to greater automotive fuel efficiency. Increasing the fuel economy of the nation's fleet would both reduce emissions of carbon dioxide, the principal greenhouse gas, as well as emissions of local pollutants. It would also decrease the national trade deficit by reducing the need for imports of foreign oil.

The tax credit against the purchase of qualified electric vehicles (EV's) included in the Energy Policy Act of 1992 has been in effect since 1993. Over this time sales of EV's have grown from 39 in 1996 to 1,238 in 1998. In total, between 1996 and December of 1998 only 2,096 electric vehicles were sold nation-wide. The high purchase price of these vehicles combined with the limitations on range and speed have prevented EV's from penetrating the automotive market, despite the California Low Emissions Vehicle mandate and the modest tax credit. In addition, the California, New York, and Massachusetts mandates for the manufacture of low emissions vehicles have been delayed due to concerns that the vehicles will not be marketable because of their high cost and consumer uncertainty about the new technology.

Hybrid electric vehicles do not suffer from the range limitations of the EV because the battery can be recharged while the car is in operation. They use both an internal combustion engine and a battery-powered electric drive train to power the wheels. A number of different hybrid vehicle designs exist, including fuel cell-powered vehicles, with a variety of operating characteristics.<sup>23</sup> These vehicles are not grid connected and are substantially more energy efficient (they can have regenerative braking ability, and the engine is sized to average load rather than peak load) and fuel flexible than

<sup>22</sup> Electric Vehicle Association of the Americas, *Major OEM EV Sales and Leasing*, January 18, 1999.

21

Department of Energy, *Hybrid Vehicle Propulsion Program*, National Renewable Energy Laboratory, [http://www.hov.doc.gov/general/] December, 1998.

conventional vehicles. With two drive trains, the hybrid electric vehicle is able to operate approximately two times more efficiently than traditional internal combustion engine vehicles. However, hybrid electric vehicles and electric vehicles both can cost more than twice as much as a standard internal combustion engine vehicle and have not yet been manufactured and sold in the U.S. in any quantity.

Toyota has announced that it plans to sell 20,000 hybrid vehicles (the Toyota Prius) in the U.S. in 2000. General Motors, Ford, and Daimler-Chrysler are also developing hybrids through the Hybrid Electric Vehicle (HEV) Program and the Partnership for a New Generation of Vehicles (PNGV) Program. Their goal is to develop vehicles that are three times more fuel-efficient than conventional vehicles.<sup>24</sup>

# 3.1.2 Effects of the Tax Credit for Energy-Efficient Vehicles Assuming JCT Revenue Estimates

The Joint Committee on Taxation (JCT) ten-year estimated budgetary effects of the tax credit for purchases of energy-efficient hybrid and electric vehicles can also be used to estimate the carbon and energy savings from the credit. In this part of the analysis we assumed that the JCT expenditure estimates are accurate and then deduced the fuel consumption savings from the amount spent on the tax credit in each year. The fuel savings estimated in this section are for all units receiving the credit. Because the JCT does not provide estimates of the use of the technology in the absence of the credit, we are unable to indicate what proportion of these savings are credit-induced. Thus, the JCT derived estimates are provided for comparison purposes only. Incremental fuel savings are derived in the Delphi Analysis section below.

#### RESULTS

Purchases of electric and hybrid electric vehicles with the proposed tax credit would displace 4.7 percent of total projected new light duty vehicle purchases in the U.S. between 2003 and 2008.



\*Purchases of new light duty vehicles increase by 1% per year.

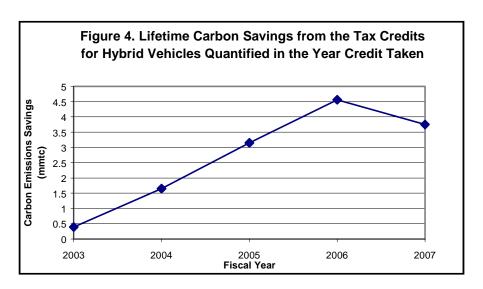
Source: Department of Energy, Transportation Energy Data Book: Edition 18. Table 6.2. Washington DC, September 1998.

<sup>24</sup> Department of Energy, *Partnership for a New Generation of Vehicles: Paths to Triple Automotive Fuel Economy*, Presented at the Northeast Sustainable Energy Association's Solar and Electric Vehicles '95 Symposium, November, 1995.

Purchases of qualified vehicles would range between 1.1 and 8.8 percent of total light duty vehicle purchases in any one year (Figure 3).

However, sales of electric and hybrid vehicles between 2003 and 2008 would displace only 1.1 percent of the total national vehicle stock.

This analysis includes only the carbon saved from the tax credit for hybrid vehicles. Savings from electric vehicles are excluded because, if current trends continue, only 0.5 percent of

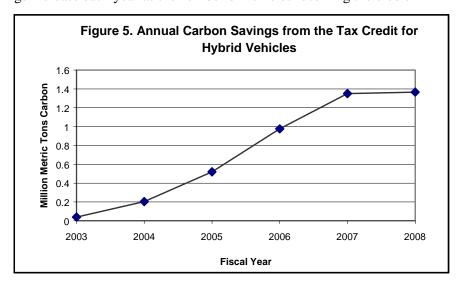


vehicles receiving the credit would be electric and because the savings from electric vehicles depend on the carbon content of the electric power source.

The tax credit for hybrid vehicles alone would result in a lifetime carbon emissions savings of 13.7 million metric tons (MtC) of carbon, although only 4.5 MtC of those savings would be realized by 2008.<sup>25</sup> Figure 4 illustrates the carbon savings that would accrue over the lifetime of the vehicles (10 years) when the vehicle-life savings are attributed to the year in which the credit is received.

The lifetime carbon savings increase each year as the number of vehicles receiving the credit

increases until 2007. the year the credit expires. The actual carbon savings that can be expected over the credit period are illustrated by Figure 5. Although this figure only illustrates carbon savings over the credit period, the savings from the tax credit continue throughout the lifetime of the vehicles and into 2016, ten years after the credit itself expires.

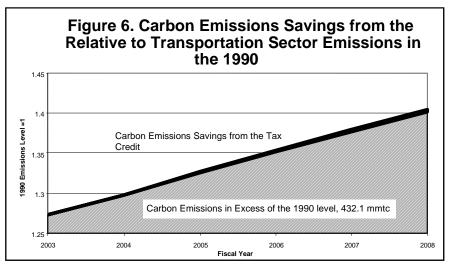


<sup>&</sup>lt;sup>25</sup> These savings estimates assume that the vehicles will use the same fuel as internal combustion engine vehicles. Savings could be far greater if these vehicles were powered by a non-fossil fuel, such as hydrogen.

Between 2003 and 2008, the carbon savings from the credit would offset only 0.5 percent, or 4.5 MtC, of transportation sector emissions in excess of the 1990 level. Figure 6 illustrates the carbon savings from the credit relative to transportation sector emissions in excess of the 1990 level that can

be expected each year over the credit period. This figure does not reflect the carbon savings from the highly fuel efficient vehicles after 2008.

Between 2003 and 2008, annual carbon emissions from the transportation sector in excess of the 1990 level are projected to total 876.3 MtC. A total of 4.45 MtC would be offset by the credit between 2003 and 2008.



\*The Energy Information Administration estimates that emissions from the transportation sector totaled 432.1 million metric tons in 1990.

Source: Energy Information Administration, Emissions of Greenhouse Gases in the United States 1997. Washington DC, October 1998.

#### **METHODOLOGY**

- The relative share of the expenditure for each efficiency category was determined by running a Logit model using the following inputs for both hybrid and conventional vehicles: current sales by vehicle type, fuel efficiency, purchase price, and the credit amount available.
- The JCT revenue expenditure estimate on the tax credit in each year was divided by the
  credit amount available for each eligible vehicle and the proportion of total sales expected for
  each category of vehicles to determine the number of vehicles in each efficiency category
  expected to receive the credit in each year.
- The carbon savings from vehicles in each category were determined by multiplying the average vehicle miles traveled per vehicle per year<sup>26</sup> by the difference in fuel economy between the efficient vehicle and a conventional vehicle<sup>27</sup> to determine the number of gallons saved by the efficient vehicles. This number was then multiplied by the average amount of carbon emitted per gallon of gasoline, 0.00239 metric tons,<sup>28</sup> to determine the amount of carbon saved annually per vehicle receiving the credit. We assumed the improved fuel efficiency would have negligible effect on the average miles traveled.
- The amount of carbon saved annually per vehicle receiving the credit was then multiplied by the number of vehicles expected to receive the credit in each credit year, and in each efficiency category, to determine the total carbon savings in each year.

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<sup>&</sup>lt;sup>26</sup> National Research Council, Transportation Research Board. Toward a Sustainable Future: Addressing the Long-Term Effects of Motor Vehicle Transportation on Climate and Ecology, National Academy Press, Washington, D.C. 1997.

<sup>&</sup>lt;sup>27</sup> See note 24.

<sup>&</sup>lt;sup>28</sup> See 19, Appendix H.

 The carbon savings from the vehicles receiving the credit in the year the credit was claimed were then multiplied by the average lifetime of vehicles, 10 years, to arrive at the lifetime carbon savings that can be expected from the credit in each year.

The credit, as described in the President's fiscal year 2000 budget proposal, may not achieve the forecast level of penetration if it retains the clause that requires vehicles receiving the credit to have a sixty percent regenerative braking capacity in a 70 to 0 braking event. No hybrids currently in development would achieve a braking capacity of this magnitude.

Moreover, carbon savings from the credit will be close to zero if manufacturers are allowed to include vehicles receiving the credit in their fleets for CAFE purposes. Historically, vehicle fleets have just met or fallen below CAFE standards. Improvements in the efficiency of some vehicles in a manufacturer's fleet could be offset by decreases in the average fuel economy of the rest of the fleet, resulting in no net efficiency gains.

# 3.1.3 Delphi Analysis of the Proposed Tax Credit for Energy-Efficient Hybrid and Electric Vehicles

#### **SUMMARY**

In the second phase of our analysis of the tiered tax credits for the purchase of energy-efficient hybrid and electric vehicles we did *not* assume that the JCT expenditure estimates were accurate. Instead, we surveyed a panel of experts to determine the impact the credit would have on the demand for hybrid and electric vehicles and the concomitant impact on the future price of these efficient vehicles. We also deviated from the parameters of the JCT-consistent analysis by assuming the credit would be enacted as part of a larger suite of policies intended to facilitate the market penetration of efficient vehicles. With the exception of the research and development provisions parallel to those contained in the R&D section of the President's Climate Change Technology Initiative, the policies included in the attending suite involve little, if any, government spending.

The altered parameters of the second analysis resulted in total expenditures on the credits for efficient vehicles of \$1.2 billion present value (market inflation rate), compared to JCT estimates of \$3.9 billion over the seven-year period the credits are available. JCT assumed far more purchases of efficient vehicles would occur within the period the tax credits are available than did our panel of experts, resulting in a much

larger expenditure than our study suggested.

The Energy Information Administration's analysis of the same tax provisions found that the credits would result in \$6.1 billion in revenue reductions, but 75% of this estimated expenditure was from purchases of electric vehicles.<sup>29</sup> The EIA

Table 1: Total Carbon Savings and Budget Expenditure

	Budget Expenditure	Carbon Savings (MtC)			
	(million \$)	During the Credit Period	After the Credit Period		
JCT estimates	3,901	4.5	13.7		
CSE estimates	1,182	11.4	257		

<sup>&</sup>lt;sup>29</sup> Department of Energy, Energy Information Administration, *Analysis of the Climate Change Technology Initiatives*, Office of Integrated Analysis and Forecasting, Washington, DC; April 1999.

study NEMS model analysis found that over one million electric vehicles would be purchased in 2006 while our study found that only 12,000 electric vehicles would be sold in 2006. The highest projection among our respondents for electric vehicle sales in 2006 was 16,000 while the lowest was 7000. This discrepancy in assumptions about the future of electric vehicles explains the large difference in estimated expenditure on the tax credit between the EIA NEMS model and this study.

The respondents to our survey indicated that, when a package of policies to encourage the development and purchase of efficient vehicles is enacted, carbon emissions savings above the reference case would reach a total of 103 million metric tons between 2000 and 2018. When the tax credit was applied on top of the package of policies, carbon savings from 2000-2018 reached 122 million metric tons. Table 1 details the findings of the study compared to the JCT constrained study. All figures represent total purchases of hybrid electric vehicles including baseline purchases when the package of policies and the tax credit are in place.

Variation in the carbon savings relative to expenditure between the two cases during the credit period is attributable to differences in the proportion of vehicles receiving the credit in each fuel economy class. The dramatic difference in the savings after the credit period is explained by the quantification of the impact of the credit and package of policies on purchases of efficient vehicles after the credit itself expires in the CSE case and not in the JCT case. In the JCT case it was assumed that the credit alone would have no further impact on purchases of efficient vehicles.

Table 2 compares the effectiveness of each policy increment, the package of policies and the tax credit, in reducing carbon emissions, increasing the rate of price decline for the efficient vehicles targeted by the tax credit (consumer surplus), and on the fuel economy of standard vehicles (spillover benefits).

Table 2: Incremental Effects of the Package of Policies and the Tax Credit 2000-2018

	Discounting	Budget Expenditure (millions \$)	Consumer Surplus (millions \$)	Spillover Benefits		Carbon Savings
				millions \$	MtC	(MtC)
Package over Baseline	0 %		79,527	76,150	9.8	103
	2.5 %	N/A	52,808	48,579		
	5 %		35,567	33,096		
Credit over Package	0 %	1545	42,624	135,099		19.6
	2.5 %	1348	29,101	89,952	13.9	
	5 %	1182	20,197	67,232		

Our study shows that, relative to business-as-usual, the incremental carbon savings gained from the policy package is far greater than that gained by the tax credit. The two policies combined would double business-as-usual purchases of efficient vehicles and therefore double the carbon savings that could be expected. Moreover, when the tax credit is applied on top of the package of policies, the incremental savings from fuel economy improvements in standard vehicles almost doubles the savings from the package of policies alone. When the policies are enacted together, consumers would save over \$100 billion, present value (market inflation rate), between 2000 and 2018 on gas bills from these spillover benefits, the effect of efficient vehicle technology advancement on standard vehicles.

<sup>&</sup>lt;sup>30</sup> We assume that all vehicle miles driven by the purchaser of an efficient vehicle are conducted in that vehicle. This may not be the case; it may be that the efficient vehicle is purchased as a second vehicle and all driver miles are not conducted in the efficient vehicle. Carbon savings in this case would accrue in proportion to the amount the efficient vehicles are substituted for standard vehicles.

Consumer surplus from the credit would exceed expenditure on the credit by \$19 billion, in present value terms (market discount rate).

Three different discount rate scenarios were used to estimate the expenditure on the credit, the consumer surplus, and the gas bill savings from efficiency improvements in standard vehicles. Even discounting at a market rate of five percent, the consumer surplus and ancillary benefits from the credit exceed expenditure on the credit by billions of dollars.

The package of policies suggested by our surveyees and described below would involve little if any expenditure beyond the research and development funding already proposed.

#### **METHODOLOGY**

A survey comprised of three sets of questions regarding market share of energy efficient vehicles was mailed to experts in the hybrid and electric vehicles industry, government agencies, academia, and non-governmental agencies. The first section asked respondents to indicate projected market share of vehicles eligible for the credits under three different policy scenarios: (1) business-as-usual, (2) with a package of low-cost policies designed by the surveyee, and (3) with the package of policies including the investment tax credit. The second section asked respondents to project the future price ratio of energy-efficient vehicles to an average conventional vehicle under each of the three policy scenarios. The third section asked respondents to evaluate the effect the three different policy scenarios would have on U.S. light duty fleet fuel economy.

The results of the survey were tabulated and used to determine: (a) the mean estimated carbon emissions savings from the tax credit and policy package relative to business-as-usual, (b) consumer surplus from the change in the price of energy-efficient vehicles, (c) budgetary expenditure on the tax credits, and (d) the carbon savings and gas bill savings from improvements over baseline in the average U.S light duty fleet fuel economy. These findings were then used to calculate the cost-effectiveness of the investment tax credit. Fossil fuel savings were also converted into monetized environmental benefits using the approach described in the Overview of Methods and Findings above.

#### PACKAGE OF POLICIES

Each respondent was asked to describe four policies that would most effectively stimulate the market for hybrid and electric vehicles. Although each described a different set of policies, a number of particular suggestions recurred. The most mentioned, in order of frequency, were:

- ➤ Higher gasoline taxes at the pump to encourage fuel efficiency or carbon taxes;
- Federal research and development of efficient vehicle technologies, or tax credits for companies engaging in such research and development;
- Efficient vehicle sales tax credits or feebates (fees on vehicles that are less fuel efficient and rebates to owners of vehicles that are more fuel efficient);
- > Development of alternative fuel distribution infrastructure;
- > Increased fuel economy standards; and
- Consumer education on the benefits of vehicle energy efficiency.

Respondents frequently listed higher fuel taxes or carbon taxes on fossil fuel as the most effective policy to advance the market for hybrid and electric vehicles. Tax incentives and further federally subsidized research into efficient and marketable vehicle technologies were also considered effective strategies to increase the penetration of hybrid vehicles in the marketplace.

With the exceptions of tax incentives and research and development funding for efficient vehicle technologies, provisions parallel to those proposed in the President's Budget, the policies our respondents considered most effective either involve little government spending, such as increases in CAFE standards and education campaigns, or are revenue generating, such as higher taxes on fossil fuels and gasoline.

RESULTS

## **Consumer Surplus**

The incremental carbon savings from the tax credit appear trivial relative to the savings from the package but have a larger effect on the future price of efficient vehicles. The price ratio of hybrid and electric vehicles to conventional vehicles in the same class will decrease faster than under business-as-usual when the package of policies is in place and faster still when the credit is applied in addition to the package of policies. When the credit is applied on top of the package of policies, consumer surplus between 2000 and 2018 dramatically increases from \$36 billion to \$56 billion, in terms of present value (market discount rate).

The consumer surplus that is generated by the policy scenarios will go both to purchasers of efficient vehicles who would have purchased the vehicles under the reference case and those who purchase because of the policy-induced reduction in price.

## **Ancillary Benefits**

In addition to the carbon savings and consumer surplus from the policies to promote hybrid and electric vehicles, the efficiency of standard vehicles that are not efficient enough to receive the credit could also experience some fuel economy gains from the development of efficient vehicle technologies. The carbon savings from increases in the fuel economy of new light duty vehicle stock relative to the reference case were found to total 14 million metric tons over 19 years when both the package of policies and the investment tax credits are in effect.

The improvement in the efficiency of light duty vehicles not only reduces carbon emissions but also saves drivers money on gas bills. Consumers would save \$100 billion, present value (market discount rate) on gas bills over the 19-year period when both the package of policies and the tax credit are in effect. The table below shows the estimated annual value of consumer surplus and ancillary benefits from the tax credit, together with the present value under alternative discount rates.

#### **Carbon Savings**

The average forecast effect of the packages of policies described above is to increase purchases of hybrid vehicles over baseline to a level that would result in carbon emissions savings totaling 103 million metric tons of carbon between 2000 and 2018.

Efficient HEVs Economic Effects Detailed						
Year	Consumer Surplus	Ancillary Economic Benefits				
2000	0.00	543.44				
2001	11.95	1,175.27				
2002	58.85	1,846.87				
2003	112.08	2,561.27				
2004	179.91	3,324.27				
2005	274.35	4,138.01				
2006	398.14	5,006.31				
2007	883.06	5,933.26				
2008	1,056.08	6,326.91				
2009	1,265.42	6,749.49				
2010	1,557.16	7,196.67				
2011	1,897.49	7,676.08				
2012	2,324.84	8,189.90				
2013	2,862.99	8,740.47				
2014	3,544.82	9,330.28				
2015	4,417.89	9,961.95				
2016	5,554.52	10,638.31				
2017	7,069.82	11,362.33				
2018	9,154.15	12,137.19				
Discounting	Total 2000-2018					
0%	42,623.54	122,838.29				
2.50%	29,100.50	89,951.82				
5%	20,196.48	67,231.81				

*HEV* = *Hybrid Electric Vehicle* 

If the tax credit proposed in the President's budget is enacted on top of this package of policies, an additional savings of 19.6 million metric tons could be expected.

The carbon savings from the package of policies and credit combined total 123 million metric tons of carbon avoided from 2000-2018. The policies combined would almost double the baseline expected carbon emissions avoided from efficient vehicles over the forecast period.

The carbon savings benefit/cost comparison table below includes incremental carbon savings attributable to investments made during the forecast period as a result of the credit and policy package. This includes not only purchases of energy-efficient vehicles that receive the credit, but also purchases caused by credit-induced price decline, demonstration effects, institutional change, etc. However, it does not include carbon savings from policies put in place during the forecast period that influence purchases of efficient vehicles after the forecast period. Carbon savings from increases in the efficiency of non-qualifying vehicles as a result of technological spillovers from the increased stock of hybrid electric vehicles are also included, but only if they occur within the 2000-2018 forecast period.

Benefit/Cost Comparison of the Investment Tax Credit for Energy Efficient Vehicles							
Discounting (%)	Expenditure (Millions\$)	Carbon Emissions Avoided (mMtC)		Cost Effectiveness	\$ Value of Carbon Savings (Millions)		
		2000- 2018	Lifetime of Equipment	(\$/metric ton)	\$5/ton	\$20/ton	\$100/ton
0	1545.1	137	191.16	8.1	955.8	3823.2	19115.9
2.5	1348.5	same	same	7.1	698.1	2792.6	13963.0
5	1181.0	same	same	6.2	521.20	2084.81	10424.03

## **Local Environmental Benefits**

Fossil fuel savings also reduce pollution that causes local health and environmental effects. These effects are monetized using a range of fuel-specific environmental values from Viscusi, et al., in the manner described in the Overview of Methods and Findings above. The table below shows annual

HEV Annual Environmental Benefits Values						
Year	Local Benefit			Carbon Benefit		
	Low Value	Middle Value	High Value	\$5/ton	\$20/ton	\$100/ton
2000	0.00	0.00	0.00	0.00	0.00	0.00
2001	0.00	0.02	0.03	0.00	0.00	0.02
2002	0.02	0.10	0.18	0.01	0.03	0.16
2003	0.06	0.37	0.65	0.03	0.11	0.57
2004	0.14	0.90	1.59	0.07	0.28	1.40
2005	0.28	1.82	3.24	0.14	0.57	2.84
2006	0.52	3.32	5.91	0.26	1.04	5.18
2007	1.28	8.20	14.61	0.64	2.56	12.82
2008	2.18	13.98	24.91	1.09	4.37	21.85
2009	3.27	20.92	37.26	1.63	6.54	32.68
2010	4.62	29.57	52.68	2.31	9.24	46.21
2011	6.32	40.44	72.03	3.16	12.64	63.18
2012	8.49	54.33	96.77	4.24	16.98	84.89
2013	11.32	72.43	129.02	5.66	22.64	113.18
2014	15.09	96.59	172.06	7.55	30.19	150.93
2015	20.25	129.57	230.80	10.12	40.49	202.45
2016	27.43	175.57	312.74	13.72	54.87	274.33
2017	37.26	238.47	424.78	18.63	74.52	372.61
2018	51.72	331.01	589.61	25.86	103.44	517.20
Discounting	Total 2000-2018					
0%	190.25	1,217.61	2,168.86	95.13	380.50	1,902.51
2.50%	126.95	812.46	1,447.19	63.47	253.89	1,269.47
5%	85.93	549.93	979.57	42.96	171.85	859.27

valuations for the environmental benefit of the incremental fuel reductions for both greenhouse gas and local environmental benefits, together with present values of those benefits for a range of real discount rates.

#### **CONCLUSIONS**

Tax credits enacted without the policy package described above and without raising CAFE standards (or excluding credited vehicles from manufacturer fleet averaging) will result in zero net carbon emissions savings. Manufacturers would simply use the efficient vehicles to offset lower efficiency in the rest of the vehicle fleet.

Assuming the package of policies described above is enacted and efficient vehicles are excluded from manufacturer fleet fuel economy averaging, very significant carbon emissions savings could accrue. Without such incentives, it is unlikely in the current economy characterized by cheap fossil fuels that the more efficient, yet more expensive, hybrid and electric vehicles will achieve market share in the near future. Air quality concerns, the need to reduce global carbon emissions, and the simple arithmetic that illustrates high return on policy investments in efficient technologies, demonstrate that failure to aggressively advance hybrid vehicles through well-designed policy would be an environmental, health, and economic loss.

As illustrated by this study, the success of the tax credit, or any policy to effectively and substantially address the growing carbon emissions from the transportation sector, largely depends on the synthesis of regulatory, market, and voluntary initiatives. For instance, manufacturers may need guaranteed markets for hybrid vehicles to continue investing in research and development necessary to produce competitive products.31

The effectiveness of tax credits for efficient vehicles can be greatly increased through coordination with other market signals. An EPA analysis of pricing mechanisms to reduce transportation emissions concluded that, "the most cost effective pricing strategy for emissions control is to target highemitting vehicles as precisely as possible; the most effective strategy for reducing fuel consumption (and CO<sub>2</sub> production) is to raise the price of fuel; the most effective way to reduce congestion is to impose a toll at congested locations; and so on."32 The market penetration of hybrid vehicles will depend on the willingness of American consumers and manufacturers to prioritize fuel efficiency. Americans will only prioritize fuel efficiency if efficiency is sufficiently cheap or inefficiency is sufficiently expensive.

<sup>&</sup>lt;sup>31</sup> University of California, San Diego, *Hydrogen Fuel Cell Vehicles*, March 6, 1996.

<sup>&</sup>lt;sup>32</sup> Department of Transportation, *Technical Methods for Analyzing Pricing Measures to Reduce Transportation* Emissions, Environmental Protection Agency, Washington, D.C., August, 1998.

# 3.2 Tax Credit for the Purchase of New Energy-Efficient Homes

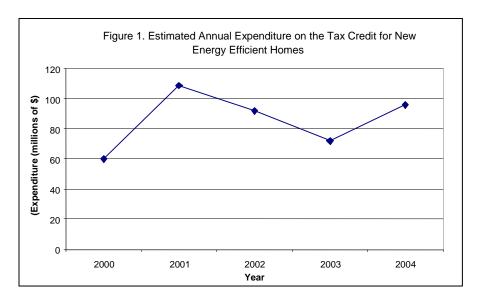
# 3.2.1 Background Information

## PROPOSAL33

A tax credit of up to \$2,000 would be available to purchasers of highly energy-efficient new homes that significantly exceed the International Energy Conservation Code (IECC) energy-efficiency standards for heating, cooling and hot water generation. A taxpayer may claim the credit only if the new home is the taxpayer's principal residence.

The tax credits would be dispensed as follows:

- \$1,000 for new homes that are at least 30 percent more energy efficient than the IECC standard and are purchased in the two-year period beginning January 1, 2000 and ending December 31, 2001;
- \$1,500 for new homes that are at least 40 percent more energy efficient than the IECC standard and are purchased in the three-year period beginning January 1, 2000 and ending December 31, 2002; and
- \$2,000 for new homes that are at least 50 percent more energy efficient than the IECC standard and are purchased in the five-year period beginning January 1, 2000 and ending December 31, 2004.



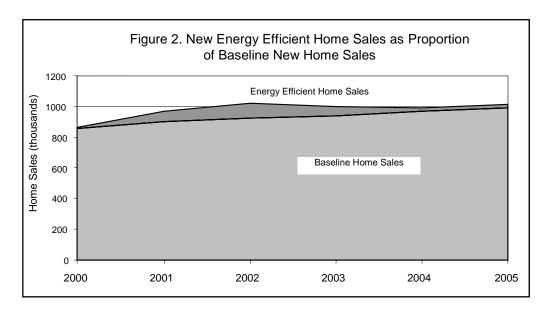
The Joint Committee on Taxation (JCT) estimates a total budget expenditure of \$429 million dollars on the tax credits for energy-efficient homes over the five-year period the credit is available.<sup>34</sup> This amount represents 6 percent of the total budget expenditure on the CCTI tax incentives. Figure 1 depicts the annual expenditure on the credit, with peak in year 2001 when the credit is available to

<sup>33</sup> Department of the Treasury, "Description of the Revenue Proposals Contained in the President's Fiscal Year 2000 Budget", Washington DC, February 1999.

<sup>34</sup> Joint Committee on Taxation, "Estimated Revenue Effects of the President's Fiscal Year 2000 Budget", February, 1999.

homes at all efficiency levels. No deductions or credits are currently provided for the purchase of energy-efficient new homes.

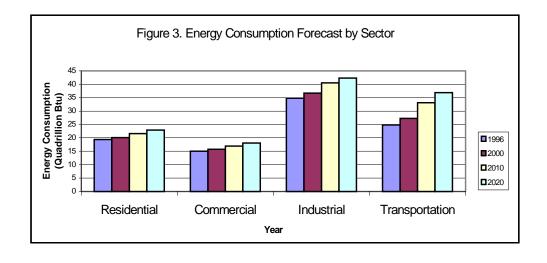
The proposal would credit about 5 percent of new home purchases between 2000 and 2005, about 0.001 percent of national residential building stock (Figure 2).



Although 5% of new home purchasers would receive the credit, the impact on residential building emissions is, at first, relatively small because of the slow rate of residential building stock turnover.

## **CONTEXT**

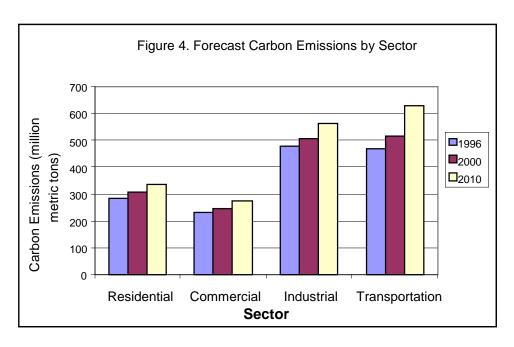
The tax credits are intended to improve energy efficiency and reduce greenhouse gas emissions in the residential building sector. Residences account for about 20 percent of primary energy use in the United States. Although energy use in all sectors is expected to increase, the residential share is forecasted to remain fairly constant into 2020 (Figure 3).35



<sup>&</sup>lt;sup>35</sup> Department of Energy, Scenarios of U.S. Carbon Reductions: Potential Impacts of Energy Technologies by 2010 and Beyond, Washington DC, September 1997.

Residences also account for about one-sixth of all U.S. greenhouse gas emissions (Figure 4).

Carbon emissions from the residential sector, including emissions from the generation of electricity consumed in the sector, are projected to increase by 1.2 percent per year into 2010, a slower rate of increase than in all but the commercial sector. <sup>36</sup>



Increasing population and high economic growth rates have contributed to a correspondingly large number of residential building starts per year. New homes built in the United States are on average larger than older homes but are frequently more energy efficient due to improvements in the efficiency of building shells, as well as heating and cooling equipment. Nevertheless, energy consumption continues to grow due to the proliferation of small appliances and the concomitant increased energy intensity of the average household. <sup>37</sup>

American consumers spend \$120 billion per year on energy consumed in residential buildings and a large fraction of this expenditure, approximately fifty-eight percent, is used for space heating, cooling, and water heating.<sup>38</sup>

# 3.2.2 Effects of the Tax Credit for Energy-Efficient Homes Assuming JCT Revenue Estimates

The Joint Committee on Taxation (JCT) ten-year estimated budgetary effects of the tax credit for purchases of efficient homes can also be used to quantify the carbon and energy savings from the tax credit. In this part of the analysis we assumed that the JCT expenditure estimates are accurate and then deduced the fossil fuel consumption savings from the amount spent on the tax credit in each year. The fuel savings estimated in this section are for all units receiving the credit. Because the JCT does not provide estimates of the use of the technology in the absence of the credit, we are unable to indicate what proportion of these savings are credit-induced. Thus, the JCT derived estimates are provided for comparison purposes only. Incremental fuel savings are derived in the Delphi Analysis section below.

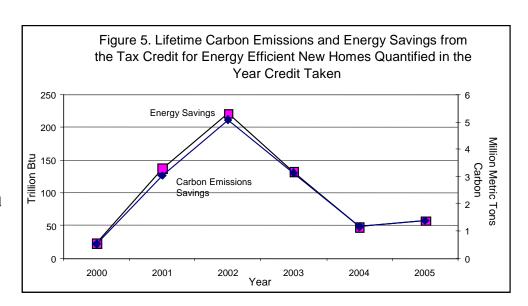
<sup>38</sup> Energy Information Administration, *Annual Energy Outlook 1999*, Washington DC.

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<sup>&</sup>lt;sup>36</sup> Energy Information Administration, *Annual Energy Outlook 1999*, page 84. Washington DC.

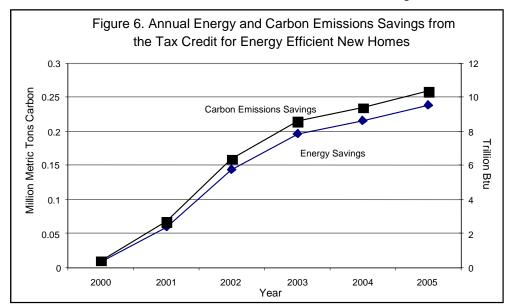
<sup>&</sup>lt;sup>37</sup> Department of Energy, *Residential Energy Consumption Survey*, 1995. Washington DC.

RESULTS Under JCT assumptions, the credit would save 14.3 million metric tons of carbon over the lifetime of the homes if it is assumed that electricity saved from efficiency improvements in heating, cooling and hot water heating technologies displaces the average electricity fuel mix and 11.4 MtC if electricity



use avoided displaces natural gas fired electricity, although only 0.86 million metric tons (0.7 under natural gas electricity assumption) would be avoided by 2005. Figure 5 illustrates carbon emissions savings from the credit when the savings that will be achieved over the lifetime of the home (sixty years) are quantified in the year the purchasers receive the tax credit. The savings would peak in year 2001, the last year the credit is available for homes that are 30% more efficient than IECC standard. In years 2003 and 2004 the credit is only available for homes that are 50% more efficient than model energy code standards. Figures 5, 6, and 7 all assume that electricity savings displaces the average electricity fuel mix.

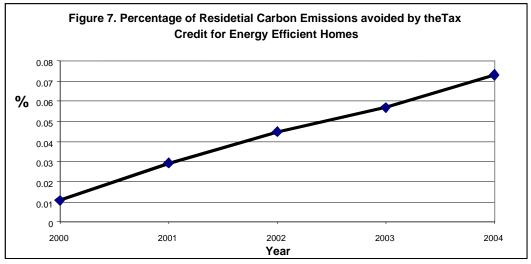
The carbon emissions and energy savings that would be realized over the credit period total 0.86 million metric tons of carbon, or 37.7 trillion Btu, between 2000 and 2005 (Figure 6). This is much



smaller than savings over the lifetime of the homes. These savings are compared to projected carbon emissions from the residential sector in excess of the 1990 level, 253.1 million metric tons, to assess

how effective the credit will be in achieving the goal of reducing national residential sector emissions to 1990 levels (Figure 7). House-life savings induced by the tax credit would constitute eleven percent of carbon emissions from the residential sector in excess of the 1990 level between 2000 and 2005, although these savings would displace only 0.05 percent of carbon emissions from the sector over the credit period.

In addition to carbon emissions reductions, the purchase of energy-efficient homes saves consumers money on their monthly energy bills. The energy bill savings per home would range from \$291.3



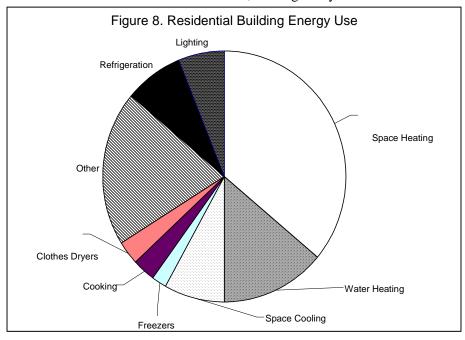
Source: Energy Resources and Renewable Energy Network, Department of Energy. Residential Building Energy Use, 1998. [http://www.eren.doe.gov/buildings/...

(1999 dollars) a year for homes that are 30 percent more energy efficient than the Model Energy Code (MEC) to \$485.5 (1999 dollars) for homes that are 50 percent more efficient than MEC. The national energy bill savings over the lifetime of the homes would total \$6.7 billion, although only \$113 million

(1999 dollars) would accrue by 2005.

## **CONCLUSIONS**

The proposed tax credit only requires that the heating, cooling, and water heating end uses of household energy use exceed the Model Energy Code by 50, 40, or 30 percent depending on the credit amount. Although heating, cooling, and water heating account for 58 percent of total household energy use (Figure 8), the fastest growing energy consumption end-use in the nation's residences is the "miscellaneous end use"



category.<sup>39</sup> Increased use of household appliances and the market penetration of various energy consuming small appliances, including personal computers, constitute the largest share of growth in residential energy use. The annual growth rate of this miscellaneous end-use category is 4.9% (approximately 59 million metric tons of carbon emissions increase by 2010), while the second highest growth area is electrical heating, growing at an annual rate of 2.0% (an increase of approximately 9 million metric tons of carbon by 2010). <sup>40</sup> The share of miscellaneous electricity use is expected to jump from 23 percent of total household energy demand in 1997 to 29 percent in 2010. <sup>41</sup>

Space heating, cooling, and water heating account for 58 percent of total energy use in residential buildings. Thus, a maximum savings of 29 percent of the average annual energy use per household receiving the credit can be expected.

As proposed, the impact of the credit on the buildings sector is limited, due to the slow rate of building stock turnover; the emphasis on heating, cooling and water heating efficiency to the exclusion of other end uses; and because it is not available for rental property.

#### *METHODOLOGY*

- The revenue projections from JCT were divided by the number of homes expected to be purchased in each year that meet each of the three different incentive requirements<sup>42</sup> multiplied by the respective credit amounts to determine what proportion of the total expenditure on energyefficient homes will be spent on homes of each efficiency level.
- Average energy and carbon savings per efficient home were calculated using the Energy Information Administration's Residential Energy Consumption Survey reference case forecast for new home energy use in each credit year. It was assumed that the energy-efficient homes reduce the forecasted heating, cooling, and water heating energy expenditure by 50, 40, or 30 percent in the year that they receive the credit and that this savings continues throughout the lifetime of the home.
- The energy savings (measured in British thermal units) and carbon savings (measured in metric
  tons) were then multiplied by the number of homes expected to receive the credit in each year to
  determine the annual carbon and energy savings from the credit.
- The energy and carbon savings per home were multiplied by the number of homes and the average lifetime of new homes (60 years)<sup>43</sup> to determine the total lifetime energy and carbon savings.
- Cumulative energy bill savings to purchasers of homes meeting the credit requirement were also
  determined by reducing the average energy bill expenditure per household per year by 29
  percent for homes that exceed MEC by 50 percent, 23 percent for homes that exceed MEC by 40
  percent, and 17 percent for homes that exceed MEC by 30 percent to reflect the savings from
  heating, cooling, and hot water heating improvements.
- The national energy bill savings were determined by multiplying the energy bill savings per household per year by the number of homes receiving the credit and by the lifetime of the home.

<sup>&</sup>lt;sup>39</sup> Koomey, Jonathan G., Lawrence Berkeley National Laboratory, *Trends in Carbon Emissions from U.S. Residential and Commercial Buildings: Implications for Policy Priorities*, In the Proceedings for the Climate Change Analysis Workshop, Springfield, VA June 6-7 1996.

<sup>&</sup>lt;sup>40</sup> Ibid. Tables 3 and 5.

<sup>&</sup>lt;sup>41</sup> See note 35.

Personal communication with Japhet Koteen, Energy Star Homes Program, Environmental Protection Agency,
 Washington, DC, January 15, 1999. The sixty-year lifetime estimate is probably conservative; many homes could last much longer, and the lifetime of homes can vary dramatically.
 Ibid.

# 3.2.3 Delphi Analysis of the Proposed Tax Credit for Energy-Efficient Homes

#### SUMMARY

In the second phase of our analysis of the tiered tax credit for the purchase of energy-efficient homes (achieving levels of efficiency 30%, 40%, or 50% greater than the Model Energy Code) we did *not* assume that the JCT expenditure estimates were accurate. Instead, we surveyed a panel of experts to determine the impact the credit would have on the demand for energy-efficient homes and the associated impact on the price of efficient housing. We also deviated from our preliminary analysis by assuming the credit would be enacted as part of a larger suite of policies intended to facilitate the market penetration of efficient residential buildings. With the exception of the research and development provisions parallel to those contained in the R&D section of the President's Climate Change Technology Initiative, the policies included in the attending suite involve little, if any, government spending.

The altered parameters of the second analysis resulted in a total expenditure on the credit for energy-efficient homes of \$35 million, present value (market discount rate), while JCT estimates an expenditure of \$369 million over the five-year period the credits are available. We found that, with the package of policies, the carbon savings from energy-efficient home purchases above business-as-usual<sup>44</sup> would reach a total of 36 million metric tons over the lifetime of the homes (29 MtC under the

assumption that the electricity displaces only natural gas combustion). When the tax credit was applied on top of the package of policies, carbon savings over the lifetime of the homes reached 47 million metric tons, although only 1.9 million metric tons would be displaced by 2018 from the tax credit alone.

Table 1: Total Carbon Savings and Budget Expenditure				
	Budget			
	Expenditure (million \$)	During the Credit Period	2000-2018	
JCT estimates	369	0.9/0.7	14.3/11.4	
CSE estimates	35	0.1/0.08	18/14.4	

# Table 1 details the findings of the

study compared to the JCT estimates. All figures in the table represent savings from the policy package and credit together and include carbon savings from business-as-usual energy efficient home purchases. The JCT estimate assumes that only the tax credit is in place. The second figure in italics in each carbon savings cell provides the savings under the assumption that the reduced electricity demand displaces electricity from natural gas fired plants instead of the forecast average electricity fuel mix.

Carbon savings in the CSE case are much higher in the period after the credit expires because they include the effects of the credit and policy package on the market for energy-efficient homes after the credit itself expires. The JCT savings after the credit period represent only the continued carbon savings from homes purchased with the tax credit.

Table 2 details the carbon savings, ancillary benefits, and consumer surplus that are achieved by each policy increment; the package of policies over business-as-usual and the credit increment over the package.

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<sup>&</sup>lt;sup>44</sup> The business-as-usual case referred to here is that defined by the recipients of our survey.

The tax credit increases the effect of the package of policies in stimulating purchases of energy-efficient homes by almost a third, and increases the rate of energy efficient home purchase price decline by about half. The effects of the package of

Table 2: Incremental Effects of the Package of Policies and the Tax Credit

		Budget	Consumer	Ancillary	Benefits	Carbon Savings	
	Discounting	Expenditure (millions \$)	Surplus (millions \$)	millions \$	Carbon (MtC)	(MtC) 2000- 2018	
Package	0 %		695	5,489			
over	2.5 %	N/A	472	3,834	0.01/0*	7.0/5.6	
Baseline	5 %		326	2726			
Credit	0 %	38.7	224	1,434			
over	2.5 %	36.7	153	1,012	0.00/0	1.9/1.5	
Package	5 %	34.8	106	728			

<sup>\*</sup> The second carbon savings figure assumes that electricity savings displace only natural gas fired turbines.

policies on the energy efficiency of new homes not receiving the credit results in energy bill savings of \$2.7 billion between 2000 and 2018, present value (market discount rate).

# **METHODOLOGY**

A survey comprised of three sets of questions regarding sales of energy-efficient homes was mailed to experts in the residential buildings industry, government agencies, academia, and non-governmental agencies. The first section asked respondents to indicate projected sales growth of homes at the efficiency levels eligible for the credit under three different policy scenarios: (1) business-as-usual, (2) with a package of policies designed by the surveyee, and (3) with the package of policies including the investment tax credit. The second section asked respondents to indicate the rate of price decline for energy-efficient homes under each of the three policy scenarios. The third section asked respondents to evaluate the effect the three different policy scenarios would have on average home energy consumption per square foot.

The results of the survey were tabulated and used to determine: (a) the mean estimated energy consumption savings by fuel from the tax credit and policy package relative to business-as-usual, (b) consumer surplus from the change in the price of energy-efficient homes, (c) budgetary expenditure on the tax credit, and (d) the effect of the tax credit on average U.S residential building energy consumption per square foot. Fuel savings were converted into carbon savings through the use of appropriate carbon coefficients. These findings were then used to calculate the cost-effectiveness of the investment tax credit. Fossil fuel savings were also converted into monetized environmental benefits using the approach described in the Overview of Methods and Findings above.

## PACKAGE OF POLICIES

Each respondent was asked to describe four low-cost policies that would most effectively stimulate the market for energy-efficient homes. Although each described a different set of policies, a number of particular suggestions recurred. In order of frequency the most mentioned policies were:

- > Integration of building process among customers, developers, and builders;
- > Tax credits to homebuilders;
- Tax credits to home owners for retrofitting existing homes:
- > Consumer rebates instead of the tax credit:
- Research and development on energy efficient design and construction;
- > Improved building energy codes at the state and local level;
- > Energy efficient mortgages; and
- > Campaign to educate consumers and builders on the benefits of energy efficiency in the home.

Although tax incentives were frequently listed among the most critical policies to advance efficiency in residential buildings, it was widely noted that, because the purchaser of a home usually is not involved in the building process, tax credits for the purchase of energy-efficient homes would be less effective than tax credits to builders of energy-efficient homes. Also, tax credits to homeowners for energy-efficient retrofit would help increase the efficiency of existing building stock and could result in far more carbon emissions savings than credits to new homes. Educating consumers and builders on energy-efficient building options and the advantages of energy-efficient homes, as well as integrating the building process among the various components, could significantly improve home efficiency without any federal expenditure.

With the exceptions of tax incentives and research and development funding for efficient housing design, provisions parallel to the funding proposed in the President's Budget, the policies the experts considered most effective in stimulating demand for energy-efficient homes would involve little or no government spending.

#### RESULTS

Removing the construction barriers that prevent the U.S. economy from capturing the benefits of energy-efficient housing by establishing communication among builders, developers, and consumers could help make energy efficient homes a consumer option. Increasing home energy efficiency would result in savings in emissions of greenhouse gases and local pollutants. It would also result in an

increase in consumer surplus caused by the decrease in price relative to the reference case coupled with an increase in consumer demand.

# **Consumer Surplus**

The increase in consumer surplus from the change in the price of efficient homes reaches \$326 million present value (market rate) over the 19-year forecast period when just the package of policies is in place and, with an expenditure of \$35 million on the tax credit, reaches \$441 million present value (market rate) when the package of policies and the investment tax credit are in place. These benefits will go to both purchasers of efficient homes who would have purchased the equipment under the reference case and those who purchase because of the policy-induced reduction in price.

# **Ancillary Benefits**

In addition to the carbon savings and consumer surplus from the policies to promote homes at efficiencies 30, 40, and 50% above MEC, homes that are not efficient enough to receive the credit could

Energy Efficient Homes Annual Economic Effects (millions of dollars)			
Year	Consumer Surplus	Ancillary Economic Benefits	
2000	0.17	1.16	
2001	0.43	3.57	
2002	0.78	7.24	
2003	1.18	12.20	
2004	1.62	18.54	
2005	2.17	25.76	
2006	2.87	33.81	
2007	3.76	42.68	
2008	4.87	52.37	
2009	6.26	62.88	
2010	8.01	74.21	
2011	10.20	86.36	
2012	12.94	99.33	
2013	16.35	113.11	
2014	20.60	127.72	
2015	25.88	143.14	
2016	32.45	159.37	
2017	40.59	176.43	
2018	50.69	194.29	
Discounting	Total	2000-2018	
0%	241.84	1,434.17	
2.50%	165.34	1,012.32	
5%	115.00	727.68	

also experience some ancillary benefit from the development of efficient building practices. The carbon savings from increases in the efficiency of national building stock not receiving the credit

were found to total 0.01 MtC, a negligible impact. However the improvement in energy efficiency also saves consumer expenditure on energy bills. Energy bill savings from energy-efficiency improvements above that expected under business-as-usual conditions would total \$2.7 billion present value (market inflation) if just the package of policies were in place and \$3.4 billion present value (market inflation) if the package of policies and the credit were in place. The table below shows the estimated annual value of consumer surplus and ancillary benefits from the tax credit increment alone, together with the present value under alternative discount rates.

# **Carbon Savings**

The package of policies increases purchases of energy efficient homes over business as usual to garner a carbon savings of 7 million metric tons between 2000 and 2018. If the tax credit is applied on top of the package of policies, an additional 2 million metric tons of carbon will be avoided. These savings would increase to over 120 MtC avoided over the lifetime of the homes.

If we assume that the electricity avoided from energy efficiency improvements in the credited homes displaces only natural gas combustion, all of these values will be reduced by a factor of 0.8.

The carbon savings benefit/cost comparison table below includes incremental carbon savings attributable to investments made during the forecast period as a result of the credit. This includes not only purchases of energy-efficient homes that receive the credit, but also purchases caused by credit-

Benefit/Cost Comparison of the Investment Tax Credit for Energy Efficient Homes							
Discount (%)	Expenditure (Millions \$)	Carbon Emissions Avoided (MtC)		Cost Effectiveness		lue of Carbor me of homes	
		2000- 2018	Lifetime of Equipment	(\$/metric ton)	\$5/ton	\$20/ton	\$100/ton
0	38.7	1.9	27	1.4	135	540	270
2.5	36.6	Same	Same	1.2	93.1	372.6	1863
5	34.9	Same	Same	1.1	67.5	270	1350

induced price decline, demonstration effects, institutional change, etc. However, it does not include carbon savings from policies put in place during the forecast period that influence purchases of efficient homes after the forecast period. Carbon savings from increases in the efficiency of non-qualifying homes as a result of technological spillovers from the increased stock of energy-efficient homes are also included, but only if they occur within the 2000-2018 forecast period.

The dollar value of the carbon savings and the emissions avoided would be adjusted downward by a factor of 0.8 under the assumption that electricity use avoided displaces only natural gas.

# **Local Environmental Benefits**

The same fossil fuel savings that produce greenhouse gas (CO<sub>2</sub>) emission reductions also result in reduced local health and environmental effects. These effects are monetized using a range of fuel-specific environmental values from Viscusi, et al., (1994) in the manner described in the Overview of Methods and Findings above. The table below shows annual valuations for the environmental benefit of the incremental fuel reductions from the tax credit for both greenhouse gas and local environmental benefits, together with present values for a range of real discount rates.

The monetized carbon savings figures in this table would be reduced by a factor of 0.8 and the local environmental benefits would be reduced by a factor of 0.2 if the alternative assumption is made that electricity use avoided by energy efficient homes displaces only natural gas fired electricity rather than the average electricity fuel mix.

## **CONCLUSIONS**

Although the building sector represents a large portion of national energy consumption and the opportunity for carbon emissions savings is magnified by the lifetime of homes, designing policies to encourage residential building efficiency must address a number of complicated issues. Most notably, builders currently have little incentive to install efficient heating, cooling, and hot water heating equipment since they will not be responsible for the energy bill and the increase in sticker price may deter potential customers. Complicating the policy problem is the lack of cohesion within the building industry. Consumers are typically not involved in the building

Energy-Efficient Homes Annual Environmental Effects (millions \$)						
Year	Lo	ocal Ber	`		rbon Ben	efit
	Low Value	Middle Value	High Value	5\$/ton	20\$/ton	100\$/ton
2000	0.00	0.03	0.06	0.00	0.00	0.02
2001	0.01	0.11	0.21	0.00	0.01	0.05
2002	0.01	0.21	0.42	0.01	0.02	0.11
2003	0.02	0.35	0.69	0.01	0.04	0.18
2004	0.03	0.52	1.03	0.01	0.05	0.26
2005	0.04	0.73	1.44	0.02	0.07	0.37
2006	0.05	0.99	1.93	0.02	0.10	0.49
2007	0.06	1.29	2.53	0.03	0.13	0.65
2008	0.08	1.66	3.26	0.04	0.17	0.83
2009	0.11	2.10	4.12	0.05	0.21	1.05
2010	0.13	2.64	5.17	0.07	0.26	1.32
2011	0.16	3.27	6.41	0.08	0.33	1.64
2012	0.20	4.03	7.90	0.10	0.40	2.02
2013	0.25	4.94	9.68	0.12	0.49	2.47
2014	0.30	6.02	11.80	0.15	0.60	3.01
2015	0.37	7.31	14.33	0.18	0.73	3.66
2016	0.44	8.85	17.34	0.22	0.88	4.42
2017	0.53	10.67	20.91	0.27	1.07	5.34
2018	0.64	12.84	25.16	0.32	1.28	6.42
Discounting	Total 2000-2018					
0%	3.43	68.57	134.40	1.71	6.86	34.29
2.50%	2.36	47.24	92.59	1.18	4.72	23.62
5%	1.66	33.11	64.90	0.83	3.31	16.56

process and do not have the opportunity to stipulate the efficiency of their new home. Moreover, consumers are often not aware of the energy use of their home because in many states energy codes are not enforced or not standardized at all, making it difficult to monitor the energy efficiency of new homes.

In addition, new home purchases only account for 0.01% of building stock in any given year, limiting the amount of carbon emissions savings relative to the sector that can be achieved through policies to encourage more efficient new homes. More immediate carbon emissions benefits may be achieved through providing rebates to homeowners who invest in energy-efficiency retrofits. Although the tax credits for efficient homes may help generate a market for efficient housing, the building industry needs to benefit from a higher degree of cooperation among builders, consumers, and developers to achieve nationally standardized energy codes. Designers of policies to promote the efficiency of the buildings sector should also recognize that the fastest growing energy end use is plug loads, a category that is not at all addressed by current energy code standards.

The nation could save significant sums of money by investing in energy-efficient homes and home improvements. However, home buyers have been reluctant to make these investments for a number of reasons. Although energy-efficiency investments are cost-effective -- the energy bill savings recoup

the efficiency premium within approximately five years<sup>45</sup> -- many buyers lack sufficient capital or building resources to make the investment. A targeted credit in conjunction with policies to facilitate whole building energy-efficiency design could provide the incentive needed to stimulate demand for energy-efficient residences and thereby spur innovation in housing design and construction, providing significant long-term economic and environmental benefits.

The proposed credit could be redesigned and implemented as part of a suite of policies, including educational efforts, energy efficiency financing mechanisms, rating systems, appliance standards, and building regulations, that could transform the nation's building stock and save consumers billions of dollars in energy bill expenditures. The credit as currently drafted will yield some energy and carbon emissions savings in the long term. It is cost-effective based on non-environmental economic benefits alone, a judgment that is strengthened when environmental benefits are taken into account. However, to take full advantage of the potential for economically-justified efficiency investments in homes, the credit must be imbedded in a larger suite of policies designed to overcome the barriers to sound decision making discussed above.

43

<sup>&</sup>lt;sup>45</sup> Glenn Chinery, Environmental Protection Agency, personal communication, December 14, 1998.

# 3.3 Energy-Efficient Building Equipment Tax Credit

# 3.3.1 Background

PROPOSAL46

The proposal would provide a tax credit for certain types of building equipment that are substantially more energy efficient than conventional equipment. Depending on the level of efficiency achieved, a credit of 10 percent or 20 percent of the purchase price would be available.

(a) (Tier I) A credit of 10 percent of the purchase price (up to a maximum of \$250 per unit) would be allowed for the purchase after December 31, 1999 and before January 1, 2002 of the following types of equipment:

<u>Electric heat pumps</u> (equipment using electrically-powered vapor compression cycles to extract heat from air in one space and deliver it to air in another space) with a heating efficiency of at least 9 HSPF (Heating Seasonal Performance Factor) and a cooling efficiency of at least 13.5 SEER (Seasonal Energy Efficiency Rating).

Central Air Conditioners with an efficiency of at least 13.5 SEER.

<u>Advanced natural gas water heaters</u> (equipment using a variety of mechanisms to increase steady state efficiency and reduce standby and vent losses) with an Energy Factor of at least 0.65 in the standard Department of Energy (DOE) test procedure.

(b) (Tier II) A credit of 20 percent of the purchase price would be allowed for the purchase after December 31, 1999 and before January 1, 2004 of the following building equipment:

<u>Fuel cells</u> (equipment using an electrochemical process to generate electricity and heat) with an electricity-only generation efficiency of at least 35 percent and a minimum generating capacity of 5 kilowatts. The maximum credit would be \$500 per kilowatt of capacity.

<u>Electric heat pump hot water heaters</u> (equipment using electrically-powered vapor compression cycles to extract heat from air and deliver it to a hot water storage tank) with an Energy Factor of at least 1.7 in the standard DOE test procedure. The maximum credit would be \$500 per unit.

<u>Electric heat pumps</u> with a heating efficiency of at least 9 HSPF and a cooling efficiency of at least 15 SEER. The maximum credit would be \$500 per unit.

<u>Central air conditioners</u> with an efficiency of at least 15 SEER. The maximum credit would be \$500 per unit.

Advanced natural gas water heaters with an Energy Factor of at least 0.80 in the standard DOE test procedure. The maximum credit would be \$500 per unit.

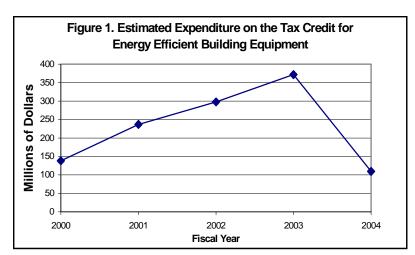
<u>Natural gas heat pumps</u> (equipment using either a gas-absorption cycle or a gas-driven engine to power the vapor compression cycle to extract heat from one source and deliver it to another) with a

<sup>&</sup>lt;sup>46</sup> Department of the Treasury, Description of the Revenue Proposals Contained in the President's Fiscal Year 2000 Budget, Washington, DC 1999.

coefficient of performance for heating of at least 1.25 and for cooling of at least 0.70. The maximum credit would be \$1,000 per unit.

The Department of the Treasury estimates that the expenditure on the tax credit for energy-efficient building equipment of both types will total 1.53 billion over the credit period.<sup>47</sup> However, it is

expected that the credit for Tier I equipment (the less efficient equipment receiving a 10% tax credit) will have a far greater cost than anticipated by the Department of the Treasury and therefore will not be included in the final proposal. The following figure represents the estimated annual budget expenditures on the tax credit only for Tier II equipment (the higherefficiency equipment). This portion of the credit would reduce federal tax revenue by

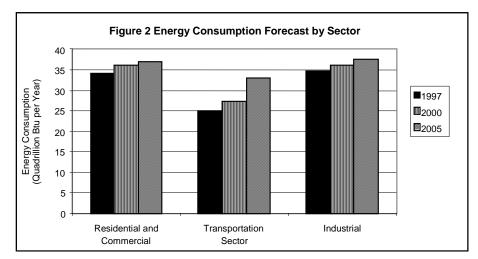


1.15 billion between 2000 and 2004.

The decline in expenditures in 2004 is explained by the expiration of the tax credit in January 1, 2004,

only three months into fiscal year 2004. Equipment purchased in later months of FY 2004 would not be eligible for the credit.

No income tax credit is provided currently for investment in energy-efficient building equipment, although a 10 percent energy



Source: Energy Information Administration, Annual Energy Outlook 1999. Table A 2. Washington D.C., December 1998.

credit is allowed for the cost of new equipment that uses solar or geothermal energy to generate electricity or to heat or cool a structure.<sup>48</sup>

<sup>&</sup>lt;sup>47</sup> Department of Treasury, Description of the Revenue Proposals Contained in the President's Budget for Fiscal Year 2000, Table 3-3. Washington DC.

<sup>&</sup>lt;sup>48</sup>Joint Committee on Taxation, Estimated Budget Effects of the Revenue Provisions Contained in the President's Fiscal Year 2000 Budget Proposal. Washington, D.C., February 1999.

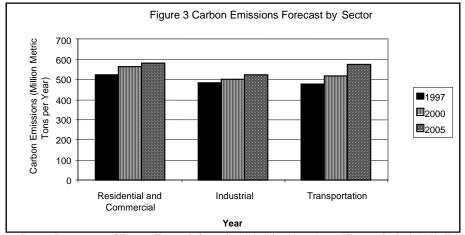
## **CONTEXT**

The EIA business-as-usual forecast projects that by 2010 energy demand in the buildings (commercial and residential combined) sector will have grown 20 percent from 1990 and 7 percent from 1997 levels, at an annual growth rate of 0.8 percent (Figure 2).

The Energy Information Administration (EIA) projects that carbon emissions from the residential and commercial sectors, including emissions from generation of electricity used in these sectors, will increase by 1.2 percent per year. This growth rate is higher than that of the industrial sector but lower than the annual 1.7 percent growth rate expected from the transportation sector (Figure 3) and

reflects the ongoing trends of electrification and penetration of new appliances and household services.<sup>49</sup>

Carbon emissions grow faster than primary energy use in the business-as-usual case, mainly reflecting changes in the fuel mix used to produce electricity. Emissions from residential buildings in 2010 are projected



Source: Department of Energy, Energy Information Administration, Annual Energy Outlook 1999. Table A19 . Washington D.C., December 1998

to have grown by 24 percent over 1990 levels while emissions from commercial buildings are expected to grow by 12 percent.<sup>51</sup>

Although proliferation of office equipment and other energy end uses is projected in the commercial as well as the residential sector, growth in carbon emissions and energy consumption is likely to be moderated by slowing growth in floorspace, efficiency standards, voluntary efficiency programs, and technology improvements.<sup>52</sup>

The tax credit for energy-efficient building equipment targets heating, cooling, and hot water heating equipment. Energy consumption for these end uses is forecasted to fall from 44 percent of total building energy consumption in 1997, to 41 percent in 2005 (Figure 4).<sup>53</sup> The miscellaneous electricity end-use accounts for over 70 percent of the growth in carbon emissions from commercial buildings and is predicted to offset nearly all carbon emission reductions from energy-efficiency improvements in other end uses.<sup>54</sup>

<sup>53</sup> See note 50. Table A.4 and A.5.

<sup>&</sup>lt;sup>49</sup> Department of Energy, Energy Information Administration, *Annual Energy Outlook 1999*. December 1998.

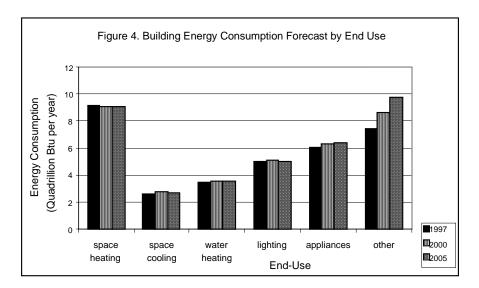
<sup>&</sup>lt;sup>50</sup> Department of Energy, Scenarios of U.S. Carbon Reductions: Potential Impacts of Energy Technologies by 2010 and Beyond, Washington, DC. September 1997.

<sup>&</sup>lt;sup>51</sup> See note 50. Appendix, Tables 4 and 5.

<sup>&</sup>lt;sup>52</sup> See note 50.

<sup>&</sup>lt;sup>54</sup> See note 49. 3.3.2.

The heating, cooling, and hot water heating technologies targeted by the credit account for a very small fraction of equipment currently sold.55 The following describes the conventional equivalent for each type of building equipment and its market:56



Electric Heat Pump Water Heaters: About 39% of U.S. households have electric water heating and approximately 4.2 million electric water heaters are sold annually in the U.S. at an operating cost of \$230 per year per unit. In total, consumers spend about \$9 billion per year on electricity for water heating. The typical new electric water heater has an energy factor rating of about 0.90. Electric heat pump water heaters eligible for the credit would have an energy factor of 1.8-2.5 and would consume 50-60% less electricity than conventional water heaters. In the absence of a tax credit, only 1000 of these heat pumps are projected to be sold annually into 2010.

Natural gas heat pumps: About 54% of US households use natural gas furnaces for space heating and 2.9 million gas furnaces are sold annually. A typical gas furnace costs about \$475 per year to operate. In total, consumers spend about \$25 billion per year for space heating using gas furnaces. The average AFUE rating of new gas furnaces is about 0.84 as a result of national standards that took effect in 1992 (requiring a minimum efficiency of AFUE 0.78). Heat Pumps qualifying for the credit would be required to achieve a heating coefficient of performance of at least 1.25 for heating and 0.70 for cooling. There are currently no heat pumps being purchased that meet the efficiency requirements of the credit. However such heat pumps would save 590-715 kg of carbon per year.

Natural gas water heaters: About 53 percent of U.S. households use natural gas for water heating and 4.7 million gas water heaters are sold annually. A typical gas water heater costs about \$170 per year to operate and has an average energy factor rating of 0.57. Natural gas water heaters eligible for the credit would be on average 30 percent more efficient than standard models and would have to achieve an Energy Factor (DOE) rating of 0.80. Only about 5000 of these are currently sold per year. In total consumers currently spend about \$9 billion per year for natural gas-fired water heating.

Central air conditioners: About 45 percent of U.S. households have central air conditioning and 4.5 million central air conditioners are sold in the U.S. each year. A typical air conditioner costs about

Communication, January 15, 1999.

<sup>&</sup>lt;sup>55</sup> Koomey, Jonathan, Energy End-use Forecasting Group, Lawrence Berkeley National Laboratory. Personal

David Boomsma, Building Equipment Division, Office of Building Technology, U.S. Department of Energy, Personal Communication, December 1998.

\$175 per year to operate and consumers spend a total of about \$8 billion for central air conditioning per year. The average SEER rating of new central air conditioners has been about 10.7 for the past five years, following national standards in 1992-93. Air conditioners eligible for the Tier II credit would have to achieve a SEER rating of 15 and would save approximately 101 kg of carbon per year.

<u>Fuel Cells</u>: Currently only one megawatt (MW) of electricity is generated from fuel cells a year and there is only one manufacturer that is currently producing and selling a phosphoric acid fuel cell system in 200 kW modules. Fuel cells are extremely expensive, averaging an installed cost of \$3000 per kW (a unit typically generates 200 kW) but would save 900 kg of carbon per year per kW of installed capacity.

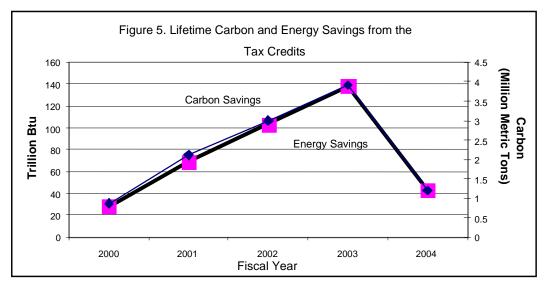
By addressing carbon emissions from the buildings sector, the credit for types of equipment that are substantially more energy efficient than conventional equipment, but are also significantly more expensive, is intended to help to accelerate the development and distribution of energy-efficient technologies, thereby reducing the national energy bill and spurring technological innovation.

# 3.3.2 Effects of the Tax Credit for Energy-Efficient Building Equipment Assuming JCT Revenue Estimates

The Joint Committee on Taxation (JCT) and Department of the Treasury published ten-year estimated budgetary effects of the tax credit for purchases of energy-efficient building equipment. These projections can also be used to quantify the carbon and energy savings from the equipment receiving the tax credit. In this part of the analysis we assumed that these expenditure estimates are accurate and then deduced the carbon emissions savings from the amount spent on the tax credit in each year. The fuel savings estimated in this section are for all units receiving the credit. Because the JCT does not provide estimates of the use of the technology in the absence of the credit, we are unable to indicate what proportion of these savings are credit-induced. Thus, the JCT derived estimates are provided for comparison purposes only. Incremental fuel savings are derived in the Delphi Analysis section below.

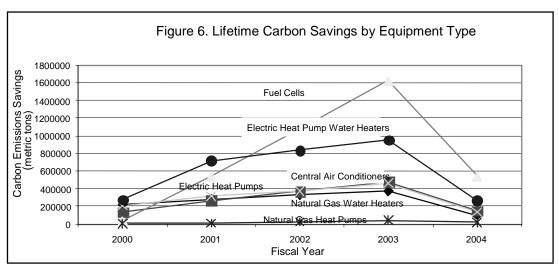
## RESULTS

The tax credit for energy-efficient building equipment, excluding indirect sales effects of the credit in the years following its expiration, would result in a carbon savings of 11 million metric tons over the lifetime of the investments (8.8 MtC if w assume only natural gas electricity is displaced) and a comparable energy savings of 382 trillion Btu. Savings of 2.1 million metric tons of carbon (1.7 under the natural gas electricity assumption) and 78.9 3 trillion Btu could be realized by 2004.

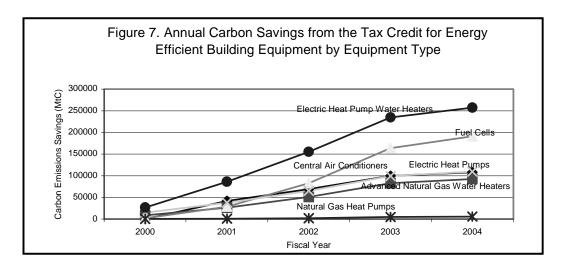


The following three figures represent carbon savings when electricity avoided displaces the average fuel mix. These figures would be adjusted downward by a factor of 0.8, or 20%, if we assume the electricity avoided displaces only natural gas fired electricity.

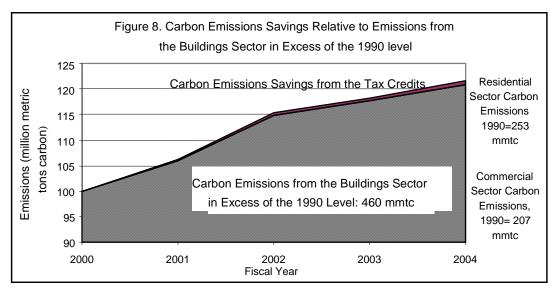
Figure 5 illustrates the carbon and energy savings from the tax credit, excluding indirect effects, over the lifetime of the investments, where the equipment-life savings are attributed to the year in which the credit is expended.



The lifetime carbon savings that can be expected from the credit for each type of equipment varies according to the number of units that are expected to be installed, the savings that can be expected from each installation, and the average lifetime of the equipment type (Figure 6). The precipitous decline in lifetime savings in 2004 merely indicates that the credit is only available for the first three months of fiscal year 2004.



These lifetime carbon emissions savings do not indicate the actual annual emissions savings that can be expected over the forecast period. The carbon emissions savings by equipment type that can be expected over the credit period are illustrated by Figure 7. This figure illustrates variations in emissions savings growth rates and installation patterns among equipment types. Carbon emissions savings from the credit would displace 0.38 percent of emissions from the buildings sector in excess



of the 1990 level between 2000 and 2004, and 0.07 percent of total emissions from the sector (Figure 8). Although these savings offset a very small percentage of total building carbon emissions in the nation, Figure 8 indicates that as installments accumulate the effects of energy efficiency investments rapidly offset a larger portion of sector emissions.

# *METHODOLOGY*

- The estimated installations for each type of equipment were multiplied by 20% of the purchase price for each unit, or the cap amount described for each credit, to determine the expenditure on each equipment type.
- The annual number of projected installations for each type of equipment were then
  multiplied by the annual carbon and energy savings that could be expected from the
  installation of each unit to arrive at the annual carbon and energy savings from each
  equipment type.
- The carbon and energy savings that continue after the installation year were calculated to arrive at the actual amount of carbon and energy saved in each year over the credit period.
- The annual carbon and energy savings in each year from each type of equipment were multiplied by the average lifetime of each equipment type to arrive at the carbon and energy savings over the lifetime of the investment.
- The savings for each equipment type in each year were summed to determine the total carbon and energy savings from the tax credit over the credit period.
- The lifetime savings for each equipment type quantified in the year the credit was received were summed to arrive at the total lifetime carbon and energy savings that can be expected as a result of the credit.

# 3.3.3 Delphi Analysis of the Proposed Tax Credit for Energy-Efficient Building Equipment

#### SUMMARY

In the second phase of our analysis of the tiered tax credit for the purchase of energy-efficient building equipment, we did not rely on the Department of the Treasury for our budget effects estimates. Instead, we surveyed a panel of experts to determine the impact the credit would have on the demand for energy-efficient building equipment and the associated impact on the price of equipment types eligible for the credit. We also deviated from the parameters of our preliminary analysis by assuming the credit would be enacted as part of a larger suite of policies intended to foster the market for efficient building technologies. With the exception of the research and development provisions parallel to those contained in the R&D section of the President's Climate Change Technology Initiative, the policies included in the attending suite would involve little, if any, government spending.

The altered parameters of the second analysis resulted in total expenditures on the credit for efficient equipment of \$108 million, present value (market inflation rate), while the Department of the Treasury estimates an expenditure of \$996 million over the seven-year period the credit is available. The variation in expenditure estimates reflects both our assumption that the 10% tax credit would not be enacted and the findings of the study that indicated that the tax credit would do little to encourage purchases of efficient equipment.

We found that when a package of policies to encourage the development and purchase of efficient equipment is enacted, carbon emissions savings between 2000 and 2018 relative to the reference case equal 4.1 million metric tons (3.3 MtC when it is assumed that avoided electricity displaces only natural gas combustion). When the tax credit was applied on top of the package of policies, an additional 2.7 million metric tons (2.2 MtC under the natural gas electricity assumption) accrued resulting in a total carbon savings from the package and credit of 6.8 million metric tons between 2000-2018.

Table 1 summarizes the findings of the study compared to the Department of Treasury constrained study. It includes carbon savings from purchases that would have been made without any policy changes as well as credit and policy package induced savings. This table indicates that JCT is much more optimistic

Table 1: Total Carbon Savings and Budget Expenditure

	Budget Expenditure (millions 1999\$)	Carbon Sav  During the  Credit Period	ings (MtC) After the Credit Period
JCT estimates 996		2.1/1.7*	11/8.8
CSE estimates	108	0.3/0.2	14/11.2

<sup>\*</sup>When electricity avoided displaces only natural gas fired electricity.

about the technologies targeted by the tax credit and their ability to penetrate the market than were our respondents. Particularly, our respondents expected very little expenditure on the tax credit for fuel cells and natural gas heat pumps. For fuel cells, this is because the credit will probably expire before fuel cells come on the market; for advanced natural gas heat pumps, because they are expected to remain prohibitively expensive relative to alternatives.

The CSE estimate of carbon savings in the period after the credit expires (2004) is dramatically higher relative to expenditure than the JCT-derived estimate because the CSE case includes savings from an increase in purchases of energy-efficient equipment due to the package of policies and the tax credit after the credit itself expires. These secondary effects of the tax credit on the rate of market

penetration were not evaluated in the JCT constrained estimate. Savings in the CSE case assume a policy scenario in which both the package of policies and the credit are in place while the Department of the Treasury constrained estimate reflects carbon savings only from installations receiving the credit. In the JCT case, without the policy package the tax credit is not expected to alter the reference case scenario in the years following the credit's expiration.

Table 2 details the savings increments from each part of the policy suite; the package of relatively inexpensive policies and the tax credit.

It is assumed that spending on the policy package will be small or include programs that are already funded. The package of policies

Table 2: Incremental Effects of the Package of Policies and the Tax Credit, 2000-2018

	Discounting	Budget Expenditure (millions \$)	Consumer Surplus (millions \$)	Carbon Savings (MtC)
Dookogo over	0 %		585	4.1/3.3*
Package over Baseline	2.5 %	N/A	418	same
	5 %		321	same
Credit over Package	0%	119	310	2.7/2.2
	2.5%	114	211	same
	5%	108	146	same

<sup>\*</sup> this figure indicates savings when fuel offsets the marginal generating unit, asseumed to be natural gas

increases carbon savings over baseline by 4 million metric tons, while the application of the tax credit on top of the policy package adds another 2.7 million metric tons. The relative impact of the package of policies and the credit on the purchase price of the targeted building equipment mimics that of the carbon savings benefits.

# METHODOLOGY

A survey comprised of three sets of questions regarding purchases of energy-efficient building equipment in three different policy environments, was mailed to experts in the heating, cooling, and water heating industry, government agencies, academia, and non-governmental agencies. The first section asked respondents to indicate projected growth in sales of equipment eligible for the credit under three different policy scenarios: (1) business-as-usual, (2) with a package of policies designed by the surveyee to promote energy-efficient building technologies, and (3) with the package of policies including the investment tax credit. The second section asked respondents to indicate the rate of price decline for energy-efficient building equipment under each of the three policy scenarios. The third section asked respondents to evaluate the spillover effect the three different policy scenarios would have on the average efficiency of standard heating, cooling or water heating equipment not receiving the credit.

The results of the survey were tabulated and used to determine: (a) the mean estimated energy savings by fuel type from the tax credit and policy package relative to business-as-usual; (b) consumer surplus from the change in the price of energy efficient heating, cooling, and water heating equipment; and (c) budgetary expenditure on the tax credits. These findings were then used to calculate cost-effectiveness of the investment tax credit. Fossil fuel savings were also converted into monetized environmental benefits using the approach described in the Overview of Methods and Findings.

## PACKAGE OF POLICIES

Each respondent was asked to describe four policies that would most effectively encourage building energy efficiency. Although each described a different set of policies, a number of particular suggestions recurred. The most mentioned in order of frequency were:

- > Taxes on electricity and hydrocarbon fuels to promote fuel switching and investments in efficient equipment;
- Policies that promote proper design and installation of heating, cooling, and water heating systems, including testing, verification and third party certification;
- > Equipment efficiency standards and national building energy codes;
- > Clear and accessible equipment labeling indicating efficiency level, such as Energy Star labeling;
- Continued research and development programs, such as PATH, Building America, and Energy Star;
- Public awareness of efficient equipment and tax incentives, and education of contractors;
- > Strengthen building performance communication among contractors, builders, and consumers about building performance;
- Tax incentives large enough so that consumers realize payback on an investment in a high-efficiency system within two to three years;
- Rebate programs in place of federal tax credits;
- > Rigorous training and certification of building equipment installers; and
- > Energy costs incorporated into the calculations for mortgage approval.

Higher electricity taxes or carbon taxes on fossil fuel and more stringent equipment standards were most frequently listed as effective policies to advance building energy efficiency. Tax incentives and further federally subsidized research into efficient and marketable building technologies were considered helpful to promoting building efficiency but less so than equipment testing, certification, and verification; fuel taxes; and equipment standards and labeling.

With the exceptions of tax incentives and research and development funding for efficient building equipment, provisions parallel to those proposed in the President's Budget, the policies our respondents considered most effective either involve little government spending, such as increases in equipment standards and education campaigns, or are revenue generating, such as higher taxes on fossil fuels and electricity.

# RESULTS

# **Consumer Surplus**

It is expected that the price of efficient heating, cooling, and water heating equipment will decrease faster than business-as-usual with the package of policies in place and faster still when the package of policies and the tax credit are in place. Consumer surplus from the change in the price of heating, cooling, and water heating equipment reaches \$321 million, present value (with market-rate discounting) over the 19-year period when just the package of policies is in place and increases to \$467 million when the package of policies and the investment tax credit are in place. The credit has less effect on the rate of price decline than does the package of policies. Not all the benefit of the credit goes to consumers; a portion is retained by manufacturers according to our panel of respondents. The consumer surplus will go to both purchasers of efficient heating, cooling, and water

Building Equipment Tax Credit Market Effects (millions dollars)		
Year	Consumer Surplus	;
2000		0.00
2001		-1.04
2002		-2.00
2003		-2.85
2004		-3.56
2005		-1.28
2006		1.17
2007		3.85
2008		6.85
2009		10.24
2010	,	18.88
2011		20.04
2012		25.69
2013	;	32.03
2014		39.20
2015		47.33
2016		35.32
2017	;	38.56
2018		<u>41.77</u>
Discounting	Total 2000-2018	
0%		310.2
2.50%		211.6
5%	,	145.9

heating equipment who would have purchased the equipment under the reference case and to those who purchase because of the policy-induced reduction in price. The table below shows the estimated annual value of incremental consumer surplus from the tax credit, together with the present value under alternative discount rates.

# **Ancillary Benefits**

In addition to the consumer surplus from the policies to promote efficient heating, cooling, and water heating equipment, equipment that is not efficient enough to receive the credit could also experience some spillover benefit from the development of efficient heating, cooling, and water heating technologies. Our data from this section of questions was sketchy and incomplete, but it should be noted that improvements in standard heating, cooling, and water heating equipment efficiency could result in carbon savings and energy bill savings additional to those indicated by the above analysis.

# **Carbon Savings**

When the package of policies described above is enacted, purchases of efficient heating, cooling, and water heating equipment over baseline would occur that would result in carbon emissions savings totaling 4.1 million metric tons of carbon between 2000 and 2018. If the tax credit proposed in the President's budget is enacted on top of this package of policies, an additional savings of 2.7 million metric tons could be expected, bringing the total to 6.8 million metric tons. These figures would be adjusted down by a factor of 0.8 under the assumption that avoided electricity displaces only natural gas fired electricity

The incremental carbon savings from the tax credit would cost \$108 million over the five years the credit is available. Efficient central air conditioners account for the largest increase in budget expenditure, \$66 million. The largest carbon savings are expected to come from fuel cells, although few would be purchased over the credit period. The tax credit would increase purchases of efficient equipment enough to achieve a cost-effectiveness of \$40/metric ton of carbon saved.

Natural gas heat pumps are expected to remain prohibitively expensive even with the package of policies and tax incentives. Many of our respondents indicated that natural gas heat pumps currently are not expected to sell at all. Moreover, the cooling performance of the gas heat pump targeted by the credit is lower than that of a standard air conditioner and, if installed in a cooling-dominated climate, would have little if any efficiency benefit.

Benefit/Cost Comparison of the Tax Incentive for Efficient Building Equipment							
Discounting			Emissions ed (mMtC)	Cost Effectiveness	\$ Value of Carbon Savings (Millions)		
%	6 (Millions\$)	2000- 2018	Lifetime of Equipment	(\$/metric ton)	\$5/ton	\$20/ ton	\$100/ ton
0	118.6	2.7	15.8	7.5	79.1	316.5	1582.6
2.5	114.0	same	same	7.2	52.3	209.3	1046.7
5	108.0	same	same	6.8	23.5	93.9	469.4

Fuel cells are the only generating technology among the building technologies analyzed and are not yet marketable. However, once fuel cells enter the market, as early as 2005, sales are expected to

grow rapidly due to a niche market in critical applications, such as health care facilities where reliable power is essential.

Electric heat pumps are currently more than twice as expensive as standard equipment and suffer from reliability problems that could be ameliorated with rigorous training requirements for contractors and vendors, and installment verification. Gas water heaters and central air conditioners will probably be most able to easily and cheaply make efficiency improvements to meet the eligibility requirements for the 20% investment tax credit.

The carbon savings benefit/cost comparison table below includes incremental carbon savings attributable to investments made during the forecast period as a result of the credit. This includes not only purchases of energy-efficient building equipment that receives the credit, but also purchases caused by credit-induced price decline, demonstration effects, institutional change, etc. However, it

does not include carbon savings from policies put in place during the forecast period that influence purchases of efficient equipment after the forecast period.

Both carbon emissions avoided and the dollar value of these avoided carbon emissions would be adjusted downward by 20% under the assumption that avoided electricity use displaces only natural gas fired electricity.

#### **Local Environmental Benefits**

The fossil fuel consumption savings also reduce local air pollution emissions, thus causing local health and environmental benefits. These benefits are monetized using a range of fuel-specific environmental values from Viscusi, et al., (1994) in the manner described in the Overview of Methods and Findings above. The next table shows annual valuations for the environmental benefit of the incremental fuel reductions

Building Equipment Tax Credit Environmental Effects (millions \$)						
Year	Lo	cal Bene		Carb	on Bene	fit
	Low Value	Middle Value	High Value	5\$/ton	20\$/ton	100\$/ton
2000	0.0	0.0	0.0	0.0	0.0	0.0
2001	0.0	0.1	0.4	0.0	0.0	0.1
2002	0.0	0.3	1.1	0.0	0.0	0.2
2003	0.0	0.6	1.9	0.0	0.1	0.4
2004	0.1	0.9	3.2	0.0	0.1	0.6
2005	0.1	1.4	4.8	0.0	0.2	0.9
2006	0.1	2.0	6.8	0.1	0.3	1.3
2007	0.2	2.8	9.5	0.1	0.4	1.8
2008	0.2	3.9	13.2	0.1	0.5	2.5
2009	0.3	5.4	18.3	0.2	0.7	3.4
2010	0.5	7.5	25.4	0.2	0.9	4.7
2011	0.7	10.5	35.5	0.3	1.3	6.6
2012	0.9	14.7	49.9	0.5	1.9	9.3
2013	1.3	20.8	70.6	0.7	2.6	13.2
2014	1.9	29.7	100.7	0.9	3.8	18.8
2015	2.7	42.6	144.6	1.3	5.4	27.0
2016	3.9	61.6	209.0	1.9	7.8	39.0
2017	5.7	89.6	303.8	2.8	11.3	56.7
2018	8.3	130.8	443.9	4.1	16.6	82.8
Discounting	Total 2000-2018					
0%	26.9	425.3	1,442.8	13.5	53.8	269.2
2.50%	17.9	282.2	957.3	8.9	35.7	178.6
5%	12.0	190.0	644.6	6.0	24.1	120.3

from the tax credit for both greenhouse gas and local environmental benefits, together with present values for a range of real discount rates.

The local environmental benefits values would be adjusted downward by a factor of 0.09 if electricity avoided is assumed to displace only natural gas fired electricity rather than the forecast average electricity fuel mix. Carbon benefits values in the table would be adjusted downward a factor of 0.8.

#### **CONCLUSIONS**

Tax credits of the duration and amount proposed in the President's budget would probably serve more as an advertising tool than as a real economic incentive. Nonetheless, the fact that the estimated consumer surplus increase exceeds the price of the credit suggests that the combination of advertising and incentive effects may be beneficial in developing the market.

The credit to purchasers of energy-efficient heating, cooling, and water heating equipment may be less successful than equally costly rebates that allow the purchaser to benefit from the purchase immediately and lower the first cost for equipment. For a tax incentive program to be successful it must lower the cost of the equipment significantly enough to make the equipment competitive with standard alternatives in the minds of consumers. Our results suggest the tax credit may need to be linked with other policies in order to achieve this end.

Creating a supportive sensible installment environment for the equipment is equally as important as making the initial purchase price affordable. Simply requiring verification of the proper installation and sizing of all standard efficiency level heating, cooling, and water heating equipment could save energy in buildings. To establish a market adequate to generate production volumes great enough to create economies of scale for efficient building equipment, either (A) consumers must be convinced that energy-efficiency investments result in a higher return than other investment options, or (B) legislation must mandate that high efficiency equipment be installed and be installed properly. Our panel of respondents suggests that objective A could be achieved through the use of rebates, electricity taxes, and consumer awareness campaigns, including product labeling; and objective B could be achieved through higher equipment standards, certification and testing of installed equipment, and development programs, such as Building America, PATH and Energy Star.

Without such policies, the trend towards greater household energy consumption will continue. In fact, because the highest energy end use category is plug loads, household energy consumption will continue to grow in all of the policy cases unless fuel taxes are increased and household appliance standards are elevated.

The tax credit for energy-efficient building equipment will be modestly effective in stimulating the market for efficient technologies. However, it is probably not sufficient to achieve the possible savings from the proliferation of these technologies without parallel improvements in efficiency standards for commercial and residential appliances or other economic incentives to invest in energy-efficient equipment.

It is particularly important to develop incentives, education programs, or mandates targeted at builders. Most building equipment is purchased by contractors wishing to minimize expenditures on building construction, who have little incentive to invest in the long-term energy bill savings of efficient equipment. This factor, in conjunction with the high purchase price of the equipment types, suggests that even with the credit the efficient equipment will not enjoy full market penetration until inefficient equipment types are discouraged by other economic or regulatory conditions.

# 3.4 Investment Tax Credit Proposed for Combined Heat and Power Systems

# 3.4.1 Background

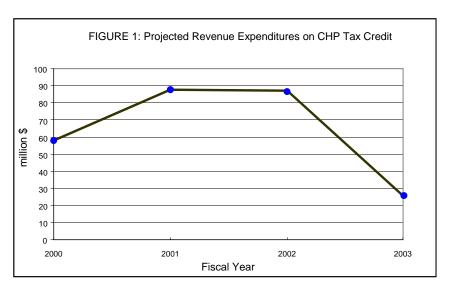
# **PROPOSAL**

The proposal would establish an eight percent investment tax credit for certain combined heat and power (CHP) systems, technologies that produce electricity as well as thermal energy and/or mechanical power from a single energy input.<sup>57</sup>

To qualify for the credit, a CHP system must:

- have an electric capacity greater that 50 kilowatts (kW) or the ability to produce an equivalent amount of mechanical power (67 horsepower);
- produce at least 20 percent of its total useful energy as thermal energy and at least 20 percent as electric and/or mechanical power;
- have a total energy efficiency greater than 60 percent for systems with less than 50 megawatts (MW) electrical capacity or 67,000 horsepower mechanical capacity, and greater than 70 percent for larger systems;
- have depreciation allowances based on a 15-year recovery period and a 150 percent declining balance method if the assets would otherwise be assigned a recovery period of less than 15 years;
- be placed in service after December 31, 1999 and before January 1, 2003; and
- be located in the United States.

The revenue estimates from the Joint Committee on Taxation (JCT), shown in Figure 1, reach \$88 million in fiscal years 2001 and 2002, with a \$29 million carry-over in fiscal 2003 for CHP installations in the last quarter of calendar year 2002. There is no delay in reaching the maximum expenditure because many CHP applications can use the same technology as used for existing separate heat and power



Source: U.S. Congress, Joint Committee on Taxation. "Estimated Budget Effects of the Revenue Provisions Contained in the President's FY2000 Budget Proposal." Washington, DC. February 1999.

generation, therefore such facilities will likely take advantage of the tax credit as soon as it is available.<sup>58</sup> The year 2001 will also see the "next wave" of new high-efficiency, smaller-scale

<sup>&</sup>lt;sup>57</sup> U.S. Congress, Joint Committee on Taxation. "Estimated Budget Effects of the Revenue Provisions Contained in the President's FY 2000 Budget Proposal." Washington, DC. February 1999.

<sup>&</sup>lt;sup>58</sup> Moomau, P. Economist, Joint Committee on Taxation. Personal communication on January 28, 1999.

technologies, such as Advanced Turbine Systems (ATS) and most fuel cell technologies, enter the CHP market. 59-60

The \$259 million spent on the CHP credit over the forecast period represents three percent of the expenditures on the total climate technologies incentive package, approximately the same percentage projected to be spent on the credits for rooftop solar and energy-efficient building equipment.

## **HISTORY**

The Crude Oil Windfall Profit Tax Act of 1980 established a 10 percent tax credit, in effect from January 1, 1980 through December 31, 1982, for cogeneration equipment not powered by oil or gas and installed in existing industrial or commercial facilities.<sup>61</sup> There are no current tax credits for CHP.

#### **CONTEXT**

Competition ended in the electricity industry in the 1920s and 1930s. Real fuel prices steadily decreased from the 1930s to the early 1960s while technological advances raised plant efficiency from less than 20 percent to 35 percent. Electric generators in the regulated monopoly market had no incentive to use all of the energy in fuel and no incentive to recover and sell waste heat. For the 70 years of legally-enforced electric monopoly, electricity and heat generation have been completely separate industries.<sup>62</sup>

Increasing costs of large electric plants led to rising electricity prices during the late 1960s and the 1970s. As a result, smaller generation technologies began to improve. Institutional and regulatory barriers to combined heat and power systems were addressed in the 1978 Public Utility Regulatory Policies Act (PURPA), which allowed non-utility generation from cogeneration facilities. PURPA required electric utilities to interconnect with cogenerators, to provide back-up power, and to purchase electricity from CHP facilities at a rate equal to the utilities' avoided costs. 4

The effects of PURPA on the CHP industry were dramatic, with a 400 percent increase (from 10 to 44 gigawatts) in industrial CHP capacity between 1980 and 1995, a growth rate of 11 percent per year. Deregulation of the airline and natural gas industries during those years spurred CHP growth by encouraging the development of more cost- and energy-efficient turbines and decreasing gas prices. 65 At the same time, a split developed in the cogeneration market between traditional plants driven by steam demand and industry-specific fuels and generation technologies, and non-traditional facilities driven primarily by demand for electricity. 66

CHP systems are found in both the industrial and commercial economic sectors. In 1997, cogeneration accounted for 9 percent (328 billion kilowatt-hours) of total U.S. electricity generation.<sup>67</sup>

<sup>&</sup>lt;sup>59</sup> Major, W. and K. Davidson. Gas Turbine Power Generation, Combined Heat and Power: Environmental Analysis and Policy Considerations, Carlsbad, CA: Onsite Sycom Energy Corporation, 1998.

Munson, R. and T. Kaarsberg, "Unleashing Innovation in Electricity Generation." Issues in Science and Technology, National Academy of Sciences, Spring 1997.

<sup>&</sup>lt;sup>61</sup> Edwards, C., A. Rousso, P. Merrill, and E. Wagner, Price Waterhouse Coopers LLP., "Cool Code: Federal Tax Incentives to Mitigate Global Warming," *National Tax Journal*, Vol. LI, No. 3, September 1998.

 <sup>&</sup>lt;sup>62</sup> Casten, T. R. and M. C. Hall, "Barriers to Deploying More Efficient Electrical Generation and Combined Heat and Power Plants," White Plains, NY: Trigen Energy Corporation, September 1998.
 <sup>63</sup> See note 62.

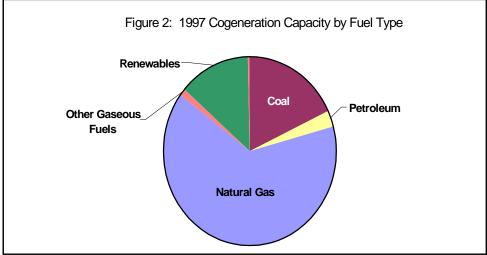
<sup>&</sup>lt;sup>64</sup> Geller, H., S. Nadel, R. N. Elliott, M. Thomas, and J. DeCicco, *Approaching the Kyoto Targets: Five Key Strategies for the U.S*, Washington, DC: American Council for an Energy-Efficient Economy, August 1998.

<sup>&</sup>lt;sup>65</sup> Cicio, P. N., Global Issues Manager, Dow Chemical, "The CHP Summit: Help... not Hurt!" Presented at The CHP Summit, Arlington, VA on December 1, 1998

<sup>&</sup>lt;sup>66</sup> Energy and Environmental Analysis, Inc. 1998, "Summary of the 1998 Industrial Cogeneration Projection." Topical Report GRI-98/0173, Arlington, VA: Gas Research Institute.

<sup>&</sup>lt;sup>67</sup> Department of Energy, Energy Information Administration. *Annual Energy Outlook 1999*, Table A8. Washington, D.C., December 1998.

Total CHP capacity in 1997 was 51,800 MW, with 64 percent of that capacity (33,400 MW) fueled by natural gas. Of the remaining CHP capacity, 18 percent was fueled by coal, 13 percent by renewables, and 3 percent by petroleum (Figure 2).68



Source: Department of Energy, Energy Information Administration. *Annual Energy Outlook 99*, Table A9. Washington, DC. December 1998.

# **Industrial Sector**

# **Industrial-scale CHP technologies:** <sup>69</sup>

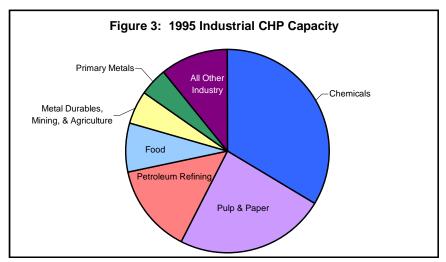
- Conventional boiler/steam turbines use the same technology as non-CHP utilities and can burn a wide variety of fuels including waste and byproducts from industrial processes, such as paper and primary metals. Although capacities range from 10 kW to over 400 MW, the typical size of these systems is 10 MW.
- Conventional combustion turbines can burn natural gas and industrial by-product gases. With power-to-heat ratios that approach 1.0, they produce excess power that could be sold to utilities. Capacities range from 20 kW to over 300 MW, with typical plants at 5 MW.
- Combined-cycle combustion turbines are the same as conventional combustion turbines but with very high power-to-heat ratios, generating greater amounts of excess electricity for sale to utilities. They also have much higher capacities, averaging 70 MW.
- **Internal combustion systems** are small reciprocating engines averaging 1 MW capacity, ranging from 10 kW to 16 MW. Their small size makes them a minor part of the industrial CHP market.

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<sup>&</sup>lt;sup>68</sup> See note 67, Table A9.

<sup>&</sup>lt;sup>69</sup> See note 66.

Five manufacturing industries historically dominated the industrial CHP market: chemicals, pulp and paper, petroleum refining, primary metals, and food. These were ideal industries for large CHP systems due to their high constant steam requirements and the availability of by-products or waste for fuel. The primary metals industry, specifically iron and steel, experienced a shift in manufacturing technology that made it less suitable for CHP, and thus represents a very small portion of total CHP capacity in 1995. The other four industries have remained large cogeneration markets (Figure 3).70



Source: Energy and Environmental Analysis, Inc. "Summary of the 1998 Industrial Cogeneration Projection." Topical Report GRI-98/0173. Arlington, VA: Gas Research Institute. 1998.

The industrial CHP market can be divided into two segments based on size. Large industrial systems, found in petroleum refineries, pulp and paper mills, and chemical plants, have capacities ranging from 25 MW up to hundreds of megawatts. Systems at this scale have the largest share of the current CHP market and represent the best short-term growth potential. Smaller industrial systems, at less than 25 MW capacity, represent another important growth segment over the next ten years as manufacturers replace aging boilers with turbines or CHP.<sup>71</sup> Significant growth in the industrial cogeneration market is expected through 2020, dominated by large non-traditional facilities until 2005. After 2005, all projected growth is attributed to smaller, industry-specific traditional CHP systems.<sup>72</sup>

## **Commercial Sector**

## Small-scale CHP systems<sup>73</sup>

**Reciprocating engines:** Packaged systems of 100 kW capacity or less have been available in the U.S. since the 1980s, and these are cost-effective down to 25 kW, a size appropriate to a small restaurant or other commercial establishment. Reciprocating engines have the lowest current cost, approximately \$300/kW, but they are also the largest and noisiest of the three CHP technologies, and they emit the most NOx. By 2010, these engines will be twice as efficient as separate heat and power systems.

<sup>&</sup>lt;sup>70</sup> See note 66.

<sup>&</sup>lt;sup>71</sup> Kaarsberg, T. and R. N. Elliott, "Combined Heat and Power: Saving Energy and the Environment." Northeast-Midwest Economic Review, March/April 1998. <sup>72</sup> See note 66.

<sup>&</sup>lt;sup>73</sup> Kaarsberg, T., R. Fiskum, J. Romm, A. Rosenfeld, J. Koomey, and W. P. Teagan, "Combined Heat and Power (CHP or Cogeneration) for Saving Energy and Carbon in Commercial Buildings," In Proceedings of the ACEEE 1998 Summer Study on Energy Efficiency in Buildings, vol. 9. Washington, DC: ACEEE, 1998.

- Gas microturbines: At present, gas turbines are only cost-effective down to a capacity of 500 kW, with a cost of approximately \$600/kW. Smaller turbines, with 100 kW capacity or less, should be available in 1999 or 2000. The newest technology in this category, the Advanced Turbine System (ATS), should be commercialized in 2000 at a cost of approximately \$350/kW.
- Fuel cells: There are four types of fuel cells (phosphoric acid, proton exchange membrane, molten carbonate, and solid oxide), but only one type, the 200 kW phosphoric acid fuel cell, is currently available in the U. S. These are the most expensive of the small-scale CHP technologies at \$3000/kW, but they are quiet, emit negligible amounts of NO<sub>x</sub>, and contain no moving parts. Competition in the transportation and telecommunications markets will reduce the high costs of fuel cells, but not by the order of magnitude necessary to make them comparable with turbines and engines. By 2010 fuel cells will be twice as efficient as separate heat and power systems.

The only types of commercial buildings currently using CHP systems are universities, hospitals, and hotels -- large high-occupancy facilities operating seven days per week with large thermal and hot water loads. While CHP is well-established in the industrial sector, the technology is not as familiar to those concerned with the energy efficiency of commercial buildings. This should change in the near future as replacements are needed for aging boilers and heating/cooling equipment.<sup>74</sup> The commercial market for CHP systems can be divided into two very distinct segments. An important long-term market is in "self-powered buildings," small commercial facilities or institutional systems which would use packaged 25 kW or larger CHP systems to generate a portion of their electricity and use the waste heat from that generation for heating and cooling. Short-term growth in this market segment is projected to be modest compared to its future potential. Even slower growth is expected in the second commercial market segment, district energy systems, which can serve multibuilding institutions such as government complexes and universities. District energy systems using CHP technology are complex and thus take several years to develop.<sup>75</sup>

# 3.4.2 Analysis of the Investment Tax Credit for CHP Assuming JCT Revenue Estimates

The Joint Committee on Taxation (JCT) ten-year estimate of the budget effect of the tax credit for CHP systems can also be used to quantify the carbon and energy savings from the equipment receiving the tax credit. In this part of the analysis we assumed that the JCT expenditure estimates are an accurate reflection of future CHP capacity installations. The fuel savings estimated in this section are for all units receiving the credit. Because the JCT does not provide estimates of the use of the technology in the absence of the credit, we are unable to indicate what proportion of these savings are credit-induced. Thus, the JCT derived estimates are provided for comparison purposes only. Incremental fuel savings are derived in the Delphi Analysis section below.

## RESULTS

Combined heat and power systems lower total carbon emissions in two different ways: by reducing the amount of power generation necessary to produce electricity and heat, and by replacing coal-fired generation with cleaner natural gas or emission-free biomass. Given the seven-year economic lifetime of CHP equipment, total carbon savings over that lifetime can be calculated. In the figure below, these lifetime savings are attributed to the year the equipment was installed and the tax credit was claimed (Figure 5). A total of 33.5 million metric tons of carbon emissions (MtC) are avoided over the economic lifetime of the CHP equipment installed due to the proposed credit (21 MtC if we

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<sup>74</sup> See note 69.

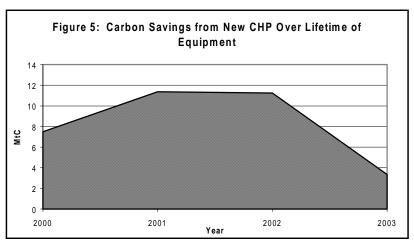
<sup>&</sup>lt;sup>75</sup> See note 71.

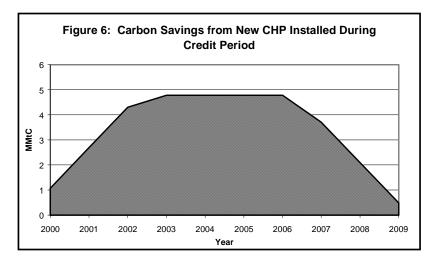
assume that the electricity savings displaces only natural gas fired electricity). The data displayed in the following three figures assumes that the electricity avoided from CHP investments displaces the average electricity fuel mix. All data would be adjusted downward by a factor of 0.63 if avoided electricity displaces only natural gas fired electricity.

In each year after 2000, carbon savings are the sum of the savings from new CHP equipment installed in that year and the savings from equipment installed in previous years of the credit period. The last

CHP installations qualifying for the tax credit in 2002 will operate for seven years, therefore carbon savings from equipment receiving the credit will continue to accrue through 2009 (Figure 6).

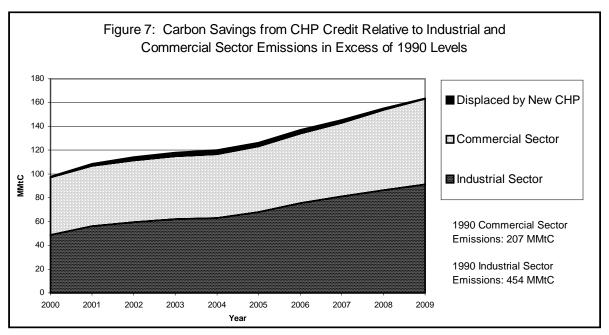
Carbon emissions from the industrial sector totaled 482 million MtC in 1997. This sector accounts for 30 percent of total U.S. carbon emissions, and emissions from the sector are increasing by 0.9 percent per year (the slowest increase among sectors). Carbon emissions in 1997 from the commercial sector were 237 million MtC, representing 16 percent of the U.S. total. Commercial sector emissions are projected to increase at a rate of 1.2 percent per year.76





The cumulative carbon savings expected from the proposed CHP credit are displayed in Figure 7 and are shown relative to the emissions from the U.S. industrial and commercial sectors in excess of the 1990 emissions (which are the target for emissions under the Kyoto Protocol). This percentage reaches a maximum in 2003 and 2004 of 2.7 percent of total emissions from the two sectors. Cumulative emissions savings begin to decline after 2006 as CHP equipment installed during the credit period reaches the end of its economic life.

<sup>&</sup>lt;sup>76</sup> See note 67, p. 38 and Table A19.



Source: Department of Energy, Energy Information Administration. *Annual Energy Outlook 1999*, Table A19. Washington, DC. December 1998.

## **CONCLUSIONS**

This analysis illustrates the power of CHP as a tool to decrease fossil fuel consumption and to help the U.S. meet goals of emissions reductions in greenhouse gases and local air pollution. CHP systems use both less fuel and cleaner fuel than in separate heat and power production.

#### **METHODOLOGY**

- The revenue projections from JCT for the 8% investment credit were multiplied by 12.5 to determine the amount spent by taxpayers in each year on new CHP systems that qualify for the credit.
- This amount was divided by an installed cost of \$650 per kW for all CHP systems, a conservative average used by ACEEE, to determine the amount of new CHP capacity added per year during the forecast period.
- CHP capacity in gigawatts (GW) was converted to terawatt-hours (TWh) of expected generation using a capacity factor of 0.685, or 6000 hours of operation per year.
- The carbon emissions from coal and natural gas displaced by new CHP capacity were calculated using an estimate of 0.16 MtC/TWh.<sup>79</sup>
- Cumulative and lifetime carbon savings over the life of the CHP equipment were calculated using an economic lifetime for gas turbines and engines of 7 years.
- The cost-effectiveness of the proposed CHP credit was calculated by dividing the
  expenditures in each year of the credit by the lifetime carbon savings from CHP equipment
  installed in each year of the credit.
- The above calculations were adjusted to reflect carbon savings from CHP installed specifically due to the credit, subtracting for savings from expected baseline increases in total U.S. cogeneration capacity.<sup>81</sup> This number has not been adjusted for expected replacements of old CHP equipment with new CHP.

# 3.4.3 Delphi Analysis of the Investment Tax Credit for Combined Heat and Power

#### **SUMMARY**

In the second phase of our analysis of the combined heat and power (CHP) investment tax credit, we did *not* assume that the JCT expenditure estimates were accurate. Instead, we surveyed a panel of experts to determine the impact the credit would have on CHP capacity as well as the installed cost per kW of capacity. We also deviated from the parameters of the preliminary analysis by assuming

<sup>78</sup> Geller, H. et al., *Approaching the Kyoto Targets: Five Key Strategies for the U.S.*, Appendix E: CHP Analysis Worksheet, note 3, Washington, DC: American Council for an Energy-Efficient Economy, August 1998.

<sup>&</sup>lt;sup>77</sup> See note 64.

Pernow, S., W. Dougherty, M. Duckworth, S. Kartha, M. Lazarus, and M. Ruth., *Policies and Measures to Reduce CO<sub>2</sub> Emissions in the United States: An Analysis of Options through 2010*, p. 9. Washington, DC: World Wildlife Fund. March 1998

<sup>&</sup>lt;sup>80</sup> See note 62, p. 28.

<sup>81</sup> See note 67, Table A9.

the credit would be enacted as part of a larger suite of policies intended to facilitate the market penetration of CHP technologies. With the exception of research and development provisions parallel to those contained in the R&D section of the President's Climate Change Technology Initiative, the policies included in the attending suite would involve little, if any, government spending.

The altered parameters of the second analysis resulted in a total expenditure on the credit for CHP of \$208 million, present value (market real discount rate of 5%), an estimate comparable to the JCT estimate of \$238 million. The package of policies was found to influence installations of CHP equipment dramatically, and applying the credit in addition to the package of polices accounted for an additional 15% of total new generation from CHP. The following table details the findings of the study compared to the JCT estimates.

All of the figures in Table 1 reflect business-as-usual installments of CHP systems, together with both those induced by the package of polices and those induced by the tax credit. The CSE estimate of carbon savings after the credit period is much higher than the JCT estimate because it represents assessment of the impact of the credit and policy package on the market penetration of CHP equipment after the tax credit itself expires. The JCT estimate of carbon savings over the after the credit period reflects only the lifetime savings of equipment installed during the credit period.

Table 2 details the carbon savings and consumer surplus that can be expected from each part of the policy scenario in the CSE case; the package of policies increment and the tax credit increment. Combined, the package of policies and tax credit would nearly double electricity generation from combined heat and power systems and,

Table 1: Total Carbon Savings and Budget Expenditure Carbon Savings (MtC) **Budget** During the After the Expenditure Credit Credit (millions \$) Period Period JCT 231 17/11\* 34/21 estimates **CSE** 15/9 339/212 208 estimates

Table 2: Incremental Effects of the Package of Policies and the Tax Credit

	Discounting	Budget Expenditure (millions \$)	Consumer Surplus (millions \$)	Carbon Savings (MtC)
Package	0 %		36,153	
over	2.5 %	N/A	26,453	135/8 <i>4</i> *
Baseline	5%		19,764	
Cradit avar	0 %	235	7,719	
Credit over	2.5 %	220	5,941	32/18
Package	5 %	208	4,674	

<sup>\*</sup>When avoided electricity displaces only natural gas fired electricity

therefore, nearly double the amount of fossil fuel that is saved by co-generation of heat and power.

# METHODOLOGY

A survey comprised of two sets of questions regarding the future of CHP was mailed to experts in the CHP industry, government agencies, academia, and non-governmental agencies. The first section asked respondents to indicate growth of CHP capacity installations under three different policy

<sup>\*</sup>When avoided electricity displaces only natural gas fired electricity rather than the average fuel mix.

scenarios: (1) business-as-usual, (2) with a package of policies designed by the surveyee, and (3) with the package of policies including the investment tax credit. The second section asked respondents to indicate the rate of price decline for the cost of CHP capacity under each of the three policy scenarios.

The results of the survey were tabulated and used to determine the mean estimated energy savings by fuel type from the tax credit and policy package relative to business-as-usual, consumer surplus from the change in the price of CHP capacity, and the budgetary expenditure for the tax credit. Carbon savings were calculated from fuel savings by use of appropriate carbon coefficients. These findings were then used to calculate the cost-effectiveness of the investment tax credit. Fossil fuel savings were also converted into monetized environmental benefits using the approach described in the Overview of Methods and Findings.

#### PACKAGE OF POLICIES

Each respondent was asked to describe the four policies that would most effectively stimulate the market for CHP. Although each respondent described a different set of policies, a number of

particular policy suggestions recurred. The most frequently mentioned policies were those that eliminated the institutional barriers to CHP proliferation. These include: revision of tax treatment of CHP capital; environmental permitting on an emissions output basis to recognize overall system efficiency; removal of grid exit fees; break up of the monopoly controlling utility interconnection; limiting the amount a utility can charge for backup; and removal of state laws banning third party generation and sale of power. It was reiterated that, considering CHP is already cost-effective, the removal of these hostile institutional barriers would do far more to advance CHP than a short-lived investment tax credit or R&D government spending. The policies the experts consider most effective in stimulating CHP installations involve little or no government spending but do involve legislative initiatives.

# RESULTS

Our analysis clearly indicates that removal of the permitting, tax treatment, and interconnection barriers to CHP would result in very significant carbon savings between 2000 and 2018. The tax credit, both because

CHP Tax Credit Economic Effects (millions \$)		
Year	Consumer Surplus	
2000	104.72	
2001	212.50	
2002	323.80	
2003	439.12	
2004	432.06	
2005	426.43	
2006	422.27	
2007	419.63	
2008	418.55	
2009	419.10	
2010	421.33	
2011	425.32	
2012	431.14	
2013	438.86	
2014	448.59	
2015	460.42	
2016	474.45	
2017	490.79	
2018	509.59	
Discounting	Total 2000-2018	
0%	7,718.67	
2.50%	5,940.56	
5%	4,674.18	

of its short-lived availability and the current cost-effectiveness of CHP investment, would increase these carbon savings only slightly. Almost 75% of the \$208 million expenditure on the credit would go to consumers who already would have purchased CHP systems under the package of policies scenario and hence would stimulate relatively little new investment.

Even so, the consumer surplus generated by the increased rapidity of price decline over the package of policies scenario for CHP capacity would exceed expenditure on the credit by \$4.4 billion and

would be more than 20 times the cost of the credit. This demonstrates the economic importance of even modest induced acceleration of technological progress.

# **Consumer Surplus**

The cost of CHP capacity will decrease as production volume increases, and production volume increases dramatically when the institutional barriers to CHP installation are removed under the package of policies scenario. Consumer surplus from the change in the price of electricity above baseline reaches \$20 billion dollars, present value (market inflation rate) over the 19-year period, when just the package of policies is in place and \$24.6 billion dollars when the package of policies and the production tax credit are in place. These savings will go both to purchasers of CHP capacity who would have purchased capacity under business-as-usual and to those who purchase the CHP capacity because of the reduction in price. The table below shows the estimated annual value of consumer surplus from the tax credit, together with the present value under alternative discount rates.

# **Carbon Savings**

The package of policies would increase CHP generation by 1270 billion kWh between 2000 and 2018, while the package of policies bolstered by the investment tax credit would increase generation by 1472 billion kWh over the same period. The associated displacement of carbon emissions from the incremental increase in CHP generation over the

19-year period would equal 135 million metric tons with just the package of policies and 167 million metric tons with the package and the investment tax credit. The expenditure on the investment tax

Benefit/Cost Comparison of the Investment Tax Credit for CHP											
Discounting %	Expenditure (Millions\$)	Carbon Emissions Avoided (mMtC)		Cost Effectiveness	\$ Value of Carbon Savings (Millions)						
		2000- 2018	Lifetime of Equipment	(\$/metric ton)	\$5/ton	\$20/ ton	\$100/ ton				
0	234.5	32.4	36.93	6.3	184.6	738.5	3692.6				
2.5	220.4	same	same	6.0	147.9	591.6	2957.8				
5	207.6	same	same	5.6	121.9	487.6	2437.8				

credit to achieve the additional 32 million metric tons of carbon savings would total \$208 million, present value (5% real market discount), over the three years the credit is available. These carbon savings figures and those in the following table would be adjusted downward by a factor of 0.63 if we assume that avoided electricity displaces only natural gas fired electricity rather than the average electricity fuel mix.

The carbon savings benefit/cost comparison table below includes incremental carbon savings attributable to investments made during the forecast period as a result of the credit. This includes not only purchases of CHP equipment that receive the credit, but also purchases caused by credit-induced price decline, demonstration effects, institutional change, etc. However it does not include carbon savings from policies put in place during the forecast period that influence purchases of CHP equipment after the forecast period.

#### **Local Environmental Benefits**

The same fossil fuel savings that produce greenhouse gas (CO<sub>2</sub>) emission reductions also result in reduced local health and environmental effects. These effects are monetized using a range of fuel-

specific environmental values from Viscusi, et al. (1994) in the manner described in the Overview of Methods and Findings above. The table below shows annual valuations for the environmental benefit of the incremental fuel reductions from the tax credit for both greenhouse gas and local environmental benefits, together with present values for a range of real discount rates. These local environmental benefits values in the table above would be adjusted downward dramatically, by 99% if it is assumed that avoided electricity generation would displace only natural gas fired electricity rather than the average electricity fuel mix. The carbon values would be adjusted downward by 38% under the same assumption.

# **CONCLUSIONS**

While the CHP investment credit would be beneficial, the low market penetration

CHP Tax Credit Environmental Effects (millions dollars)											
Year		Local Ben	efit	Carbon Benefit							
	Low Value	Middle Value	High Value	5\$/ton	20\$/ton	100\$/ton					
2000	2.89	79.14	154.81	1.44	5.78	28.88					
2001	5.88	160.99	314.92	2.94	11.75	58.75					
2002	8.96	245.62	480.49	4.48	17.93	89.64					
2003	12.16	333.13	651.68	6.08	24.32	121.58					
2004	12.55	343.99	672.92	6.28	25.11	125.54					
2005	12.96	355.16	694.76	6.48	25.92	129.62					
2006	13.38	366.64	717.22	6.69	26.76	133.81					
2007	13.81	378.45	740.32	6.91	27.62	138.12					
2008	14.26	390.59	764.07	7.13	28.51	142.55					
2009	16.29	446.28	873.02	8.14	32.58	162.88					
2010	17.38	476.32	931.78	8.69	34.77	173.84					
2011	18.58	509.12	995.95	9.29	37.16	185.81					
2012	19.89	544.96	1,066.06	9.94	39.78	198.89					
2013	21.32	584.15	1,142.71	10.66	42.64	213.19					
2014	22.88	627.01	1,226.56	11.44	45.77	228.84					
2015	24.60	673.92	1,318.32	12.30	49.19	245.96					
2016	26.47	725.27	1,418.78	13.23	52.94	264.70					
2017	28.52	781.52	1,528.82	14.26	57.05	285.23					
2018	30.77	843.15	1,649.37	15.39	61.54	307.72					
Discounting											
0%	323.56	8,865.42	17,342.57	161.78	647.11	3,235.55					
2.50%	240.64	6,593.43	12,898.10	120.32	481.27	2,406.36					
5%	183.06	5,015.86	9,812.04	91.53	366.12	1,830.60					

of CHP technology in the industrial and commercial sectors is not primarily due to limited availability or high costs, but rather to a wide array of regulatory and financial barriers and to the unintended consequences of environmental regulations. The overall effect of these barriers is to maintain the status quo: large generating facilities using outdated, low-efficiency technology and the separation of heat and power generation.

Simply revising the tax depreciation schedule for CHP capital to reflect the real economic and physical lifetime of CHP equipment, requiring utilities to provide fair rates for back-up power and grid interconnect, and revising emission permitting schemes on the basis of output rather than input, would cause the number of CHP installations to increase dramatically. However, our analysis shows that, even though the benefits of the credit are small relative to the package of policies, the value of both the non-environmental and the environmental benefits are large compared to the cost of the credit. In addition, the credit may help to maintain the CHP market while the institutional barriers are being removed.

### Legal and regulatory barriers

- *No incentive for efficiency:* In a regulated monopoly, there is no way to profit from increased efficiency.
- Retail electric sales prohibited: It is illegal to sell power or heat to third parties in some states, including Louisiana, Maryland, and North Carolina. Although the 1992 Energy Policy Act opened wholesale power sales to everyone, states still control retail sales.
- Transmission competition banned: Only utilities can build new transmission and distribution wires.
- Interconnect rules determined by utilities: This is a logical policy to ensure that power from nonutility sources is compatible with the grid, but requiring utility approval of the interconnection design creates time and cost barriers that discourage on-site CHP generation.
- *Utilities charge high rates for back-up power:* Under PURPA, utilities must provide the back-up power for cogeneration facilities, but the required "fair" rate is set by the utilities themselves.
- *Utilities charge exit fees:* Large fees are assessed when facilities leave the grid.
- Condoned anti-competitive practices: Utilities often charge lower electric rates to all-electric buildings, thus discouraging customers from generating heat themselves or purchasing heat from non-utility sources. CHP plants are frequently outbid or bought out by utilities offering lower rates. Percent-of-load rate penalties are applied when customers receive too much of their electric load from non-utility sources.

### **Environmental barriers**

- Input-based rules ignore efficiency: Most environmental regulations, such as those in the Clean Air Act (CAA), mandate end-of-pipe technologies to meet input-based standards, such as parts per million of criteria pollutants in exhaust gas. A more efficient plant could use half as much fuel and produce half as much pollutant as a less efficient plant and still have the same concentration of pollutant in its exhaust. In fact, current CAA regulations increase CO<sub>2</sub> emissions because the pollution control devices that power plants are mandated to use are themselves electric and therefore decrease the plants' overall fuel efficiency. (Note: EPA has revised NSPS to include output-based NO<sub>x</sub> standards that give credit for CHP applications<sup>82</sup>).
  - Regulations extend use of older inefficient plants: EPA's New Source Performance Standards (NSPS) require that new plants in areas that do not achieve the National Ambient Air Quality Standard must meet the Lowest Achievable Emissions Rate (LAER). However, existing plants do not need to meet these stringent standards, thus it is cheaper and easier to continue operating old inefficient plants than to build new plants with twice the efficiency that would reduce emissions by up to 90%. Over two-thirds of U.S. generating capacity predates the 1972 CAA and is therefore exempt from NSPS.
  - Permits required before construction begins: This regulatory approach is based on the paradigm of large central utility power plants, which could theoretically have political leverage to receive an undeserved air permit after investing billions in a new plant. This requirement applies to plants of all

<sup>82</sup> See note 59.

sizes, therefore small CHP plants using standard generating and pollution control technology must wait 18 months or more for an air permit before construction can begin.

- *Pollution offsets not allowed:* A new CHP system lowers total emissions by reducing the need for heat from existing boilers. Because existing equipment is maintained as backup and emergency heat sources, the CHP facilities are not credited with these avoided emissions in the permitting process.
- Regulations prevent optimization with grid: New sources must meet emissions standards under all operating conditions or must shut down. CHP systems, with continuous steam obligations, need to operate at least at part load all of the time. Because input-based measurements of emissions increase when turbines are operated below 50 percent of full capacity, highly efficient CHP plants operating at part load often do not meet new source emission limits and are forced to shut down.

Table 1: Depreciation Rules for CHP Property				
CHP Property	Cost Recovery Period	Depreciation Method		
Electricity production assets with <500 kW capacity or steam production assets with <12,500 lbs/hr capacity	5 to 10 years	200% declining balance		
Electricity production assets with >500 kW capacity or steam production assets with >12,500 lbs/hr capacity, used by taxpayer on-site	15 years	150% declining balance		
Steam production assets, including combined-cycle, generating electricity for sale	20 years	150% declining balance		
Structural components of residential buildings	27.5 years	straight-line		
Structural components of non-residential buildings	39 years	straight-line		

### The tax policy barrier

Engines or turbines used in transportation applications are assigned depreciation periods of 5 to 7 years, but if these same technologies are incorporated into CHP systems the depreciation period increases to 15, 20, or even 39 years (see Table 1). The tax rules are based on the existence of large utility boilers still in service after 25 to 35 years, but these boilers only operate 100 to 300 hours per year for peak shaving, so in 30 years they may have only operated for the equivalent of a single year. Cogeneration systems, however, operate 24 hours per day every day of the year, and in seven years they have endured a full seven years of wear.

- A credit that is available for only three years will primarily have the effect of accelerating the installation of CHP installations that are already in the planning stages. It generally takes at three years to plan and site a CHP facility. Therefore the effectiveness of the credit in stimulating a strong market for CHP would be greatly enhanced if it were extended for a few more years.
- There is a concern that existing steam or electricity generating facilities can add small amounts of heat recovery or mechanical power and thus qualify for the investment credit without being true CHP facilities.<sup>83</sup>

<sup>&</sup>lt;sup>83</sup> See note 84. Personal communication by telephone on January 11, 1999.

Although the investment tax credit for CHP is very cost-effective, the primary problem in the expansion of the CHP market is the barriers, particularly the depreciation issue, not the economics of installing CHP systems.<sup>84</sup> As a result, an investment credit has not been a priority for the CHP industry because it does little to mitigate these barriers.

Efforts to remove the barriers to CHP must proceed whether or not there is a tax credit. However, our analysis suggests that, in the context of such efforts, the investment credit can provide a modest boost to the industry and a substantial net public benefit.

<sup>&</sup>lt;sup>84</sup> Elliott, R. N. Senior Associate, American Council for an Energy-Efficient Economy and President, U.S. Combined Heat and Power Association. Personal communication by telephone on January 8, 1999.

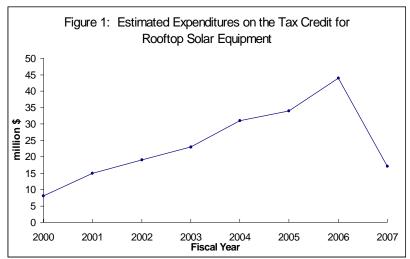
# 3.5 Tax Credit for Rooftop Solar Equipment

# 3.5.1 Background

# **PROPOSAL**

The proposal would provide a tax credit for rooftop photovoltaic (PV) systems and for solar water heating (SWH) systems that are not used to heat swimming pools. This nonrefundable credit would

equal 15 percent of the investment with a cap of \$1,000 for water heaters and \$2,000 for PV, subject to the limitations of the general business credit. The credit for solar water heating systems would extend for five years, from December 31, 1999 to January 1, 2005. For photovoltaics, the credit would last seven years, from December 31,1999 to January 1, 2007. Taxpayers would have to choose between the proposed credit and the existing 10 percent investment tax credit for businesses.85



Source: U.S. Congress, Joint Committee on Taxation. "Estimated Budget Effects of the Revenue Provisions Contained in the President's FY2000 Budget Proposal." Washington, D.C., February 25, 1999.

The Joint Committee on Taxation (JCT) projects the expenditure on the tax credit for rooftop solar equipment to steadily increase until 2005, when the credit for solar water heating systems would expire. The expenditure in 2006 and 2007, therefore, represents only expenditure on PV systems. The dramatic decrease in expenditure in 2007 is due to the difference between calendar and fiscal years used in calculating the expenditure.

The tax credit for rooftop solar equipment represents only 2.6 percent of the projected expenditures on the CCTI tax incentives package in the President's FY 2000 budget, roughly the same percentage as the credits for energy-efficient building equipment or for combined heat and power systems. A total of \$193 million is projected to be spent on the solar credit over the entire credit period (2000 to 2007).

### **HISTORY**

The Federal tax credit for solar energy property was first enacted in the Energy Tax Act of 1978. Residential taxpayers received a credit equal to 30 percent of the first \$2,000 of investment in solar energy property and 20 percent of the next \$8,000 spent, with a cap of \$2,200. The Crude Oil Windfall Profits Tax Act of 1980 raised the credit amount to 40 percent of the first \$10,000 spent, with a \$4,000 cap. 86

The residential credit permanently expired in 1985, but the 15 percent commercial credit was reinstated at the original 15 percent level for 1986 and then at 12 percent for 1987 through 1991, and

<sup>&</sup>lt;sup>85</sup> Department of the Treasury, General Explanations of the Administration's Revenue Proposals, February 1999. <sup>86</sup> Edwards, C., A. Rousso, P. Merrill, and E. Wagner, Price Waterhouse Coopers LLP., "Cool Code: Federal Tax Incentives to Mitigate Global Warming," *National Tax Journal*, Vol. LI, No. 3, September 1998.

10 percent in 1992.87 The 10 percent business tax credit for solar equipment, extended by the 1992 Energy Policy Act, excludes systems purchased by public utilities, passive solar designs, swimming pool heaters, and solar equipment used to produce steam for industrial or commercial processes. In addition to the investment credit, commercial entities can take a 5-year accelerated depreciation for solar equipment that would normally have a 20-year tax life.88 A 200 percent declining balance method is used, based on 95 percent of the original value of the solar equipment.89

Millions of SWH systems were sold before World War II, but after the war customers turned to other technologies perceived as providing "higher quality" hot water. <sup>90</sup> The oil embargoes of the 1970s ignited the modern industry for solar thermal applications, including water heating systems. Fuel shortages, high fuel prices, and federal and state tax incentives spurred enormous market growth, with the number of manufacturing firms increasing from 45 to 225 and the production of solar collectors increasing from 1.3 million square feet to 17.2 million square feet between 1974 and 1984. This rapid growth, however, led to poorly designed, poorly built, and poorly installed equipment with high failure rates, giving the industry a negative reputation. <sup>91</sup>

Expiration of the federal tax credits in 1985 caused a major market crash, exacerbated by the drop in oil prices in 1986. Despite the reinstatement of the business credit and the rise in oil prices after 1986, the solar thermal market never recovered. The rate of growth in solar collector shipments finally stabilized at 4 percent per year through 1995. 92

The first solar photovoltaic cell was developed by Bell Laboratories in 1954. Beginning in the late 1950s, PV was used to power U.S. satellites and spacecraft, and the success of PV in the space industry began to generate commercial applications. The first terrestrial PV applications in the 1960s were very expensive at \$1,000 per peak Watt (Wp). In the 1980s, the federal government encouraged the development of terrestrial PV through the Federal PV Utilization Program, which installed over 3,000 small systems, many of which are still operating today.

**CURRENT SITUATION** 

### **Solar Water Heaters**

Solar water heaters are divided into three classes by temperature and application: low temperature heaters (up to 110 degrees F) used primarily for swimming pools; medium temperature heaters (110 to 180 degrees F) for hot water, space, and process heating; and high temperature heaters (greater

<sup>&</sup>lt;sup>87</sup> Energy Information Administration, U.S. Department of Energy, *Renewable Energy Annual 1996*, Washington, D.C., April 1997.

<sup>&</sup>lt;sup>88</sup> Solar Energy Industries Association, "Investment Tax Credit for Solar Energy Property," Viewed at http://www.seia.org/taxcredi.htm on November 9, 1998.

<sup>&</sup>lt;sup>89</sup> Solar Energy Industries Association, "Federal 5-Year Depreciation Schedule for Solar Energy Property," Viewed at http://www.seia.org/legdepre.htm on November 9, 1998.

<sup>&</sup>lt;sup>90</sup> Hoffman, J. and J. Wells with W. Guiney, *Transforming the Market for Solar Water Heaters: A New Model to Build a Permanent Sales Force*, Renewable Energy Policy Project, Washington, D.C., August 1998.

<sup>&</sup>lt;sup>91</sup> Office of Technology Assessment, U.S. Congress, *Renewing Our Energy Future*, OTA-ETI-614, Washington, D.C., September 1995.

<sup>&</sup>lt;sup>92</sup> Energy Information Administration, U.S. Department of Energy, *Renewable Energy Annual 1996*, Washington, D.C., April 1997.

<sup>&</sup>lt;sup>93</sup>Energy Information Administration, U.S. Department of Energy, *Renewable Energy Annual 1996*, Washington, D.C., April 1997.

<sup>&</sup>lt;sup>94</sup> National Renewable Energy Laboratory, U.S. Department of Energy, *Solar Electric Buildings: An Overview of Today's Applications*, Report #DOE/GO-10097-357, January 1997.

<sup>&</sup>lt;sup>95</sup> Lower Colorado River Authority and Planergy, Incorporated, A Handbook for Assessing the Market Potential for Off-Grid PV Power Systems in Utility Service Territories, Austin, TX. December 1997.

than 180 degrees F) in dish or trough configurations for bulk power production. SWH systems include passive systems, such as thermosiphon, an integral collector/storage or batch heaters that do not employ an electric pump, and active systems (draindown, drainback, indirect, and phase-change) which are more flexible and eliminate the danger of freezing in the winter. The most common type of solar collector used in these systems is the flat-plate collector, which can only utilize direct sunlight above the collector surface. Evacuated-tube collectors are more efficient as well as more expensive, operating at higher temperatures and in both direct and indirect sun. Concentrating collectors, used mainly for commercial applications, operate at even higher temperatures, equipped with tracking systems to use direct sun throughout the day.

The current SWH market is basically dormant, with most sales resulting from repairs and replacements rather than new installations. There is minimal penetration of SWH into the new homes market. Further development of the SWH market is hindered by low electricity prices, the even lower cost of gas and heat pump water heaters, the demise of utility rebate programs, and the lack of promotion of solar heaters by building contractors, consumer organizations, and home improvement stores.<sup>99</sup>

The market for solar water heaters consists primarily of two sectors, pool heaters and medium-temperature water heaters. Fully 91 percent of sales are to the residential sector and 9 percent to the commercial sector. The sales are highly concentrated in five states (California, Arizona, Hawaii, Florida, and Oregon) and in Puerto Rico due to good insolation, state incentives, and demand for low-technology pool and hot water heaters. In 1997, 93 percent of collector shipments were for swimming pool heating, an increase of 10 percent from 1996, while only 7 percent were for hot water heating, constituting a 22 percent annual decline, part of a long-term trend.<sup>100</sup>

Solar water heaters have comprised 0.2 percent of the water heater market over the past 15 years but today this market share is smaller, between 0.1 and 0.2 percent, as previous credits have expired and fossil fuel prices are low. The potential market for SWH, however, is large. There are over 90 million gas and electric water heaters currently in use, with an expected lifetime of 10 to 15 years, creating a replacement water heater market on the order of 6 to 9 million installations per year, in addition to installations in new buildings.<sup>101</sup>

Although the life-cycle cost of a solar water heating system is at least 20 percent lower than a conventional gas or electric system, the high initial purchase price of a solar water heating system has discouraged consumers from installing solar heating systems. The average system sells for \$2,500 to \$3,500 and will pay for itself in energy savings in approximately 4 to 7 years. As solar sales increase, economies of scale will allow lower production costs, and the selling price should drop.

<sup>&</sup>lt;sup>96</sup> Energy Information Administration, U.S. Department of Energy, *Renewable Energy Annual 1998*, *with Data for 1997*. Washington, D.C., December 1998.

<sup>&</sup>lt;sup>97</sup> North Carolina Solar Center, *Passive and Active Solar Hot Water Systems*, Information Factsheet #SC-104, July 1996.

<sup>&</sup>lt;sup>98</sup> Energy Efficiency and Renewable Energy Network, U.S. Department of Energy, "Renewable Energy: Solar Thermal." In Consumer Energy Information: EREC Reference Briefs. Viewed at http://www.eren.doe.gov/consumerinfo/refbriefs/tpsolth.html on November 11, 1998.

<sup>&</sup>lt;sup>99</sup> Hoffman, J. and J. Wells with W. Guiney, *Transforming the Market for Solar Water Heaters: A New Model to Build a Permanent Sales Force*, Renewable Energy Policy Project, Washington, D.C., August 1998.

<sup>&</sup>lt;sup>100</sup>Energy Information Administration, U.S. Department of Energy, *Renewable Energy Annual 1998, with Data for 1997*, Washington, D.C., December 1998.

Hoffman, J. and J. Wells with W. Guiney. Transforming the Market for Solar Water Heaters: A New Model to Build a Permanent Sales Force, Renewable Energy Policy Project, Washington, D.C., August 1998.
 Energy Efficiency and Renewable Energy Network, , U.S. Department of Energy. "Renewable Energy: Solar

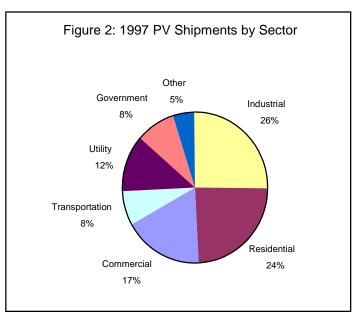
<sup>&</sup>lt;sup>102</sup> Energy Efficiency and Renewable Energy Network, , U.S. Department of Energy. "Renewable Energy: Solar Thermal." In *Consumer Energy Information: EREC Reference Briefs*. Viewed at http://www.eren.doe.gov/consumerinfo/refbriefs/tpsolth.html on November 11, 1998.

Prices of solar water heating systems have already decreased by 30 percent between 1980 and 1990 and are projected to continue decreasing, albeit at a slower rate. 103

### **Photovoltaics**

Solar cells using crystalline silicon (CSi) dominate the PV market at 96 percent of current shipments.<sup>104</sup> Newer, more efficient technologies are making progress, with amorphous silicon thin films beginning to enter the market and copper indium diselenide and cadmium telluride thin films under development.<sup>105</sup> Absent aggressive development policies, these newer films are not expected to be fully commercially viable until 2020.106

Photovoltaics have the smallest current capacity among renewable energy sources, but the most potential for widespread application.107 Customer-sited photovoltaics (CSPV), a term for grid-connected rooftop systems as well as building-integrated photovoltaics (BIPV), are expected to be commercially viable in the near future. 108 The potential market for 1 to 5 kilowatt (kW) fixed rooftop PV arrays in the residential sector is approximately 30 gigawatts (GW), with 10 million homes located in areas with good insolation.109 Commercial PV has a potential of 3 to 5 GW on an estimated 50 square kilometers of



rooftops. Encouraging factors for the expansion of commercial rooftop PV are the rapid development of BIPV, favorable tax and depreciation regulations for businesses, and electricity loads well-matched to PV output. In addition, the availability of net metering is less important for commercial PV systems because businesses have large minimum loads and will therefore use a large percentage of the electricity they generate.<sup>110</sup>

<sup>&</sup>lt;sup>103</sup> Energy Efficiency and Renewable Energy Network, , U.S. Department of Energy. "Renewable Energy: Solar Thermal." In Consumer Energy Information: EREC Reference Briefs. Viewed at http://www.eren.doe.gov/ consumerinfo/refbriefs/tpsolth.html on November 11, 1998.

Energy Information Administration, U.S. Department of Energy, Renewable Energy Annual 1998, with Data for 1997, Washington, D.C., December 1998.

105 National Renewable Energy Laboratory, U.S. Department of Energy, *Solar Electric Buildings: An Overview of Today's* 

Applications, Report #DOE/GO-10097-357. January 1997.

U.S. Department of Energy; Electric Power Research Institute, "Residential Photovoltaics," In Renewable Energy Technology Characterizations, Topical Report 109496. December 1997.

Alliance to Save Energy, American Council for an Energy-Efficient Economy, Natural Resources Defense Council, Tellus Institute, and Union of Concerned Scientists, Energy Innovations: A Prosperous Path to a Clean Environment, Washington, D.C., June 1997.

<sup>&</sup>lt;sup>108</sup> U.S. Department of Energy; Electric Power Research Institute, "Residential Photovoltaics," In *Renewable Energy* Technology Characterizations, Topical Report 109496. December 1997.

<sup>&</sup>lt;sup>109</sup> U.S. Department of Energy; Electric Power Research Institute, "Residential Photovoltaics." In Renewable Energy

Technology Characterizations, Topical Report 109496. December 1997.

110 Perez, R., H. Wenger, and C. Herig, Valuation of Demand-Side Commercial PV Systems in the United States, National Renewable Energy Laboratory. Golden, CO. 1998.

The domestic PV market currently consists of 24 percent residential and 18 percent commercial sales (see Figure 2). The record growth of PV shipments continued in 1997, with total shipments increasing by 31 percent. These shipments were primarily CSi cells and modules for export. The commercial sector experienced the greatest growth, a 57 percent increase, while the residential sector grew by 30 percent. Grid-connected and remote (off-grid) electricity generation was the largest PV end use at 36 percent of total shipments. Grid-connected PV applications increased by 70 percent in 1997 while PV for remote applications declined by 21 percent.<sup>111</sup> Although the U.S. leads with 43 percent of the worldwide market's \$1 billion of sales,112 only 30 percent of the PV technologies are installed domestically.113

In 1992, the average residential rooftop system ranged from 2 to 4 kW at a cost of about \$15 per watt which has since then substantially decreased, dependent upon the application.<sup>114</sup> The current average cost per watt for both residential and commercial systems is \$7 per watt with an average system size of 2.5 kW, thus the average cost per unit is \$17,500. CSPV systems at \$6 to \$7 per watt are already cost-effective in five states (Hawaii, California, Arizona, New York, and Massachusetts) and are being utilized.<sup>115</sup> The 1994 report from the Utility Photovoltaic Group (UPVG) found that, if prices fall to or near \$3 per watt, some 9,000 MW of domestic demand would exist for PV products.<sup>116</sup>

### CARBON SAVINGS POTENTIAL

The generation of electricity from fossil fuels, the largest single source of carbon emissions in the United States, is expected to emit a total of 596 MMtC in 2010.<sup>117</sup> Electric power plants produce 36 percent of all carbon dioxide emissions<sup>118</sup> and by 2020 electricity generation will account for 38 percent of all U.S. carbon emissions. Similarly, residential and commercial carbon emissions are expected to increase 1.2 percent annually, contributing 19 percent and 16 percent, respectively, to the overall carbon emissions in 2020. The continued growth of consumer demand for energy services will be somewhat offset by increases in efficiency and technology. 119

However, currently, only 8 percent of energy consumed in the U.S. is generated from renewable sources, with solar energy representing only 1 percent or 71 trillion Btu of this amount.<sup>120</sup> If properly utilized, within 15 years solar technology could generate sufficient electricity to provide power to 40 million homes and offset 70 days of oil imports. 121

<sup>&</sup>lt;sup>111</sup> Energy Information Administration, U.S. Department of Energy, Renewable Energy Annual 1998, with Data for 1997, Washington, D.C., December 1998.

<sup>112</sup> Solar Energy Industries Association, "PV: Lighting Up The World," Viewed at http://www.seia.org/taxcredi.htm on July 29, 1999.

Maycock, Paul, PV Energy Systems, Conversation on July 26, 1999.

Osborn, Donald E., and David E. Collier, *Utility Grid-Connected Distributed Power Systems*, National Solar Energy Conference. ASES Solar 96. Asheville, NC. April, 1996.

Wenger, Howard, Christy Herig & Roger Taylor, Patrina Eiffert, and Richard Perez, "Niche Markets for Gridconnected Photovoltaics," IEEE Photovoltaic Specialists Conference, Washington, D.C., May 13 – 17, 1995.

116 "UPVG Finds PV System Price of US \$3000/kW the Turning Point," The UPVG Record, Washington, D.C., Spring,

<sup>117</sup> Solar Energy Industries Association, Energy Production and Pollution, Viewed at http://www.seia.org/taxcredi.htm on July 29, 1999.

<sup>&</sup>lt;sup>118</sup> See note 117.

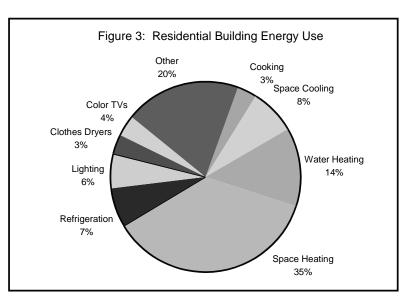
<sup>&</sup>lt;sup>119</sup> Energy Information Administration, U.S. Department of Energy, Annual Energy Outlook 1999: With Projections to 2020, Washington, D.C., December, 1998.

<sup>&</sup>lt;sup>20</sup> Energy Information Administration, U.S. Department of Energy, Renewable Energy Annual, 1998, with Data for 1997, Washington, D.C., December, 1998.

<sup>&</sup>lt;sup>121</sup> Energy Efficiency and Renewable Energy Network, U.S. Department of Energy, "Renewable Energy: Solar Thermal," In Consumer Energy Information: EREC Reference Briefs, Viewed at http://www.eren.doe.gov/ consumerinfo/refbriefs/tpsolth.html on November 11, 1998.

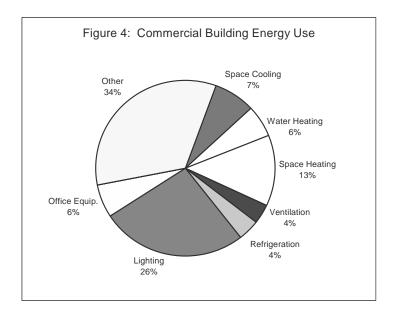
Because residential and commercial buildings now use one-third of the energy consumed in the U.S., the potential market for solar buildings technologies is substantial. Figure 3 depicts the total energy consumption for residential buildings, 57 percent of which is used for space heating and cooling and water heating.

Overall, about \$13 billion per year is spent on energy for heating water in U.S. homes.122 Using solar energy to heat residential building water could provide a reliable and clean power source as well as consumer savings. The average hot water use for a four-person family is 104 gallons of water at a cost of \$1.61 per day. This amounts to \$588 per year with a conventional electric water heating system. Solar technology



could save some 50 to 85 percent of this amount, 123 reducing the water heating costs per year to a maximum of \$294 or to as little as \$88, excluding maintenance costs. 124

Improvements in technology have allowed solar products that were previously available primarily for commercial buildings now to be available to homeowners. With reduced costs for installation and improvements in aesthetics, these systems will be a cost-effective and attractive option for both residential and commercial buildings. The diverse applications of the technologies include heating water for domestic or commercial use. supplying hot air and steam, as well as generating electricity. A homeowner could save up to \$500 the first year a new solar water heating system is installed.125



<sup>&</sup>lt;sup>122</sup> Solar Energy Industries Association. "Solar-Thermal: Warming Our Lives With Sun-Power" Viewed at http://www.seia.org/taxcredi.htm on July 29, 1999.

<sup>&</sup>lt;sup>123</sup> Solar Energy Industries Association, "Using Sunshine To Heat And Power Our Homes," Viewed at http://www.seia.org/taxcredi.htm on July 29, 1999.

<sup>&</sup>lt;sup>124</sup> North Carolina Solar Center, "Low-Costs Solar Applications for Retrofit or Affordable Housing," Information Factsheet #SC-123, June 1997.

<sup>&</sup>lt;sup>125</sup> Energy Efficiency and Renewable Energy Network, U.S. Department of Energy, "Renewable Energy: Solar Thermal," In *Consumer Energy Information: EREC Reference Briefs.* Viewed at http://www.eren.doe.gov/consumerinfo/refbriefs/tpsolth.html on November 11, 1998.

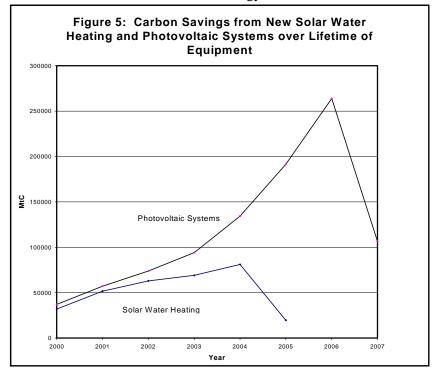
Figure 4 depicts that space heating and cooling and water heating accounts for 26 percent of the total commercial building energy consumption in relation to other energy uses. Though not as great as residential consumption, energy savings can be realized for commercial buildings, as well. A commercial solar water heating system can realize a 40 to 80 percent savings on electric or fuel bills.<sup>126</sup>

# 3.5.2 Effects of the Solar Credit Assuming JCT Revenue Estimates

The Joint Committee on Taxation (JCT) ten-year estimate of the budget effect of the tax credit for purchases of solar systems can be used to quantify the carbon and energy savings from the equipment receiving the credit. In this part of the analysis we assumed that the JCT expenditure estimates are accurate and then deduced the fossil fuel consumption savings from the amount spent on the tax credit in each year. The fuel savings estimated in this section are for all units receiving the credit. Because the JCT does not provide estimates of the use of the technology in the absence of the credit,

we are unable to indicate what proportion of these savings are credit-induced. Thus, the JCT derived estimates are provided for comparison purposes only. Incremental fuel savings are derived in the Delphi Analysis section below.

CARBON SAVINGS
Provided that the JCT
expenditure estimates are
accurate, the tax credit will
save 1.27 MtC over the
lifetime of the equipment
installed during the credit
period, with the average
lifetime of 15 years for
SWH<sup>127</sup> and 30 years for
the photovoltaic systems.<sup>128</sup>
It will save 1.02 MtC if the
electricity displaced by PV



systems is assumed to be gas fired only. Figure 5 depicts the lifetime carbon emissions displaced by SWH and PV systems during the five- and seven-year credit periods, respectively, with the lifetime savings for each system shown in the year of its installation. The dramatic drop in 2007 is due to the difference between calendar and fiscal years.

The data describing the PV carbon savings curve in figures 5 and 6 would be adjusted downward by a factor of 0.63 if it is assumed that avoided electricity displaces only natural gas fired electricity. Figure 6 describes the actual carbon savings that will be realized during the credit period. In each year

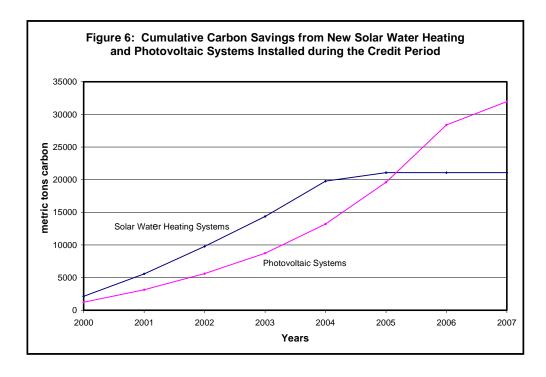
<sup>126</sup> Solar Energy Industries Association, "Solar Taking Care of Business," Viewed at http://www.seia.org/taxcredi.htm on July 29, 1999.

<sup>127</sup> Hoffman, J. and J. Wells with W. Guiney, "Transforming the Market for Solar Water Heaters: A New Model to Build a Permanent Sales Force," Renewable Energy Policy Project, Washington, D.C., August 1998.

<sup>128</sup> Osborn, Donald E., and David E. Collier, "Utility Grid-Connected Distributed Power Systems," National Solar Energy Conference, ASES Solar 96. Asheville, NC. April, 1996.

after 2000, carbon savings are the sum of the savings from new SWH and PV equipment installed in that year and the savings from the equipment installed in previous years of the credit period.

The carbon savings from solar systems receiving the credit will continue throughout the lifetime of the equipment. However, the actual carbon emissions avoided during the years the credit is available total 0.23 million metric tons. By 2010 the units that received the credit will have achieved a carbon savings of 0.39 million metric tons and by 2018 0.81 million metric tons.



### **METHODOLOGY**

- We derived the amount spent on the credit for PV by dividing the expected installed Wp generation by the average Wp per PV system (2,500 W) to determine the number of systems eligible for the credit in each year. We then multiplied the number of systems forecasted to be installed by the credit amount per system, 15% of the installed cost. We assumed 75% of PV system purchasers would take the credit.
- Subtracting the estimated amount spent on the credit for rooftop PV from the JCT combined estimate provided the amount spent on SWH.
- We divided the total amount spent on the SWH credit by the average amount credited per system (\$350) to find the number of SWH systems receiving the credit during the credit period.
- The carbon savings per unit were derived by multiplying the energy savings per unit (SWH = 2.5 MWh (SEIA)<sup>129</sup> and PV = 4.49 MWh (McNeal Technologies)<sup>130</sup>) by the carbon content of the average fuel mix. 131
- The lifetime of the technologies (SWH,15 years, and PV, 30 years) multiplied by the carbon savings per unit multiplied by the number of units installed in the credit year provided the total carbon savings per year. The sum of all lifetime carbon savings then vielded the total carbon savings for the credit period.
- Carbon savings realized over the credit period are the sum of the savings from new SWH and PV equipment installed in that year and the savings from the equipment installed in previous years of the credit period.
- To find the cost-effectiveness of each provision, the JCT revenue projections were divided by the total lifetime carbon savings for each technology.

#### 3.5.3 Delphi Analysis of the Proposed Tax Credit for Rooftop Photovoltaics and Solar Water Heaters

### SUMMARY

In the second phase of our analysis of the 15 percent tax credit for purchases of solar systems, we did not assume that the JCT expenditure estimates were accurate. Instead, we surveyed a panel of experts to determine the impact the credit would have on the market for solar systems as well as the cost per unit. We also modified the parameters of our preliminary analysis by assuming that the credit would be enacted as part of a larger suite of policies intended to facilitate market penetration of solar technologies. With the exception of research and development provisions parallel to those contained in the R&D section of the President's Climate Change Technology Initiative, the considered policies would involve little, if any, government spending.

The altered parameters of the second analysis resulted in a total expenditure on the credit for solar technologies of \$358 million (with market discount rate of 5%), while JCT estimates an expenditure of \$148 million (see table 1 below). The much higher expenditure in our estimates is accompanied by

<sup>&</sup>lt;sup>129</sup> Lowenthal, Peter, Solar Energy Industries Association, Conversation on July 26, 1999.

Mulligan, Heather, McNeal Technologies. Conversation on July 29, 1999.

Energy Information Administration, U.S. Department of Energy, *Renewable Energy Annual 1996*, Washington, D.C., April 1997.

higher carbon savings and other benefits. Table 1 details the findings of the study compared to the JCT estimates.

Table 1: Total Carbon Savings and Budget Expenditure

	Pudget	Carbon Savings (MtC)			
	Budget Expenditure (million)	During the Credit Period	2000-2018		
JCT estimates	148	0.81/0.64*	1.27/1.01		
CSE estimates	358	1.53/1.22	20.01/16.0		

<sup>\*</sup>When avoided electricity from PV applications displaces only natural gas fired electricity rather than the average electricity fuel mix.

The CSE estimates of carbon savings reflect the policy scenario in which both the package of policies and the credit are in place, while the JCT estimates reflect carbon savings only from installations receiving the credit. Both include business as usual purchases. The JCT estimate also assumes that the tax credits do not alter the reference case scenario in the years following their expiration. Table 2 details the incremental effects of the tax credit in the CSE case.

Table 2: Incremental Effects of the Package of Policies and the Tax Credit (CSE estimates)

	Discounting	Budget Expenditure	Consumer Surplus (million \$)	Ancillary Benefits (million \$)	Carbon Savings (MtC)
Package over Baseline	0% 2.5% 5%	N/A	278.2 202.7 150.4	281.7 193.7 135.0	6.41/5.1
Credit over Package	0% 2.5% 5%	431.1 407.3 358.0	786 560 406	136.6 90.2 60.1	3.9/3.1

### *METHODOLOGY*

A survey comprised of three sections of questions regarding sales of solar systems was mailed to experts in the solar industry, government agencies, academia, and non-governmental agencies. The first section asked respondents to indicate growth of the market for PV systems and solar water heaters under three different policy scenarios: (1) business-as-usual, (2) with a package of policies designed by the surveyee, and (3) with the package of policies including the production tax credit. The second section asked respondents to indicate the rate of price decline for PV and solar water heaters under each of the three policy scenarios. The third section asked respondents to evaluate the effect the three different policy scenarios would have on exports of PV modules and solar thermal collectors.

The results of the survey were used to determine:

- (a) the mean estimated energy consumption savings by fuel from the tax credit and policy package relative to business-as-usual;
- (b) consumer surplus due to the decline in the price of solar systems;
- (c) budgetary expenditure on the tax credit; and
- (d) additional profits of U.S. exporters of the solar systems under the different policy scenarios.

Fuel savings were converted into carbon emission reductions using the appropriate carbon coefficients. These findings were then used to calculate the cost-effectiveness of the investment tax credit. Fossil fuel savings were also converted into monetized environmental benefits using the approach described in the Overview of Methods and Findings above.

# PACKAGE OF POLICIES

Each respondent was asked to describe policies that would most effectively stimulate the market for solar systems. Although each described a different set of policies, a number of particular policy suggestions recurred. The most frequently mentioned policies were:

- higher tax credits and other more aggressive economic incentives than those proposed in the President's budget;
- net metering and uniform utility-grid interconnections standards;
- research and development to demonstrate the reliability of solar systems;
- development through education of an infrastructure for the installation and maintenance of PV's, as well as public education on energy efficiency;
- system benefits charges; and
- the outlawing of neighborhood covenants banning solar systems.

Tax credits or other economic subsidies were deemed necessary to level the playing field with fossil fuels. Our respondents generally found that the proposed tax credit will have limited effect as long as the institutional barriers to widespread PV application are not addressed. In addition, the credit must be high enough to make solar systems competitive in the long-term with conventional energy sources.

With the exceptions of tax incentives and research and development provisions parallel to those proposed in the President's Budget, the policies the experts considered most effective in stimulating demand for solar systems would involve little or no government spending. They would however, involve legislative initiatives.

### RESULTS

Removing the institutional barriers that prevent the U.S. economy from capturing the benefits of solar energy by establishing utility net metering and requiring standard interconnect rules, embarking on a campaign to reverse the negative publicity solar systems have received, and providing tax incentives to make solar energy more attractive relative to fossil fuels, will significantly advance the domestic market for solar systems. The by-products of stimulating the market include both greenhouse gas and local pollution emissions savings from clean solar energy, a significant consumer surplus from the decrease in price relative to the reference case coupled with an increase in consumer demand, and an increase in U.S. exports of solar technologies.

# **Consumer Surplus**

The costs of solar systems are expected to decrease under business-as-usual. The package of policies, as well as the tax credit, will accelerate the price decline and result in substantial benefits to

consumers. We quantified these consumer benefits as the consumer surplus associated with the additional price declines, accompanied by domestic sales increases under each policy scenario.

The savings, calculated as consumer surplus, from the price declines of solar systems resulting from implementation of the package of policies alone will reach 150 to 278 million dollars over the 2000-2018 period (depending on the discount rate used). The tax credit would induce an additional 406 to 786 million dollars of consumer benefits.

### **Ancillary Benefits**

Currently, most PV modules and solar thermal collectors manufactured in the United States are exported. The proportion of rooftop solar technologies that is exported has increased from 63 percent of shipments in 1996 to 73 percent in 1997.<sup>132</sup> Over the same period, there was a one-percent decline in domestic solar energy production due to the retirement of older equipment in the residential and commercial sectors after that equipment reach the end of its useful life of 20 years. 133 However, the growing exports have more than offset stagnating domestic demand.

In addition to the consumer surplus achieved by fostering a strong domestic market for PV's and solar water heaters, the policies we considered would also strengthen the ability of U.S. producers to export. Policies to promote domestic demand such as those described in this analysis would initially shift the solar

Solar Equipment Tax Credit Market Effects (millions \$)			
Year	Co	nsumer Surp	lus
	PV	Solar Water Heaters	Total
2000	0.0	0.0	0.0
2001	0.96	0.2	1.2
2002	2.01	1.0	3.0
2003	3.16	2.3	5.4
2004	4.43	4.1	8.5
2005	5.84	6.4	12.2
2006	7.41	8.9	16.4
2007	9.17	12.2	21.3
2008	9.31	14.9	24.2
2009	9.47	18.2	27.6
2010	9.66	22.3	31.9
2011	9.89	27.4	37.3
2012	10.18	34.0	44.1
2013	10.52	42.2	52.7
2014	10.93	52.7	63.7
2015	11.43	66.1	77.6
2016	12.04	83.2	95.3
2017	12.76	105.1	117.8
2018	13.63	133.0	146.6
Discounting	Total 2000-2018		
0%	152.80	634.095604	786.8934
2.50%	115.43	444.83	560.27
5%	88.86	317.20	406.06

system industry from primarily export-based to a domestic base until manufacturers are able to accommodate both domestic and export demand. Our panel of respondents believes the strengthening of the domestic market will, in the long run, increase exports of PV modules and solar thermal collectors relative to the reference case. With the package of policies and tax credit in place, the U.S. could expect to experience an increase in revenue and profits from solar system component exports.

We have used our results to determine the expected export revenue of U.S. manufacturers by assuming that export prices will mimic the behavior of domestic prices. Using an average profit margin of 15 percent, we then arrived at an estimate of additional export profits under the different policy scenarios (see table 2 above). The table below shows the estimated annual value of consumer surplus from the tax credit, together with the present value under alternative discount rates.

<sup>132</sup>Energy Information Administration, U.S. Department of Energy, Renewable Energy Annual 1998, with Data for 1997,

Washington, D.C., December 1998.

133 Energy Information Administration, U.S. Department of Energy, *Renewable Energy Annual 1998, with Data for 1997,* Washington, D.C., December 1998.

### **Carbon Savings**

We were able to identify the effects the different policy scenarios would have relative to a baseline case. This approach avoids counting installations that would occur without the tax credit but recognizes that they will still benefit from the provision of the credit. Our study found that, with the package of policies, the carbon savings from solar system installations above the reference case would reach a total of 6.41 million metric tons. When the tax credit was applied on top of the package of policies, carbon savings above the baseline reached 8.67 million metric tons over the 2000-2018 period. These carbon savings values and the ones in the following table would be adjusted downward by a factor of 0.8 to accomadate the assumption that electricity avoided from PV applications would displace only natural gas fired electricity rather than the average electricity fuel mix.

The carbon savings benefit/cost comparison table below includes incremental carbon savings attributable to investments made during the forecast period as a result of the credit and policy package. This includes not only purchases of photovoltaics and solar water heaters that receive the credit, but also purchases caused by credit-induced price decline, demonstration effects, institutional change, etc. However, it does not include carbon savings from policies put in place during the forecast period that influence purchases of solar equipment after the forecast period.

Benefit/Cost Comparison of the Tax Incentive for Solar Equipment							
Discounting	Expenditure	` ′		Cost Effectiveness	\$ Value of Carbon Savings (Millions)		
%	(Millions\$)			(\$/ton)	\$5/ ton	\$20/ ton	\$100/ ton
0	431.1	10.0	73.4	5.9	367.0	1467.8	7339.0
2.5	407.3	same	same	5.6	254.3	1017.3	5086.6
5	358.1	same	same	4.9	179.6	718.4	3592.1

	Solar Equipment Tax Credit Environmental Effects (millions \$)						
	Year	Lo	cal Ber		Carl	bon Be	enefit
•		Low Value	Middle Value	High Value	5\$/ton	20\$/ton	100\$/ton
	2000	0.00	0.00	0.00	0.00	0.00	0.00
	2001	0.01	0.14	0.27	0.01	0.04	0.20
•	2002	0.03	0.44	0.86	0.03	0.13	0.63
	2003	0.05	0.92	1.79	0.07	0.26	1.32
	2004	0.09	1.60	3.12	0.11	0.46	2.29
•	2005	0.14	2.52	4.89	0.18	0.72	3.59
•	2006	0.20	3.55	6.90	0.25	1.01	5.07
	2007	0.27	4.73	9.19	0.34	1.35	6.75
	2008	0.34	6.03	11.72	0.43	1.72	8.62
	2009	0.47	8.16	15.84	0.58	2.33	11.65
	2010	0.59	10.25	19.91	0.73	2.93	14.64
	2011	0.73	12.75	24.77	0.91	3.64	18.21
	2012	0.90	15.77	30.63	1.13	4.50	22.52
	2013	1.11	19.44	37.77	1.39	5.55	27.77
	2014	1.37	23.94	46.51	1.71	6.84	34.20
	2015	1.69	29.49	57.30	2.11	8.43	42.13
	2016	2.08	36.39	70.70	2.60	10.40	51.98
	2017	2.57	45.01	87.45	3.21	12.86	64.30
	2018	3.19	55.84	108.49	3.99	15.95	79.77
	Discounting		T	otal 20	00-201	8	
	0%	15.83	276.96	538.09	19.78	79.13	395.65
	2.50%	10.84	189.62	368.40	13.54	54.18	270.88
	5%	7.54	131.99	256.44	9.43	37.71	188.56
							<u> </u>

### **Local Environmental Benefits**

The same fossil fuel savings also result in reduced local air pollution, with the attendant health and environmental effects. These effects are monetized using a range of fuel-specific environmental values from Viscusi, et al. in the manner described in the Overview of Methods and Findings above. The table below shows annual valuations for the environmental benefit of the incremental fuel reductions from the tax credit for both greenhouse gas and local environmental benefits, together with present values for a range of real discount rates.

The local environmental benefits values in this table would be adjusted downward by a factor of 0.05 if it is assumed that avoided electricity use from PV applications displaces only natural gas fired electricity rather than the average electricity fuel mix. Similarly the carbon values would be adjusted downward 20 percent.

### **CONCLUSIONS**

The package of policies intended to remove the institutional barriers to solar proliferation would result in a substantial increase in solar system purchases. The addition of the credit would further increase that increment by about half. However, it is clear that the credit alone would have little effect if no related technology promotion policies are adopted.

It is widely agreed among experts in solar technologies that, until the price of fossil fuels increases or the infrastructure environment becomes inclusive for solar applications rather than prohibitive, solar will remain a niche market, albeit a growing one, for the next five to ten years. The rapid growth of the solar market experienced in the late 1970's was due to a 40 percent investment tax credit, a much larger credit than that currently proposed in the President's Fiscal Year 2000 Budget. The market essentially crashed immediately upon the credit's expiration, and this pattern would probably be repeated if the tax credit were enacted without other initiatives addressing the institutional barriers to solar systems.

Our panel of experts found that the proposed tax credit would encourage consumers to purchase additional units, and that this growth in production would lead to the realization of economies of scale

and experience and lower the per-unit cost. The premium that large numbers of consumers are willing to pay for clean power appears to be about 5 percent to 15 percent over competing alternatives. Although the package of policies and the credit would result in a substantial increase in the purchase of solar systems and a significant further decline in price, they do not appear to be aggressive enough to realize the potential of solar systems as a mass-market energy source. 134 However, they would continue the orderly expansion of the industry and the steady decline of solar system costs toward competitive levels.

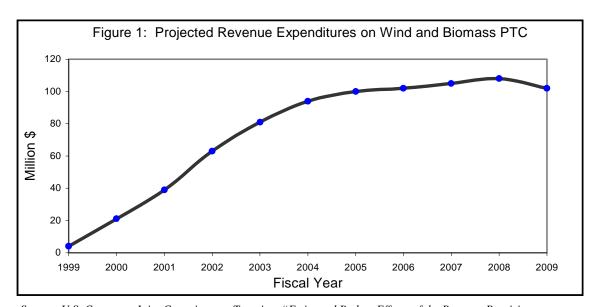
From a purely economic point of view, considering non-economic benefits but not spillover benefits, the credit is marginal. When the mid-range local environmental benefit value is included, whether or not the credit is cost-effective depends on one's view of the level of distortion induced by the tax system.

# Extension of the Production Tax Credit for Wind and Biomass

#### 3.6.1 **Background**

### PROPOSAL.

The proposal would extend the current \$0.015 per kilowatt-hour (kWh) production tax credit for electricity generated by wind or "closed-loop" biomass technologies for an additional five years. It would also expand the definition of eligible biomass to include non-closed-loop biomass energy production, excluding biomass from municipal solid waste, as well as provide a \$.010 tax credit for biomass co-fired in coal plants. The extension covers taxpayer-owned facilities selling electricity to an unrelated third party that are placed in service by July 1, 2004. The credits are indexed for inflation and limited to the first 10 years of production from a qualified facility. 135



Source: U.S. Congress, Joint Committee on Taxation. "Estimated Budget Effects of the Revenue Provisions Contained in the President's FY1999 Budget Proposal." Washington, DC. February 24, 1998.

The revenue estimates from the Joint Committee on Taxation (JCT) in Figure 1 show an increase in the total amount spent on the production tax credit and in the growth rate of expenditures between

<sup>&</sup>lt;sup>134</sup> Wenger, Howard and Herig, Christy, Policy Options to Accelerate Grid-Connected PV Markets, Presented at the American Solar Energy Society's Solar '97 Conference. Washington D.C., April 1997. 

135 PL 102-486, Title XIX, Subtitle A, Section 45 (26 USC 45).

1999 and 2004. Because this is a production credit, the shape of the curve indicates very rapid growth in the amount of wind and biomass energy produced as a result of the credit. The rate of growth slows markedly between 2004 and 2008, due to the expiration of the credit in mid-2004. Payouts from the extension of the production tax credit would continue until 2014.

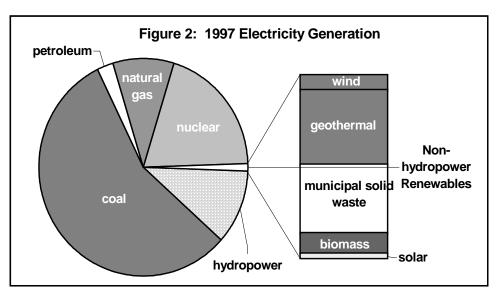
The \$819 million spent on the wind and biomass production credit over the forecast period represents approximately 11.2 percent of total expenditures for the climate change tax incentives in the President's FY 2000 budget.

### **HISTORY**

Global warming fears and the Gulf War led to the passage of the 1992 Energy Policy Act (PL 102-486) containing the current production tax credit for electricity produced from wind and closed-loop biomass, defined as "any organic material from a plant which is planted exclusively for purposes of being used at a qualifying facility to produce electricity." This tax credit was extended in December 1999 until December of 2001.

### **CONTEXT**

Electricity generation accounted for 36 percent of all U.S. carbon emissions in 1997 and is projected to grow to 38 percent by 2020. This increase is due to an expected 1.4 percent annual growth rate in

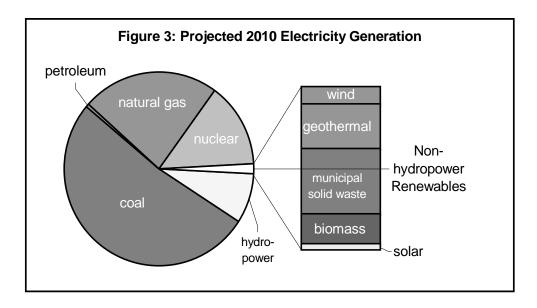


Source: Department of Energy, Energy Information Administration. *Annual Energy Outlook 1999*, Tables A8 and A17. Washington, D.C., December, 1999.

electricity consumption as well as the loss of nearly half of the carbon-free generating capacity from U.S. nuclear plants. Low natural gas prices and decreasing coal prices will make these the fuels of choice for new generating capacity to meet growing demand and to replace retired nuclear capacity. Growth of renewables is expected to be slow in a market of cheap fossil fuels. 136

Wind power represented 0.88 percent of electric generation from renewables and 0.12 percent of total electric generation in 1997 (Figure 2). These percentages are expected to increase to 1.98 and 0.22 respectively by 2010 (Figure 3).

<sup>136</sup> Department of Energy, Energy Information Administration, *Annual Energy Outlook 1999*, "Issues in Focus," Washington, DC, December, 1998.



Closed-loop biomass systems (also known as dedicated feedstock supply systems), where a crop such as switchgrass or alfalfa is grown for the exclusive purpose of energy production, are not commercially available in the U.S. at this time.<sup>137</sup> There is only one small closed-loop biomass plant expected to come online during the years covered by the credit extension, with negligible electricity production compared to that produced by wind, and the Energy Information Administration does not include any closed-loop biomass in its projections until after 2010.<sup>138</sup>

However, non-closed-loop biomass systems, systems using wood waste biomass or non-dedicated feedstock to produce electricity (excluding municipal solid waste biomass), currently represent 1.08 percent of electricity generation from renewables and 0.15 percent of total electric generation. These percentages are expected to increase to 3.0 and 0.33 percent, respectively, by 2010 (Figure 3).

### Wind Energy

The wind energy market in the U.S., nascent in the early 1980s, was spurred by the energy crises of the 1970s, concerns about nuclear power and environmental quality, and federal investment tax credits. Rapid growth of the windpower industry slowed after the tax credits expired in 1985 and as fossil fuel prices declined throughout the late 1980s. 139

Uncertainties about electric industry restructuring and the bankruptcy of several major turbine manufacturers slowed wind industry growth to a low point by 1997. In 1998, however, there was a sudden increase in plans for new wind facilities and efforts to update existing plants. Factors in this industry revitalization include state mandates, lower costs for wind-generated electricity, a better grasp of how project financing affects these costs, improved technology, and the impending expiration of the production tax credit in mid-1999. Great potential for wind energy exists in green

<sup>&</sup>lt;sup>137</sup> Department of Energy; Electric Power Research Institute, "Overview of Biomass Technologies" in *Renewable* Energy Technology Characterizations, Topical Report 109496, December 1997.

138 Cadogan, J., Office of Photovoltaic and Wind Technology, Department of Energy, Personal communication,

November 5, 1998.

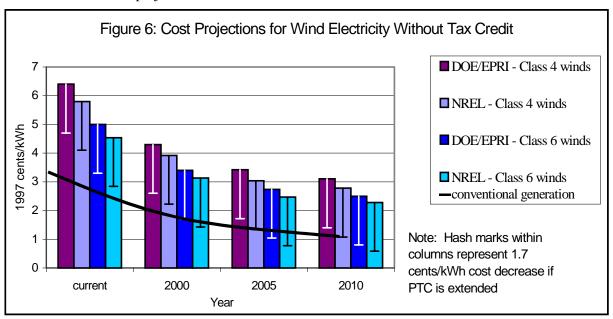
<sup>&</sup>lt;sup>139</sup> Union of Concerned Scientists, Renewable Energy—How Wind Energy Works, Viewed at http://www.ucsusa.org/energy/wind.html on September 24, 1998.

pricing initiatives, national greenhouse gas emission reduction policy, and state renewable energy plans.140

It is important to know how much of the new wind capacity during the 1990s is directly due to the production tax credit that began with the 1992 Energy Policy Act. According to the National Wind Technology Center, the results of the production tax credit have only been seen in the past two years, with 300 to 400 megawatts (MW) of new wind capacity in Texas, Minnesota, Wyoming, and Colorado, in addition to 100 to 200 MW in California from repowering existing facilities.<sup>141</sup>

Virtually all online projects also benefit from special circumstances in addition to production tax credit, although the tax credit has made wind energy more cost-effective. This reduces the cost of enacting state-level renewable promotion policies, such as renewable portfolio standards, and may benefit wind in relation to other alternative generation technologies.<sup>142</sup>

Of the additional 600 to 700 MW of new wind capacity expected to be installed by June 1999 to qualify for the production tax credit, most projects involve these special arrangements. The 425 MW Northern States Power project in Minnesota is the result of a state mandate, the 35 MW Lower



Sources: Parsons, B. "Grid-Connected Wind Energy Technology: Progress and Prospects." National Renewable Energy Laboratory: Golden, Colorado. November 1998. Department of Energy; Electric Power Research Institute. "Project Financial Evaluation" in Renewable Energy Technology Characterizations, Topical Report 109496. December 1997.

Colorado River Authority project involved municipal financing, a 41 MW new wind project in Wyoming is a result of a deal with the Bonneville Power Authority, and deliberative polling of electricity customers resulted in a 75 MW Texas project. 143

<sup>&</sup>lt;sup>140</sup> Parsons, B., *Grid-Connected Wind Energy Technology: Progress and Prospects*, National Renewable Energy Laboratory: Golden, Colorado. November 1998.

<sup>&</sup>lt;sup>141</sup> Parsons, B., National Wind Technology Center, National Renewable Energy Laboratory, Golden, CO. Personal communication November 3, 1998.

142 Petersik, Tom., Office of Renewable Energy and Midterm Projections, Energy Information Administration,

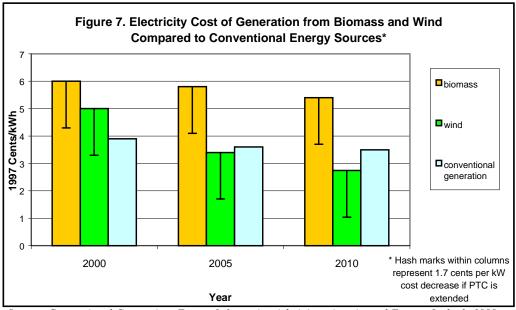
Department of Energy. Personal communication, November 11, 1998.

<sup>&</sup>lt;sup>3</sup> Cadogan, J., Office of Photovoltaic and Wind Technology, Department of Energy, Personal communication, November 5, 1998.

As with current projects, new wind power facilities are expected to result primarily from state mandates and voluntary state initiatives where an extended credit would be a critical factor in energy costs but not the primary impetus behind the decision. Without the production tax credit, the wind energy market is expected to stall, with occasional 10 MW green pricing projects and the remaining "bits and pieces" of the Minnesota NSP project not yet online. Due to the uncertainty about the extension, projects are currently accepting bids with and without the production tax credit.<sup>144</sup>

Without a true accounting for environmental externalities in the pricing of electricity from fossil fuels or incentives such as the production tax credit, wind power will have difficulty competing with fossil fuels on a large scale in the near future. Figure 6 shows price projections for wind-generated electricity through 2010 from two independent sources. Class 4 wind speeds average 5.6 to 6.0 meters per second (m/s) at a height of 10 meters, while Class 6 winds average 6.4 to 7.0 m/s at the same height.

The tax credit could make wind energy competitive with fossil fuels as early as 2005. Biomass power is projected to remain slightly more expensive than conventional fuels even with the production credit (Figure 7).



### Source: Conventional Generation: Energy Information Administration, Annual Energy Outlook, 1999.

# **Biomass Energy**

Biomass power as an industry was essentially created by the Public Utilities Regulatory Policy Act (PURPA). These systems, other than closed-loop biomass, have not yet been eligible for tax credits and now account for a larger portion of renewable energy production than does wind energy. In fact, biopower is the largest single source of non-hydro renewable electricity.<sup>147</sup>

<sup>145</sup> See note 141.

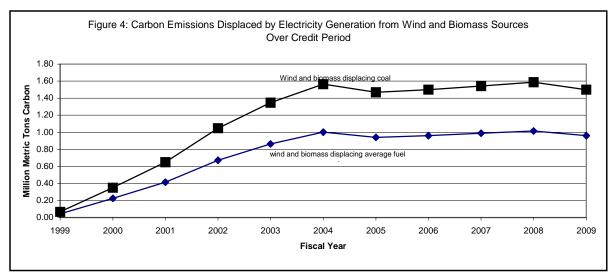
<sup>147</sup> Department of Energy, Electric Power Research Institute, "Overview of Biomass Technologies" in *Renewable Energy Technology Characterizations*, October, 1997.

<sup>&</sup>lt;sup>144</sup> See note 140.

<sup>&</sup>lt;sup>146</sup> See note 141.

Biomass can be used to generate electricity as needed and can therefore be attractive as base load power. About 350 non-municipal waste biomass power plants with a combined rated capacity of 7000 MW, about one percent of total electricity generating capacity and about eight percent of non-utility generating capacity, feed electricity into the nation's power lines. Another 650 enterprises generate electricity with biomass for their own use as cogenerators. Much of this capacity is associated with the wood and wood products industries that obtain over half of their electricity and thermal energy from biomass. 149

Although all current electricity capacity from biomass relies on direct combustion/Rankine cycle technology, there are three primary ways to produce energy using biomass sources: direct combustion, gasification, and pyrolysis. New biomass gasification plants are not expected to be commercially available until 2005, after the investment credit expires.



Currently, biomass is cost-effective only in situations in which waste biomass is available at a low or even negative cost or when it is possible to take advantage of the by-products of primary energy processes. Crops grown exclusively for energy purposes are not yet cost-effective, primarily because, unlike food crops and fossil fuel, energy crops are not subsidized. Another barrier to the growth of biomass electrification is the "chicken-and-egg" problem; biomass power plants will not be built unless a reliable supply of biomass is economically available, yet farmers will not raise a fuel crop unless they are guaranteed a market.<sup>150</sup>

In addition, biomass plants are bigger investments than either solar or wind facilities. Utilities can make safe incremental investments in wind and solar kilowatt-sized generators but biomass plants with megawatts of capacity require a greater commitment of capital, and therefore greater risk. Without additional incentives to invest in biomass systems, investors may only be willing to invest in small plants and biomass co-fired in coal plants. <sup>151</sup>

<sup>150</sup> Morris, David. *The Economics of Plant Matter Derived Electricity*, The Institute for Local Self Reliance. March 22, 1994.

US Congress, Office of Technology Assessment, Renewing Our Energy Future, OTA-ETI-614, September, 1995.
 Department of Energy, Energy Information Administration., Renewable Energy Annual 1998: Issues and Trends, Washington, DC March 1999.

<sup>1994. &</sup>lt;sup>151</sup> Paulos, Bentham, *Green Marketing and Biomass Energy,* Presented at the BioEnergy '98: Expanding BioEnergy Partnerships Conference, December 1998.

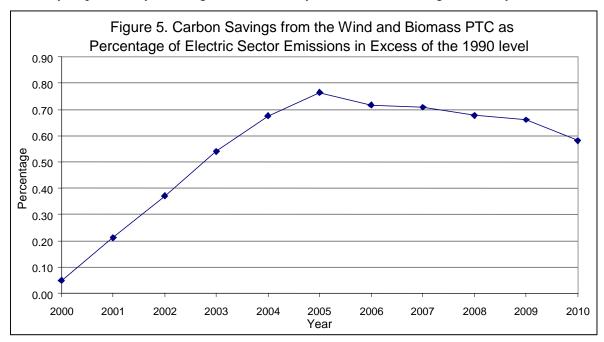
# 3.6.2 Effects of the Production Credit Assuming JCT Revenue Estimates

The Joint Committee on Taxation (JCT) ten-year estimate of the budget effect of the tax credit can also be used to quantify the carbon and energy savings from the equipment that receives the tax credit. In this part of the analysis, we assumed that the JCT expenditure estimate are accurate and deduced the carbon savings from the amount spent on the tax credit in each year. The fuel savings estimated in this section are for all units receiving the credit. Because the JCT does not provide estimates of the use of the technology in the absence of the credit, we are unable to indicate what proportion of these savings are credit-induced. Thus, the JCT derived estimates are provided for comparison purposes only. Incremental fuel savings are derived in the Delphi Analysis section below.

### RESULTS

One of the arguments for the production tax credit extension and other renewable energy incentives is the need for a reduction in U.S. carbon emissions to comply with the Kyoto Protocol. Figure 4 illustrates the total carbon emissions avoided if the production tax credit for wind is extended and the definition of eligible biomass systems expanded.

Carbon emissions displaced by the credit increase rapidly until 2004, when the credits expire for all new facilities. The carbon savings continue into 2014, as do the production tax credit expenditures. Savings total 12.9 MtC over this interval (8.06 MtC if it is assumed that wind and biomass generated electricity displaces only natural gas fired electricity rather than the average electricity fuel mix).



Wind generation displacing the average U.S. fuel mix represents 0.06 percent of total carbon emissions from the electric sector between 1999 and 2009. Biomass electricity generation displaces 0.04 percent of the total projected carbon emissions from the sector while biomass cofired with coal displaces 0.02 percent. Generation from all three wind and biomass sources with the production tax credit displaces 0.11 percent of emissions from the electricity sector between 1999 and 2009 (Figure 5). This percentage would rise to 0.18 percent if the electricity generated from these sources displaces primarily coal.

These carbon savings assume that biomass electricity production results in no net carbon emissions. However, with the exception of closed loop biomass systems, this is probably not an-entirely accurate assumption. Unlike closed-loop biomass, non-closed-loop biomass is one of the more technique dependent opportunities for carbon savings; there are many ways utilities and energy producers could qualify for the credit without any net carbon savings. As long as biomass is replacing coal as an energy source, there will be some net benefits. However, if the energy producer merely burns waste biomass, such as the by-products of timber harvesting and does not ensure that the carbon released is re-absorbed by new plant matter, the net greenhouse benefits become difficult to measure.

Perhaps more important than carbon emissions savings benefits, encouraging the co-firing of biomass in coal plants, already technologically feasible, could help establish an infrastructure for more intensive uses of biomass power in later years.

### *METHODOLOGY*

- The revenue projections from JCT were divided by \$.017 (the current inflation-adjusted production tax credit)<sup>152</sup> to determine the number of kilowatt-hours of electricity produced by wind and biomass systems that are expected to qualify for the production tax credit.
- Carbon savings for the projected amount of wind and biomass generation were calculated using the following values: 160 kilograms of carbon (kgC) emitted per megawatt-hour (MWh) if wind and biomass replace the U.S. average fuel mix and 257 kgC/MWh if wind and biomass replace primarily coal.<sup>153</sup>

# 3.6.3 Delphi Analysis of the Production Tax Credit for Wind- and Biomass-Generated Electricity

SUMMARY, BIOMASS AND WIND

In the second phase of our analysis of the extension of the wind and biomass production tax credit, we did *not* assume that the JCT expenditure estimates were accurate. Instead, we surveyed a panel of

experts to determine the impact the credit would have on electricity production from these sources as well as the cost of generation. We also deviated from the parameters of the preliminary analysis by assuming the credit would be enacted as part of a larger suite of policies intended to facilitate the market penetration of biomass and wind energy. With the exception of the research and development provisions parallel to those contained in the R&D section of the President's Climate Change Technology

Table 1. Total Carbon Savings and Budget Expenditure					
	Dudget	Carbon Savings (MtC)			
	Budget Expenditure (million \$)	During the Credit Period	After the Credit Period		
JCT est.	795	12.8	204		
CSE est.	3,718	56	2409		

<sup>152</sup> Rostroff, A.; Sanderson, G, *Tax Incentives for Bioenergy Projects,* Presented at Bioenergy '98: Expanding Bioenergy Partnerships, Madison, WI, October 1998.

<sup>&</sup>lt;sup>153</sup> Department of Energy, Scenarios of U.S. Carbon Reductions: Potential Impacts of Energy Technologies by 2010 and Beyond, (a.k.a. "5 Lab study") Washington, DC. September 1997.

Initiatives, the policies included in the attending suite would involve little, if any, government spending.

The Table 1 details the findings of the study compared to the JCT estimates. Greater savings accrue in proportion to expenditure in the CSE case because the secondary effects of the credit on wind and biomass electricity production *after* the credit itself expires are assessed. The table describes carbon savings from all investments, those that would have occurred prior to the tax credit and policy package as well as those induced by the policies.

The altered parameters of the second analysis resulted in a total expenditure on the credit for wind and biomass of \$3.7 billion, present value (market inflation rate of 5%), a substantial increase over the JCT estimate of \$795 million dollars.

Table 2 describes the incremental increase in savings from each policy increment—the package of policies and the production tax credit.

Table 2: I	Table 2: Incremental Effects of the Package of Policies and the Tax Credit, 2000- 2018						
		Budget	Consumer	Ancillary	Benefits	Carbon Savings	
	Discounting	Expenditure (million \$)	Surplus (million \$)	Millions \$	MtC	(MtC) 2000- 2018	
Package	0 %		4,183	5,174	1.3/0.81*	46/28.8	
over Baseline	2.5 %	N/A	3,187	3,748			
	5 %		2,238	2,772			
Credit	0 %	5,327	3,896	11,139	0.4/.25	42/26.3	
over Package	2.5%	4,685	2,771	8,066			
	5%	3,718	2,014	5,962			

\*When it is assumed that wind and biomass generated electricity displaces only natural gas fired electricity rather than the average electricity fuel mix.

The incremental installations induced by the credit save 41.8 million metric tons of carbon between the years of 2000 and 2018, compared with the JCT-consistent estimate of 12.8 million metric tons over the same time period. It was also found that the credit induced carbon savings would continue for the thirty year lifetime of facilities placed in service during the credit period to result in a total of 201 million metric tons of carbon emissions displaced by electricity generation from wind and biomass sources over the life of the incented plants (again from both the credits and the package induced installations and baseline growth). This figure would be reduced to 126 MtC under the assumption that wind and biomass electricity replaces only natural gas fired electricity.

The package of policies is almost equally effective at stimulating demand for wind- and biomass-produced electricity as is the production tax credit. When the production tax credit is applied on top of the package of policies, carbon savings are almost doubled, totaling 88 million metric tons saved by 2018. The savings that would actually accrue over the lifetime of wind and biomass facilities installed between 2000 and 2004 would be much greater, totaling 201 million metric tons. Under business-as-usual circumstances 2208 million metric tons would be saved over the lifetime of these

facilities. With the tax credit and policy package the total comes to 2,409 million metric tons. The policy package increment has greater effect on consumer surplus and ancillary benefits than does the credit increment.

### **BIOMASS**

### Methodology

A survey comprised of three sets of questions regarding biomass energy production was mailed to experts in the biomass industry, government agencies, academia, and non-governmental agencies. The first section asked respondents to indicate growth of biomass-generated electricity production under three different policy scenarios: (1) business-as-usual, (2) with a package of policies designed by the surveyee, and (3) with the package of policies including the production tax credit. The second section asked respondent to indicate the rate of price decline for the biomass cost of electricity under each of the three policy scenarios. The third section asked respondents to evaluate the ancillary effects of biomass electricity generation, such as rural economic revitalization, in terms of the percent of the value of biomass-generated electricity.

The results of the survey were tabulated and used to determine the mean estimated fossil fuel consumption savings from the tax credit and policy package relative to business-as-usual, consumer surplus from the change in the price of biomass-generated electricity, budgetary expenditure on the tax credit, and the dollar savings from the ancillary benefits of biomass electricity production. These findings were then used to calculate the cost-effectiveness of the production tax credit. Fossil fuel savings were also converted into monetized environmental benefits using the approach described in the Overview of Methods and Findings above.

### **Package of Policies**

Each respondent was asked to describe the four policies that would most effectively stimulate the market for biomass-generated electricity. Although each respondent described a different set of policies, a number of particular policy suggestions recurred. The most frequently mentioned were those related to research and development of biomass production, such as research on: conversion technologies including gasification and small scale (less than 20 MW) conversion, the soil/waste benefits of biomass compared to cash crop production, and pre-conversion processing of fuels. Most of these R&D initiatives are contained in the President's Budget Proposal. Production tax credits frequently recurred as did a number of inexpensive proposals including: utility disclosure of fuel sources, consumer choice to specify what energy sources are used for their electricity, consumer and industry education initiatives, renewable portfolio standards, emissions trading programs, partnerships with the

Biomass Tax Credit Market Effects (millions \$)					
Year	Consumer Surplus	Ancillary Economic Benefits			
2000	4.59	46.60			
2001	9.43	97.04			
2002	14.52	152.02			
2003	19.88	212.34			
2004	25.54	279.01			
2005	27.11	325.30			
2006	28.79	375.81			
2007	30.60	428.99			
2008	32.55	485.03			
2009	34.64	544.14			
2010	36.90	606.55			
2011	39.34	672.51			
2012	41.96	742.30			
2013	44.79	816.18			
2014	47.84	894.49			
2015	51.13	977.54			
2016	54.68	1,065.70			
2017	58.50	1,159.37			
2018	62.62	1,258.95			
Discounting	Total 2	000-2018			
0%	665.40	11,139.88			
2.50%	492.95	8,065.96			
5%	373.21	5,961.92			

forest products industry to demonstrate advanced biomass gasifiers, and net-metering. Also included in the packages of policies suggested by the experts are a few provisions that could be revenue

Benefit/Cost Comparison of the Production Tax Credit for Biomass								
Discounting	Expenditure	Carbon Emissions Avoided (mMtC)		Cost Effectiveness	\$ Value of Carbon Savings (Millions)			
%	(Millions\$)	2000- 2018	Lifetime of Equipment	(\$/metric ton)	\$5/ ton	\$20/ ton	\$100/ ton	
0	1983.8	11.3	35.6	55.7	178.0	711.9	3559.3	
2.5	1614.7	same	same	45.4	138.7	554.8	2774.2	
5	1327.2	same	same	37.3	110.8	443.4	2216.9	

generating, such as the removal of subsidies to ethanol and gasohol, a carbon tax on fossil fuels, and fair pollution rules involving emissions standards and fees on CO<sub>2</sub>, NO<sub>x</sub>, and SO<sub>2</sub>, mercury and particulates.

With the exceptions of research and development funding of biomass technologies and production tax credits, the policies the experts considered most effective in stimulating biomass-generated electricity growth would involve little or no government spending but would involve legislative initiatives.

### Results

# - Consumer Surplus -

The cost of electricity generated from biomass will increase at a slower rate than business-as-usual with either the package of policies alone or the package of policies together with the production tax credit. The savings from the change in the price of electricity calculated as consumer surplus reaches 525 million dollars in present value (market discount rate) over the 19-year forecast period when just the package of policies is in place and 898 million dollars when the production tax credit is applied in addition to the package of policies. These savings will go to consumers of biomass-generated electricity--both those who would have purchased the electricity without the favorable policies and those who purchase the electricity because of the reduction in price.

# - Ancillary Benefits -

In addition to the carbon savings achieved by fostering the biomass industry, other non-environmental benefits to the economy accrue in proportion to the advancement of the industry. Among these are: increased revenues from agricultural waste, increased revenue from forest products waste, increased revenue from dedicated energy crop cultivation, economic revitalization of rural areas, and saved landfill space. It was found that when combined these related benefits could equal 44% of the total value of biomass electricity generation. At that rate the revenue from these sources, at a market discount rate of 5%, would equal \$2.7 billion over the 19-year period when the package of policies is in place. With an expenditure of \$1.3 billion on the tax credit, these ancillary benefits would increase to \$6 billion, present value (market inflation rate). Most of this revenue or savings would go to industries that are able to cheaply use organic industry waste for electricity generation. The table below shows the estimated annual value of consumer surplus and ancillary benefits from the tax credit, together with the present value under alternative discount rates.

# - Carbon Savings -

The displacement of carbon emissions from the increase in biomass electricity generation over business-as-usual would equal 28 million metric tons by 2018 with just the package of policies in place (17.5 MtC if biomass generation displaces natural gas fired electricity rather than the average electricity fuel mix). With a total expenditure of 1.3 billion on the production tax credit, an additional 11.3 million metric tons of carbon savings could be achieved, bringing the total to 39 million metric tons (7 MtC and 24 MtC respectively under the natural gas replacement only assumption). Monetized emission reductions from the tax credit are reported below for a range of emissions valuations.

The carbon savings benefit/cost comparison table above includes incremental carbon savings attributable to investments made during the forecast period as a result of the credit. This includes not only installments of biomass facilities that receive the credit, but also installments caused by credit-induced price decline, demonstration effects, institutional change, etc. However, it does not include carbon savings from policies put in place during the forecast period that influence installments after the forecast period.

The carbon emissions avoided and dollar value of carbon savings would be adjusted downward by a factor of 0.63 to accommodate the assumption that biomass electricity would displace only natural gas fired electricity.

### - Local Environmental Benefits -

The same fossil fuel savings that produce greenhouse gas (CO<sub>2</sub>) emission reductions also result in reduced local health and environmental effects. These effects are monetized using a range of fuelspecific environmental values from Viscusi, et al. in the manner described in the Overview of Methods and Findings above. The table below shows annual valuations for the environmental benefit of the incremental fuel reductions from the tax credit for both greenhouse gas and local environmental benefits, together with present values for a range of real discount rates. The local environmental values in this table would be adjusted downward by 99% if it is assumed that biomass electricity generation displaces only natural gas fired electricity rather than the average electricity fuel mix. Likewise, the carbon values would be adjusted downward 38%.

# **Biomass Conclusions**

When the production tax credit is implemented as part of a large suite of

Biomass Tax Credit Environmental Effects (millions \$)						
Year	Local I	,	σ.,		n Benefit	
	Low Value	Middle Value	High Value	5\$/ton	20\$/ton	100\$/ton
2000	0.57	14.92	30.75	0.29	1.15	5.74
2001	1.18	30.58	63.03	0.59	2.35	11.76
2002	1.81	47.01	96.91	0.90	3.62	18.08
2003	2.47	64.24	132.43	1.24	4.94	24.71
2004	3.17	82.30	169.67	1.58	6.33	31.65
2005	3.63	94.38	194.57	1.81	7.26	36.30
2006	4.12	106.99	220.57	2.06	8.23	41.15
2007	4.62	120.16	247.72	2.31	9.24	46.22
2008	5.15	133.91	276.06	2.58	10.30	51.50
2009	5.70	148.26	305.64	2.85	11.40	57.02
2010	6.28	163.23	336.51	3.14	12.56	62.78
2011	6.88	178.85	368.71	3.44	13.76	68.79
2012	7.51	195.14	402.29	3.75	15.01	75.05
2013	8.16	212.13	437.31	4.08	16.32	81.59
2014	8.84	229.84	473.82	4.42	17.68	88.40
2015	9.55	248.30	511.88	4.78	19.10	95.50
2016	10.29	267.54	551.54	5.14	20.58	102.90
2017	11.06	287.59	592.87	5.53	22.12	110.61
2018	11.86	308.47	635.93	5.93	23.73	118.64
Discounting		•	Total 2	000-201	8	•
0%	112.84	2,933.84	6,048.22		225.68	1,128.40
2.50%	82.29		4,410.71		164.58	822.89
5%	61.28		3,284.60		122.56	612.80

policies, it is capable of significantly increasing the amount of electricity that is generated from biomass and thereby achieving recognizable carbon savings as well as benefits to the economy both in consumer surplus and by diversifying the rural economy and increasing efficiency in both the agricultural and forest products industries.

Without these policies, competition for higher-value use of crop acreage, both farm and non-farm, will preclude expansion of biomass for electric generation. The cost of cultivating and transporting dedicated energy crops will continue to prevent closed-loop biomass from becoming cost-competitive in an electric market dominated by cheap fossil fuels. Until the electric market genuinely embraces renewable energy sources, electricity generated from forest products or agriculture waste sources by the forest product and agriculture industry for non-utility use, as well as urban waste and biomass cofired with coal, will remain the only cost-effective uses of biomass for electricity generation.

It is argued that investments in biomass power will be even more cost-effective as they revitalize rural economies and thereby reduce federal expenditures on agricultural subsidies, estimated at about \$10 billion per year. However, unless fossil fuel electricity prices increase, it is unlikely that energy crops would be a cost-effective option for the nation's farmers. Biomass power, a renewable energy source with no net carbon emissions, will probably remain more expensive than wind energy and is also more complicated, involving complex land-use and land management priorities. Bolstered by a package of economic and policy incentives, it may serve an important role as a transitional and base load fuel source within a larger national renewable energy portfolio.

WIND

# Methodology

A survey comprised of three sets of questions was also conducted regarding the future of wind electricity production. It was mailed to experts in the wind energy industry, government agencies, academia, and nongovernmental agencies. The first section asked respondents to indicate growth of wind-generated electricity production under three different policy scenarios: (1) business-as-usual, (2) with a package of policies designed by the survey respondent, and (3) with the package of policies including the production tax credit. The second section asked respondents to indicate projected wind cost of electricity under each of the three policy scenarios. The third section asked respondents to evaluate the effects of each policy scenario on wind turbine exports.

The results of the survey were tabulated and used to determine the mean estimated carbon emissions savings from the tax credit and policy package relative to business-asusual, consumer surplus from the change in the price of wind generated electricity, budgetary expenditure on the tax credit, and the dollar savings from the export effects of stimulating the domestic market for wind electricity production. These findings were then used to calculate the cost-effectiveness of the production tax credit for wind energy. Fossil fuel savings

Wind Production Tax Credit Market Effects (millions \$)			
Year	Consumer Surplus		
2000	9.7		
2001	20.4		
2002	32.5		
2003	46.5		
2004	62.8		
2005	69.6		
2006	77.9		
2007	87.9		
2008	100.1		
2009	115.0		
2010	133.3		
2011	155.6		
2012	182.9		
2013	216.5		
2014	257.6		
2015	308.1		
2016	369.9		
2017	445.9		
2018	539.0		
Discounting	Total 2000-2018		
0%	3,231.0		
2.50%	2,279.0		
5%	1,641.0		

<sup>&</sup>lt;sup>154</sup> See note 151.

were also converted into monetized environmental benefits using the approach described in the Overview of Methods and Findings above.

# **Package of Policies**

Each respondent was asked to describe the four policies that would most effectively stimulate the market for wind-generated electricity. Although each respondent described a different set of policies, a number of particular policy suggestions recurred. The most frequently mentioned policy was implementation of renewable portfolio standards followed by production tax credits, research and development of wind energy production, reduction of subsidies to fossil and nuclear fuel generators, fair transmission and distribution rules, net-metering, carbon and pollution taxes, and green marketing.

Only two of these policy suggestions involve substantial federal investment, the production tax credit, which is the subject of this analysis, and research and development, for which the President has already proposed to allocate funding. The other policies the experts considered most effective in stimulating wind-generated electricity growth would involve little government spending or are revenue generating, but would involve legislative initiatives.

### **Results**

# - Consumer Surplus -

The cost of electricity generated from wind will increase at a slower rate than business-as-usual with either the package of policies alone or when the package of policies is bolstered by the production tax credit. The savings from the change in the price of electricity from business-as-usual, calculated as consumer surplus, reaches \$1.7 billion, present value (market discount rate), over the 19-year period when just the package of policies is in place and \$3.4 billion when the package of policies and the production tax credit are in place. These savings will go to consumers of wind-generated electricity both that would have purchased the electricity without the favorable policies and those that purchase the electricity because of the reduction in price.

### - Ancillary Benefits -

In addition to the carbon savings achieved by fostering the domestic wind industry, other non-environmental benefits to the economy accrue in proportion to the advancement of the industry. We attempted to determine the effect the package of policies and the tax credit would have on revenue from exports of wind turbines and global carbon emissions. We found that the package of policies and tax credit stimulated the domestic demand for wind-generated electricity and exports dropped below business-as-usual levels briefly until manufacturers were able to meet domestic demand without compromising foreign market share. The increased revenue to domestic wind turbine exporters from the presence of the domestic market, at a market discount rate of 5%, would equal \$36 million over the 19-year period when just the package of policies is implemented and \$220 million when the production tax credit and package of policies are in place.

If electricity generated from these exported turbines displaced the average fuel mix, carbon savings of 1.68 million metric tons over business-as-usual would accrue. However, the only way U.S. wind turbine exports will substantially increase is if the cost of the technology falls below the cost of European turbines. Having a robust domestic market would give U.S. manufacturers sufficient volume to price aggressively. The table below shows the estimated annual value of consumer surplus

<sup>156</sup> It should also be noted that current U.S. exports of wind turbines represent only one manufacturer, making projections highly uncertain.

<sup>&</sup>lt;sup>155</sup> It could be argued that increases in U.S. wind turbine exports would not represent an increase in demand for wind turbines but would simply shift wind turbine export market share from foreign nations to the U.S. and would therefore represent no net carbon benefits.

and ancillary benefits from the tax credit, together with the present value under alternative discount rates.

# - Carbon Savings -

When implemented, the package of policies described above increases carbon savings from wind electricity over baseline by 18.2 million metric tons between 2000 and 2018. When the production tax credit is applied in addition to the package of polices, savings increase by 30 million metric tons to a

Benefit/Cost Comparison of the Production Tax Credit for Wind Electricity									
Discounting %	Expenditure (Millions\$)	Carbon Emissions Avoided (mMtC)		Cost Effectiveness	\$ Value of Carbon Savings (Millions)				
		2000- 2018	Lifetime of Equipment	(\$/metric ton)	\$5/ ton	\$20/ ton	\$100/ ton		
0	3342	30	165	20	829	3316	16581		
2.5	3070	same	same	18.0	583	2333	11669		
5	2390	same	same	14	419	1678	8390		

total savings of 48.2 million metric tons over nineteen years. The savings will continue as long as facilities placed in service during this period remain in service, totaling one billion metric tons of savings by 2030. In this case, the production tax credit is far more effective at stimulating the market for wind electricity than is the package of policies described by our respondents. If, however, aggressive policies such as renewable portfolio standards, were included in the package of policies, the goal of making wind electricity cost competitive would already be met, and the production tax credit would then be pocketed by producers.

The expenditure on the production tax credit to achieve the additional 49 million metric tons of savings would total 2.4 billion over the first ten years of production from generating facilities installed between 2000 and 2004. Monetized emission reductions from the tax credit are reported below for a range of emissions valuations.

The carbon savings benefit/cost comparison table below includes incremental carbon savings attributable to investments made during the forecast period as a result of the credit. This includes not only installments of wind turbine facilities that receive the credit, but also installments caused by credit-induced price decline, demonstration effects, institutional change, etc. However, it does not include carbon savings from policies put in place during the forecast period that influence installments after the forecast period.

Both the carbon emissions avoided and the dollar value of carbon savings figures would be adjusted downward by 37% (a factor of 0.63) if it is assumed that wind electricity production displaces natural gas fired electricity rather than the average electricity fuel mix.

# - Local Environmental Benefits -

The same fossil fuel savings that produce greenhouse gas (CO<sub>2</sub>) emission reductions also result in reduced local health and environmental effects. These effects are monetized using a range of fuel-specific environmental values from Viscusi, et al. in the manner described in the Overview of Methods and findings above. The table below shows annual valuations for the environmental benefit of the incremental fuel reductions for both greenhouse gas and local environmental benefits,

Wind	d Product	ion Tax Cre millie)	edit Envir ons \$)	onmental	Effects		
Year	Local Be		σσ ψ/	Carbon Benefit			
	Low Value	Middle Value	High Value	5\$/ton	20\$/ton	100\$/ton	
2000	0.0	0.0	0.0	0.0	0.0	0.0	
2001	0.6	17.7	34.6	0.3	1.3	6.5	
2002	1.5	40.0	78.3	0.7	2.9	14.6	
2003	2.5	68.2	133.3	1.2	5.0	24.9	
2004	3.5	95.4	186.6	1.7	7.0	34.8	
2005	5.0	136.3	266.7	2.5	10.0	49.8	
2006	5.9	162.1	317.1	3.0	11.8	59.2	
2007	7.1	193.3	378.1	3.5	14.1	70.5	
2008	8.4	231.0	451.9	4.2	16.9	84.3	
2009	10.1	276.7	541.3	5.0	20.2	101.0	
2010	12.1	332.2	649.8	6.1	24.2	121.2	
2011	14.6	399.5	781.5	7.3	29.2	145.8	
2012	17.6	481.3	941.6	8.8	35.1	175.7	
2013	21.2	580.8	1,136.2	10.6	42.4	212.0	
2014	25.6	701.9	1,373.1	12.8	51.2	256.2	
2015	31.0	849.3	1,661.5	15.5	62.0	310.0	
2016	37.6	1,028.9	2,012.8	18.8	75.1	375.5	
2017	45.5	1,247.7	2,440.8	22.8	91.1	455.4	
2018	55.3	1,514.5	2,962.6	27.6	110.5	552.7	
Discounting							
0%	305.0	8,356.9	16,347.9	152.5	610.0	3,050.0	
2.50%	211.8	5,804.6	11,354.9	105.9	423.7	2,118.5	
5%	149.9	4,106.7	8,033.6	74.9	299.8	1,498.8	

together with present values for a range of real discount rates.

The local environmental benefits would be reduced by 99% and the carbon values by 37% if it is assumed that wind electricity generation displaces only natural gas fired electricity rather than the forecast average electricity fuel mix.

### **Wind Conclusions**

When the production tax credit for wind energy is implemented as part of a larger suite of policies, including research and development and renewable portfolio standards, it is capable of significantly increasing the amount of electricity that is generated from wind. The threshold for wind electricity to achieve full market penetration is when the cost of electricity falls below or near that of fossil fuels, more than likely by 2010 given our policy scenarios. This increase in electricity generation from clean energy results in significant carbon savings, as well as benefits to the economy. These benefits include increased consumer surplus, decreased fossil fuel imports, and diversification of the rural economy in instances where farmers are able to lease land to wind turbines. <sup>157</sup>

<sup>&</sup>lt;sup>157</sup> Some argue that farmers will benefit from the option to lease land to wind electricity producers for the erection of turbines at no cost to agrarian yield.

Some steps in this direction have already been taken. Established renewable portfolio standards (RPS) programs such as those in Arizona, Connecticut, Massachusetts, Nevada, and Maine are expected to encourage 263 MW of new wind capacity in the next ten years. State mandates and green power initiatives in California, Colorado, Iowa, Minnesota, New York, and Wisconsin are expected to add an additional 1,017 MW of wind capacity. 158

Other policies at both the Federal and state levels, such as RPS, public benefit funds, and renewable mandates, will need to be employed along with a production tax credit in order to fulfill the credit's purpose. If such policies are enacted, this study suggests it will be possible to increase the penetration of wind energy technology into the electricity generation market to achieve economies of scale and thereby lower the price of wind-generated electricity until it is competitive with electricity from fossil fuels.

<sup>158</sup> Department of Energy, Energy Information Administration., *Annual Energy Outlook 1999*, "Legislation and Regulations," Washington, DC. December, 1998.

# 4. Appendix A

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# 5. Appendix B

Distribution of Questionnaire Responses by Provision and Sector							
Provision	Business	Academic	NGO	Government	Total		
Hybrid and Electric Vehicles	1	1	4	5	11		
Energy Efficient Homes	3	2	1	4	10		
Energy Efficient Building	2	1	3	5	11		
Equipment							
Combined Heat and Power	5	2	2	4	13		
Photovoltaics and Solar Water	6	3	3	1	13		
Heaters							
Wind	5	1	3	2	11		
Biomass	4	3	2	3	12		
Total	26	13	18	24			