ENERGY EFFICIENCY AND JOB CREATION:
THE EMPLOYMENT AND INCOME BENEFITS FROM INVESTING IN ENERGY CONSERVING TECHNOLOGIES

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Executive Summary

Numerous studies have examined the energy, economic, and environmental impacts of a national energy strategy that emphasizes greater energy efficiency. *America's Energy Choices*, for example, showed that vigorous adoption of cost-effective energy efficiency and renewable energy measures could reduce national energy intensity in 2030 by nearly 50 percent, dramatically reduce our nation's petroleum dependence, save consumers more than $2 trillion net over the next 40 years, and cut carbon dioxide emissions in 2030 by more then 70 percent relative to emissions in 1988.[1] However, *America's Energy Choices* and similar studies only consider direct economic impacts — the cost of energy efficiency measures and the value of the energy savings.

The purpose of this study is to build on *America's Energy Choices* by analyzing the indirect economic benefits of a high efficiency energy strategy — the impacts on employment and income that could result from shifting economic activity away from the energy supply sectors of our economy and from reducing the cost of energy services. We compare a High Efficiency scenario for all end-use sectors of the economy to a Reference, business-as-usual scenario.[2] We also examine the employment and income impacts that result solely from improving the fuel economy of automobiles and light trucks.

The analysis is conducted using an input-output economic model. Dividing the economy into 25 sectors, the input-output model estimates the overall employment and income effects from changes in spending patterns in particular sectors.[3] The changes consist of investments in energy efficiency measures and reductions in energy consumption and thus energy bills. The model accounts for direct (i.e., on-site) effects, indirect (i.e., supplier) effects, and induced (i.e., respending) effects from investments and expenditures at all levels.

The High Efficiency scenario assumes extensive efficiency improvements in all sectors of the economy -- more efficient vehicles, improved appliances, better insulated buildings, more efficient lighting, manufacturing improvements, and the like. All of the

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1. *America's Energy Choices: Investing in a Strong Economy and a Clean Environment*, Alliance to Save Energy, American Council for an Energy-Efficient Economy, Natural Resources Defense Council, and Union of Concerned Scientists, Washington, D.C., 1991.

2. The high efficiency scenario used in this study is based on the Market case scenario in *America's Energy Choices*.

3. The IMPLAN input-output model was updated and modified for conducting this study. The IMPLAN model was originally developed by the U.S. Forest Service.

efficiency measures are cost effective on a life-cycle basis considering only direct energy costs (i.e., without quantifying and taking into account externalities). The additional investment in energy efficiency measures in the High Efficiency scenario averages about \$46 billion per year during 1992-2010. These investments result in about 20 percent less energy consumption in 2010 compared to the Reference scenario, with absolute energy consumption rising slightly during 1992-2000, but then declining slightly during 2001-2010. Energy use per unit of GDP falls 2.4 percent per year on average during 1990-2010 in the High Efficiency scenario. This rate nearly matches the decline in energy intensity in the United States during 1973-86. We also estimate a 24 percent reduction in carbon dioxide (CO_2) emissions, 14 percent reduction in nitrogen oxides (NO_x) emissions and five percent reduction in sulfur dioxide (SO_2) emissions in 2010 in the High Efficiency scenario relative to the Reference scenario.

Based on our input-output analysis, the High Efficiency scenario leads to more jobs, higher personal income, and marginally higher GDP throughout the twenty-year period (See Table S-1). We estimate that about 293,000 new jobs could be created by 1995, 471,000 new jobs by 2000, and nearly 1.1 million jobs by 2010 on a net basis. The addition of 1.1 million jobs in 2010 represents approximately a 0.7 percent increase in the projected employment level that year (see Figure S-1). Likewise, the rise in personal income during the twenty-year period in the high efficiency case reaches 0.5 percent by 2010, while the increase in GDP is less than 0.1 percent.

The positive employment and income results are due primarily to the relatively low labor intensity of the energy sectors (coal, oil and gas extraction, fuel refining, and electric and gas utilities) compared to the economy as a whole. Conserving energy reduces the energy bills paid by consumers and businesses, thereby enabling greater purchase of non-energy goods, equipment, and services. The result is a shift of economic activity away from energy supply industries and towards sectors of the economy which employ more workers per dollar received. Regarding the different effects, less than 10 percent of the net jobs created are associated with direct investment in efficiency measures while more than 90 percent are associated with energy bill savings and respending of those savings.

Most sectors of the economy gain jobs and generate additional income while a few sectors lose jobs and generate less income in response to widespread energy efficiency improvements (see Table S-2). Our analysis shows the largest absolute increase in jobs is in the construction, retail trade, and services industries. These sectors install energy efficiency measures and gain new business orders from the respending of energy bill savings.

As expected, the energy supply industries employ fewer workers in the High Efficiency scenario as compared to the Reference scenario. The oil and gas extraction industries and gas utilities lose the most workers in percentage terms. It is important to recognize that the projected job losses in Table S-2 are based on comparison with the Reference scenario. Considering the projected change in the actual employment levels between 1990 and 2010, a total of about 200,000 jobs could be lost in the five energy sectors by 2010 in the High Efficiency scenario. These potential job losses are due primarily to expected productivity improvements, not to changes in absolute energy use during 1990-2010. In addition, individual companies may be able to reduce any adverse job impacts by diversifying into the energy efficiency field (e.g., if utilities hire workers to implement energy efficiency programs).

Efficiency improvements solely in automobiles and light trucks also yield favorable jobs and income results. In the Vehicle Efficiency scenario, we assume that the average rated fuel economy of new cars increases from 28 miles per gallon in 1990 to 40 miles per gallon in 2000 and then to 50 miles per gallon by 2010, with equivalent percentage improvements in the fuel economy of light trucks. Compared to the Reference scenario, the Vehicle Efficiency scenario produces 72,000 and 244,000 more jobs in the overall economy by 2000 and 2010, respectively. About 20 percent of the net increase in jobs is within the motor vehicle industry itself. Furthermore, we find that there is a net gain in jobs in the nation as a whole even if there is either a moderate increase in the fraction of vehicles that are imported or a slight drop in vehicle sales at the same time that fuel economy increases. Conversely, a decrease in import share or an increase in vehicle exports would yield even more new jobs than indicated above.

The results of this study are consistent with other input-output studies that examine how energy efficiency improvements affect employment levels. These other studies, which consider more limited efficiency investments and/or geographic coverage, indicate that specific energy efficiency measures or programs create more jobs at the regional or state level as compared to energy supply projects.

In conclusion, this study adds a new dimension to the national debate over energy priorities. Energy efficiency improvements lead to more jobs and higher personal income at the national level, in addition to saving consumers money, reducing energy imports, and cutting pollutant emissions associated with energy supply. In terms of energy policy objectives, it is unnecessary to choose either economic benefits and jobs on the one hand or environmental protection on the other. We can create more jobs and better protect the environment by adopting policies that enhance energy efficiency. Given the economic, energy, and environmental challenges that our nation faces, can we afford not to act?

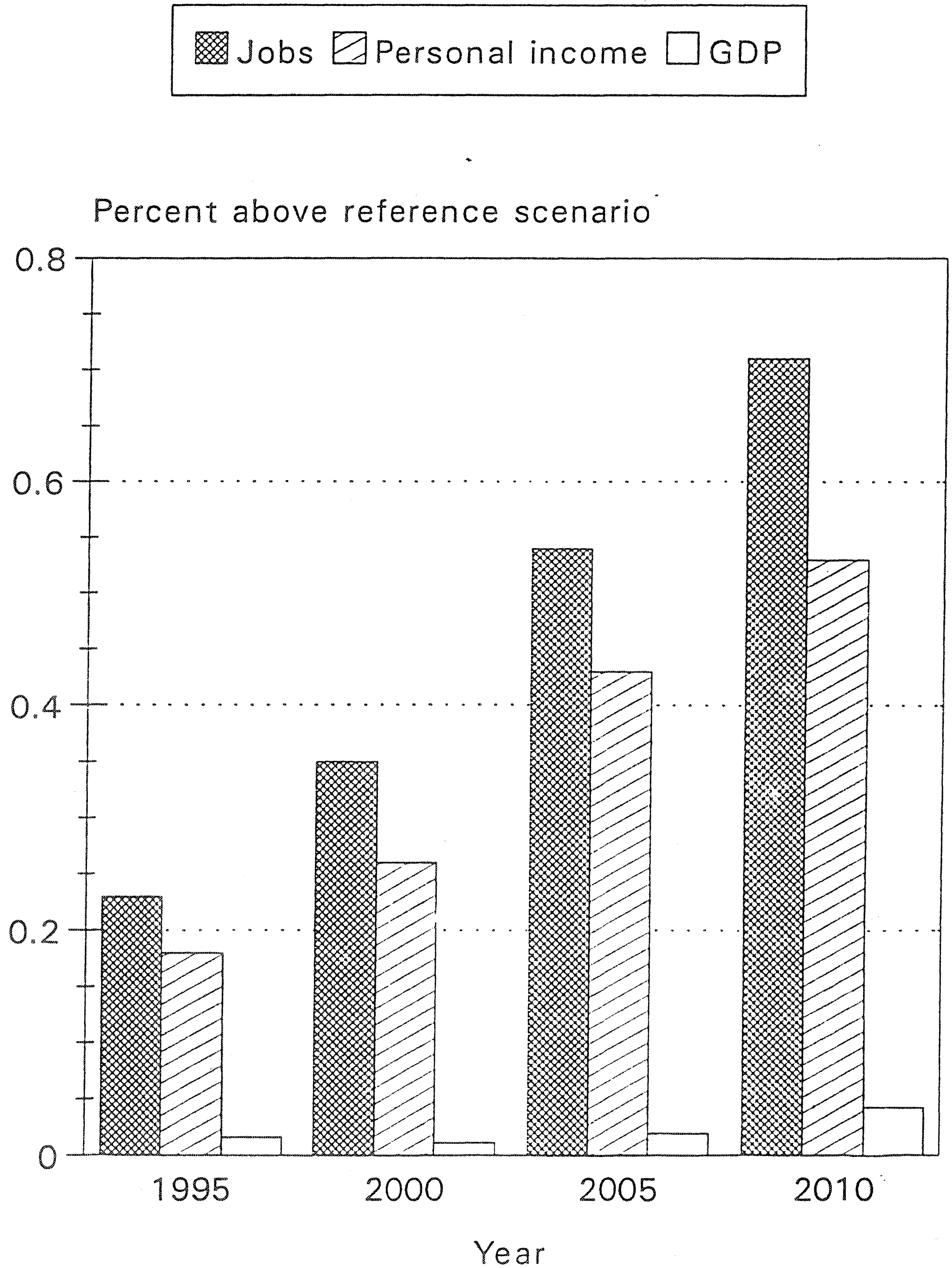
TABLE S-1. SUMMARY OF INPUT-OUTPUT ANALYSIS

	1990	1995	2000	2005	2010
Reference Scenario					
GDP (Billion 1990$)	$5,514	$6,205.6	$6,993.0	$7,889.7	$8,911.1
Jobs (Thousands)	122,600	129,273	136,494	144,273	152,650
Income (Billion 1990$)	$3,290	$3,712.4	$4,192.9	$4,741.0	$5,366.3
Energy (Quads)	85.02	90.49	95.61	101.20	106.10
Btu/GDP (1990$)	15,419	14,582	13,672	12,827	11,906
High Efficiency Scenario					
GDP (Billion 1990$)	$5,514	$6,206.6	$6,993.8	$7,891.2	$8,914.8
Jobs (Thousands)	122,600	129,566	136,965	145,049	153,737
Income (Billion 1990$)	$3,290	$3,719.0	$4,203.6	$4,761.2	$5,394.8
Energy (Quads)	85.02	87.14	88.07	87.06	85.35
Btu/GDP (1990$)	15,419	14,040	12,593	11,033	9,574
Net Efficiency Gains					
GDP (Billion 1990$)	n/a	1.0	0.8	1.5	3.7
Jobs (Thousands)	n/a	293.0	471.0	776.0	1,087.0
Income (Billion 1990$)	n/a	6.6	10.7	20.2	28.5
Energy (Quads)	n/a	-3.4	-7.5	-14.1	-20.8
Btu/GDP (1990$)	n/a	-542.0	-1,079.0	-1,794.0	-2,332.0

Table S-2. Differences in Employment Levels in 2010, High Efficiency vs. Reference Scenario

Sector	Net Job Changes	Percent Change
Subtotal Gains	*1,503,088*	n/a
Construction	342,101	4.4%
Retail Trade	197,491	1.1%
Services	152,264	0.3%
Agriculture	118,569	3.6%
Restaurants	105,259	1.3%
Health Services	91,651	0.8%
Finance, Insurance, Real Estate	77,931	0.8%
Non-Durable Goods	73,589	0.8%
Other Manufacturing	72,824	1.1%
Motor Vehicles	53,587	6.2%
Wholesale Trade	44,644	0.5%
Hotels and Lodging	34,404	1.4%
Food Processing	27,270	1.8%
Stone, Glass, Clay	26,403	4.1%
Primary Metals	23,417	2.3%
Transportation/Communications	22,873	0.4%
Chemicals	22,018	1.8%
Pulp and Paper	10,958	1.5%
Miscellaneous Mining	3,943	2.1%
Water/Sewer Utilities	892	0.4%
Subtotal Losses	*(416,309)*	n/a
Refining	(8,095)	(5.4%)
Coal Mining	(20,300)	(11.9%)
Gas Utilities	(71,090)	(31.0%)
Oil and Gas Extraction	(139,080)	(30.4%)
Electric Utilities	(177,744)	(21.6%)
Net Employment Gain	*1,086,779*	n/a

Figure S-1
Net increase in jobs, personal income, and GDP
in the High Efficiency scenario



I. Introduction

In many respects, the United States is still the world's most powerful economy. Per capita economic output is greater in the United States than in any other industrialized country when purchasing power parity is used to calculate gross domestic product. But with the lingering recession and unemployment approaching the eight percent mark, community and business leaders increasingly worry about the nation's ability to generate economic growth and new employment opportunities. Their concern is reinforced by a productivity growth rate that slipped from a robust 2.8 percent per year in the 1960's to a lackluster one percent per year in the 1980's. Under these circumstances, development strategies are being stretched in new directions to find a way back to the growth plane.

The prevailing economic development models are somewhat like a three-legged stool which supports our nation's material well-being. One leg might be thought of as the factories and equipment needed to produce the nation's goods and services. The second leg is the labor force required to operate the factories and the equipment, while the third leg is the influx of natural resources which becomes the material basis for goods and services. Unfortunately, most development theorists focus on only two of the three legs: that is, the nation's factories and equipment (which they refer to as *capital*) and its work force (or *labor*). The third leg, America's resource flow, is often ignored.

Instead, it is assumed that if stockholders receive sufficient compensation for their investment in capital, if production workers are reasonably educated, and if wages are paid at a rate sufficient to maintain the skills of the work force, the economy will always find the resources it needs to continue the nation's production efforts. This is not the case. The continuing failure to restore the nation's rate of productivity growth to the levels of the 1960's, coupled with the unexpected successes of the Japanese and West German economies, has prompted a serious reexamination of conventional development strategies. Among the issues being looked at more closely is the relative inefficiency of American energy use.

A. The Role of Resources in Economic Activity

When viewed from a materials and energy perspective, the American economy is perhaps only 10 to 15 percent efficient.[1] Some observers suggest that it may be this level of resource inefficiency which constrains the effective use of capital and labor. Electricity, typically thought of as being 100 percent efficient at the end use, is a case in point. It takes energy to explore, mine and produce the coal, natural gas and oil needed to power electrical turbines. It takes energy to build transmission lines and power plants. And, of course, there are large losses of useful energy in the power generation, transmission and distribution systems of a utility.

Once the electricity reaches a building or factory, there are other losses that occur in the end use or manufacturing process. Motors that power pumps, assembly lines and fabrication equipment dissipate energy, particularly under variable loads. Steam, water, and other forms of process heat are lost to the air. And inefficient heating, air-conditioning and ventilation systems in the factory use more energy, partly to compensate for the process losses. In buildings, inefficient lighting generates more heat than useful light while appliances consume much more electricity than is necessary.

Inefficient production and use of electricity, as well as other forms of energy, can inhibit economic growth in a number of ways. First, substantial amounts of capital must be devoted to energy supply investments — in fact, energy supply represented 40 percent of new plant and equipment expenditures as of 1982.[2] Second, net oil imports — $57 billion as of 1990 — are a major contributor to our trade deficit already and are expected to increase substantially with "business-as-usual" policies during the next 20 years.[3] In short, inefficient energy use diverts dollars from other productive investments and from the U.S. economy as a whole.

1. Richard S. Claassen and Louis A. Girifalco, "Materials for Energy Utilization," *Scientific American*, October 1986, pages 103-117.

2. J. Goldenberg, T.B. Johansson, A.K.N. Reddy, and R.H. Williams, *Energy for a Sustainable World*, Wiley Eastern Limited, 1988, page 27.

3. The U.S. Department of Energy projects that net oil imports will cost the United States $94 billion in 2000 and $142 billion in 2010. See *Annual Energy Outlook 1992*, DOE/EIA-0383(92), Energy Information Administration, U.S. Department of Energy, 1992.

B. The Ongoing Energy Debate

During the last 20 years, the United States has experienced three major political and economic crises related to energy use and especially to our dependence on imported petroleum. Despite those painful lessons, U.S. dependence on imported oil exceeds seven million barrels per day. Moreover, our current wasteful use of energy inflicts heavy damage on the environment and threatens the nation's ability to complete in the global marketplace. When measured in terms of energy use per dollar of gross domestic product (GDP), the U.S. is about twice as energy intensive as West Germany, Switzerland, Denmark and Japan.[4] Part of this difference is due to the efficiency of energy use, part is due to different energy services, and part is due to structural differences among countries.

In 1986, the United States consumed 74.3 Quads of primary energy, almost identical to the amount of energy consumed in 1973.[5] Even more remarkable, the nation's real GDP grew by 35 percent during this same period. As a result, our energy intensity — measured by energy use over gross domestic product, or *E/GDP* — declined by 26 percent, or 2.3 percent annually.[6] Indeed, despite relatively stable energy use during this period, population grew by 14 percent, industrial production (measured in real dollars) increased by 29 percent and the number of passenger cars increased by 33 percent. Efficiency improvements in all sectors explain about two-thirds of this gain. Structural changes and interfuel substitution explain the balance.[7]

In the 1980's, energy conservation fell from political favor. Oil prices plummeted in 1986. Since 1986, energy use has been rising at about the same rate as GDP. At the same time, there has been growing concern about urban smog, global warming and other environmental problems linked to energy use. These concerns, together with a slumping economy, have triggered a protracted debate about the need for revising our national energy policies.

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4. These comparisons are taken from 1988 data contained in *Energy Balances of OECD Countries, 1987-1988*, Organisation for Economic Cooperation and Development, Paris, France, 1990.

5. One Quad is equal to 10^{15} Btus of energy. This is equal to about 170 million barrels of crude oil, or about 26 days of U.S. motor gasoline consumption (based on 1990 figures).

6. *Annual Energy Review 1991*, DOE/EIA-0384(91), U.S. Energy Information Administration, U.S. Department of Energy, Washington, D.C., June 1992.

7. Office of Technology Assessment, *Energy Use and the U.S. Economy*, OTA-BP-E-57, Congress of the United States, June 1990, page 4. See also, Lee Schipper, Richard B. Howarth, and Howard Geller, "United States Energy Use From 1973 to 1987: The Impacts of Improved Efficiency," *Annual Review of Energy*, Volume 15, 1990, pages 455-504.

Characterizing one side of the debate is President Bush's National Energy Strategy (NES)[8], which emphasizes a continued reliance on fossil fuels and nuclear power. With only limited support for energy efficiency, energy consumption is projected to grow from 85 Quads in 1990 to over 126 Quads in the year 2030 under the NES policy scenario.[9]

On the other side of the debate are studies and strategies that emphasize increased investments in energy efficiency and renewable energy technologies. According to these studies, the potential for cost-effective energy savings is very significant.[10] In the midst of this debate, a group of four energy and environmental groups launched a new technical study, known as *America's Energy Choices*, in order to examine the role that energy efficiency and renewable energy technologies can play in meeting the nation's economic and environmental challenges.[11]

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8. U.S. Department of Energy, *National Energy Strategy: Powerful Ideas for America*, Washington, D.C., 1991.

9. What is especially revealing about the lack of support for energy efficiency in the NES is that DOE performed analysis indicating that widespread efficiency improvements are feasible. For example, one working document outlined a scenario that would reduce U.S. energy consumption in the year 2030 by 31 percent over current policies. Ironically, the analysis indicated a strengthening of GNP as a result of increased energy efficiency. See, Energy Information Administration, Very High End-Use Conservation Excursion, *Energy Consumption and Conservation Potential: Supporting Analysis for the National Energy Strategy*, SR/NES/90-02, U.S. Department of Energy, Washington, D.C., 1990.

10. There now exists a large body of literature describing cost-effective technologies to improve overall energy efficiency. Examples include Howard S. Geller, Eric Hirst, Evan Mills, Arthur H. Rosenfeld and Marc Ross, "Getting America Back on the Energy-Efficient Track: No-Regrets Policies for Slowing Climate Change," American Council for An Energy-Efficient Economy, Washington, D.C., October 1991; Office of Technology Assessment, *Building Energy Efficiency*, U.S. Congress, OTA-E-518, Washington, D.C., May 1992; Roger S. Carlsmith, *et al.*, "Energy Efficiency: How Far Can We Go?", Oak Ridge National Laboratory, Oak Ridge, TN, January 1991; ICF Incorporated, *Preliminary Technology Cost Estimates of Measures Available to Reduce U.S. Greenhouse Gas Emissions by 2010*, Fairfax, VA, August 1990; Marc Ross, Marc Ledbetter, and Feng An, "Options for Reducing Oil Use by Light Vehicles: An Analysis of Technologies and Policy, American Council for An Energy-Efficient Economy, Washington, DC, December 1991; and Office of Technology Assessment, *Energy Efficiency in the Federal Government*, U.S. Congress, OTA-E-492, Washington, D.C., May 1991.

11. See, Union of Concerned Scientists, et al, *America's Energy Choices: Investing in a Strong Economy and a Clean Environment*, Washington, D.C., 1991, page 1.

The study relied on a computerized modeling system known as the Long-Range Energy Alternative Planning (LEAP) model to investigate the implications of four energy futures through the year 2030.[12] The four scenarios include a:

Reference Case, a business-as-usual scenario which reflects current energy policies and trends;

Market Case, which selects energy technologies based on the goal of minimizing the cost of energy services;

Environmental Case, which assigns monetary values to the environmental impacts of energy use;

Climate Stabilization Case, which seeks to meet predetermined targets for reduction of carbon dioxide emissions to the atmosphere.

Each of these four cases assumes successively greater reliance on energy efficiency and renewable energy technologies.

The Reference Case, built on assumptions published by the U.S. Department of Energy,[13] indicated a 41 percent rise in the nation's energy use by the year 2030 (from 1988). Perhaps more importantly, carbon dioxide emissions were projected to rise 58 percent by that same year. Each of the three efficiency and renewable energy investment strategies demonstrated a dramatic reduction in both energy use and pollutant emissions.

Based upon data used for the most aggressive scenario (the Climate Stabilization Case), by the year 2030 the nation's energy requirements would be cut nearly in half from the Reference scenario. The carbon dioxide emissions would actually be reduced by more than 70 percent from 1988 levels in that same year.

Perhaps the most intriguing result of the *America's Energy Choices* study is that consumers would enjoy a net energy bill savings of some $2.3 trillion over the 40-year period ending in 2030.[14] This result arises from efficiency measures that save energy at lower cost than producing equivalent amounts of energy from new conventional sources such as fossil-fuel power plants.

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12. LEAP was designed by the Stockholm Environment Institute-Boston Center at the Tellus Institute, Boston, MA 02110.

13. *1990 Annual Energy Outlook*, DOE/EIA-0383(90), Energy Information Administration, U.S. Department of Energy, 1990.

14. *America's Energy Choices*, op. cit., page 2.

II. Economic Impacts

Until recently, one of the less appreciated benefits of energy efficiency investments is their ability to promote new employment opportunities throughout all levels of the economy. A number of studies have shown that as energy efficiency is more widely implemented, economic well-being is also strengthened. This, in turn, enhances job opportunities (see Part IV of this study).

While the direct economic impacts of energy efficiency and renewable energy options were analyzed in *America's Energy Choices* (AEC), the study did not explore the employment and income benefits of the more aggressive efficiency scenarios. The model used in the study was not designed to estimate the indirect impacts which result from improvements in energy productivity.

To understand the full opportunity for employment and income benefits from energy efficiency improvements, this current project was launched. More specifically, this report explores the changes in gross domestic product (GDP), jobs, and employment compensation that result from the Market Case efficiency investments found in *America's Energy Choices*. To distinguish the results of this inquiry from the AEC findings, we use the term **High Efficiency scenario** which connotes investments in energy-efficient technologies as prescribed for all sectors in the AEC Market Case.

A. Energy Efficiency Investments

The starting point of *America's Energy Choices* was to track, in detail, exactly how energy is used within the residential, commercial, industrial and transportation sectors. From there the AEC report explored a variety of assumptions and technologies to determine an appropriate mix of investment opportunities that might fit within different energy efficiency scenarios.

The analysis included applications that ranged from commercial lighting and residential appliances to the movement of freight and people on the nation's highways, railroads and airlines. It examined space heating and cooling, industrial motor drives, and the development of renewable energy technologies such as solar water heating, solar electricity generation, and biomass fuel production.

Table II-1 provides a list of representative energy efficiency technologies (or bundles of technologies) examined in the AEC study, together with their respective cost of conserved energy (1990$).[15] The purpose is to illustrate the range of costs and technologies associated with the type of investments recommended in the Market Case.[16] The efficiency investments save energy at much lower cost than supplying energy in today's marketplace.

Table II-1. Costs of Energy Efficiency Investments[17]

Technology	Average Cost of Conserved Energy ($/MBtu)
Engine Controls for Heavy Trucks	$2.24
Office Building Improvements	$2.71
Efficient New Office Buildings	$2.74
Hospital Building Improvements	$2.88
Efficient New Retail Buildings	$3.51
High Efficiency Gas Furnace	$3.68
Retail Building Improvements	$4.15
Improved Automobile Efficiency	$4.24
Residential Lighting Improvements	$6.83
Commercial Lighting Improvements	$6.85
Efficient Industrial Motors	$7.33
High Efficiency Refrigerators	$10.35

Source: These representative technologies or technology bundles are taken from the "Technical Appendixes" of *America's Energy Choices*, op. cit.

15. The cost of conserved energy is the incremental cost of the technology necessary to save a given amount of energy. The investment is amortized over the useful life of the technology using a three percent real discount rate. The three percent rate is intended to reflect the cost of capital to society based on the long-term average yield on U.S. Treasury bonds. This discount rate does <u>not</u> represent the cost of capital to consumers or businesses in the marketplace.

16. More than 100 separate technologies were evaluated in the complete study. For a complete recitation of costs and other assumptions about each of the scenarios and technology applications, see the technical appendices associated with *America's Energy Choices*, op. cit.

17. For comparison, the average 1990 residential electric price was $22.96/MBtu, the average 1990 residential natural gas price was $5.62/MBtu, while the average price of gasoline was $9.74/MBtu (including taxes).

With a Reference Case established to show how the economy would likely behave through the year 2030, the AEC analysis then developed a scenario that included energy efficiency and renewable energy technologies that appeared to be cost effective for consumers using market energy prices. The resulting forecasts yielded the Market Case of *America's Energy Choices*. The projected total energy requirements and carbon dioxide emissions associated with these two scenarios are highlighted in Table II-2.

Table II-2. Summary Results of the Reference and Market Scenarios of America's Energy Choices

Data	**1988**	**2000**	**2010**	**2030**
Gross National Product (Billion 1990$)	5,292	7,090	8,941	12,792
Reference Case				
Primary Energy (Quads)	85.3	96.4	105.0	120.2
Energy/GNP (kBtu/$)	16.1	13.6	11.7	9.4
CO_2 Emissions (Billion Tons)	5.3	6.0	6.8	8.3
Market Case				
Primary Energy (Quads)	85.3	88.5	83.4	82.2
Energy/GNP (kBtu/$)	16.1	12.5	9.3	6.4
CO_2 Emissions (Billion Tons)	5.3	5.4	4.7	3.8

As the information from Table II-2 illustrates, both the AEC's Reference Case and Market Case assume the same level of economic growth as measured by the projected levels of Gross National Product (GNP), expressed in billions of 1990 dollars. The difference between the two cases is the level of energy consumption associated with each. In the Reference Case, energy intensity declines from 16,100 Btus per dollar of GNP in 1988 to 9,400 Btus in the year 2030.

By comparison, the Market Case shows a much steeper decline in energy intensity, dropping to 6,400 Btus per dollar of GNP by 2030. The difference in energy intensities results from a cumulative $1.2 trillion investment in energy efficiency and renewable energy technologies in the period 1988 through the year 2030 (net present value based on a three percent real discount rate). The investment is projected to reap a cumulative energy bill savings of $3.1 trillion in that same period, yielding a net savings of $1.9

trillion (once again in terms of a net present value based on a three percent real discount rate).

For comparative purposes, the carbon dioxide emissions associated with each case are also shown in the above table. As might be expected, the added investment in efficiency and renewable technologies in the Market Case lowered projected emissions by 54 percent over the Reference Case in the year 2030. While the Reference Case indicates an absolute increase in emissions, moving from 5.3 to 8.3 billion tons in the years 1988 to 2030, the Market Case shows an absolute decline in emissions to only 3.8 billion tons in 2030.

B. Framework of Analysis

While the Reference and Market Case found in *America's Energy Choices* were used as the starting point for the employment and income analysis in this study, four significant changes were made. The first change was to shorten the time frame from the years 1988 through 2030 to the years 1990 through 2010. The second change was to move the starting year from 1988 in the Market Case to the actual economic profile for 1990. The efficiency investments were not assumed to begin until 1992, however. A third point was to report national output as the Gross Domestic Product (GDP) rather than GNP as done in the original study. This change was done to incorporate the revised reporting format of the federal government. The fourth change was to consider only vehicle efficiency improvements in the transportation sector. Structural and behavioral changes that lead to reduced vehicle use were not included in this analysis because of the uncertainty surrounding their cost, lead time, and energy impacts.

The major economic parameters for 1990 are summarized in Table II-3.[18] The 1990 data form only the starting point for comparison between the Reference and the High Efficiency scenarios developed in this study. The projections for the year 2010 in the Reference scenario are based upon a variety of data sources.[19] As will be discussed

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18. The 1990 GDP and income (i.e., employee compensation) data was obtained from the *Survey of Current Business*, U.S. Department of Commerce, Bureau of Economic Analysis, July 1992. The 1990 employment data were provided by the Office of Employment Projections, Bureau of Labor Statistics, U.S. Department of Labor. Employment includes both wage and salary workers, the self-employed and unpaid family members. Energy forecasts and prices were taken from the *Annual Energy Outlook 1992*, DOE/EIA-0383(92), Energy Information Administration, U.S. Department of Energy, January 1992.

19. Energy forecasts and prices were taken from the *Annual Energy Outlook 1992*, DOE/EIA-0383(92), Energy Information Administration, U.S. Department of Energy, January 1992. Forecasts for GDP growth were taken from *America's Energy Choices*, which, in turn, was based on Department of Energy projections as of 1991. Two other reports, *Outlook 2000*, Bureau of Labor Statistics, U.S. Department of Labor, April 1990, and *BEA Regional Projections to 2040*, Bureau of Economic

later in this report, an input-output model was calibrated to the 1990 economy and projected forward to 2010 based upon these economic forecasts.

Table II-3. 1990 U.S. Economic Profile Data

GDP (Billion 1990$)	$5,514
Total Employment	122,584,000
Income (Billion 1990$)	$3,290
Energy (Quads)	85.02
Energy/GDP (kBtu/$)	15.4

Costs and Savings Compared to Reference Scenario

Once the economic and energy consumption trends were established in the Reference scenario, changes were introduced in the model to reflect new energy efficiency investments. Based upon the original data in *America's Energy Choices*, the efficiency investments and cumulative energy savings for the years 1995, 2000, 2005 and 2010 are presented in Table II-4. The data are reported for each of the major end-use sectors in billions of 1990 dollars.

Using the year 2010 totals as the focal point, for example, we note in Table II-4 that about $60 billion of efficiency improvements will be made in that year. At the same time, the energy bill savings in 2010 from all efficiency measures in the economy that year is estimated to be $167 billion. These energy savings accrue from efficiency investments made in the years 1992 through 2010. These include savings for all fuel types and end-uses.[20]

Analysis, U.S. Department of Commerce, June 1990, also were used to select economic growth assumptions.

20. Again, for a complete review of the assumptions behind the efficiency and renewable energy investments, see the Technical Appendices for *America's Energy Choices*. It should be noted that while the energy prices by fuel, end-use and year were adapted from the DOE *Annual Energy Outlook*, they were modified to reflect assumptions about fixed and variable cost components as well as the responsiveness of the prices to reduced energy demand. See the discussion on this point found in section II-D.

Table II-4. Summary of Annual Efficiency Investments and Energy Savings of the High Efficiency Scenario (Billions of 1990$)

End-Use	1995		2000		2005		2010	
	Invest	Save	Invest	Save	Invest	Save	Invest	Save
Residential	11.98	6.77	12.19	15.37	19.45	28.75	19.87	42.48
Commercial	2.33	2.29	2.33	5.17	7.83	15.41	7.83	25.76
Industrial	15.12	4.59	15.11	12.47	13.36	20.49	13.36	29.16
Transportation	5.14	8.60	5.48	21.83	18.33	45.22	18.60	69.56
Total	34.57	22.25	35.11	54.84	58.97	109.86	59.65	166.96

The data for 1995 (Table II-4) show that the efficiency investments exceed the savings during the early and mid-1990's. This occurs because each investment occurs once with the installation of the new efficient equipment, while the energy savings from that equipment will occur in subsequent years. After several years of such investments, the total annual energy savings from all prior investments begin to exceed that year's new investment total.

By 2000, the energy savings from investments in efficiency measures in previous years are worth $55 billion while an additional $35 billion is spent on new efficiency improvements that year. By 2010, the savings are nearly 2.8 times the investment for that year. The cumulative investment in energy efficiency measures from 1990 through 2010 is about $835 billion (1990$). The cumulative energy savings during that same period of time is estimated to be about $1.4 trillion (1990$). This results in a net savings of nearly $600 billion for consumers and businesses relative to the Reference scenario (net present value at three percent real discount rate). Once again, this is a first order assessment. It only considers the direct cost of efficiency measures and the value of the resulting energy savings. Also, additional energy savings will occur after 2010 from investments made prior to that date. These savings are excluded from this study, making our results conservative in terms of the overall benefits from energy efficiency improvements.

Establishing an Economic Model

Each sector of the economy — whether agriculture, construction, health or electric utility services — supports different levels of total economic activity, employment and personal income. As the level of expenditures are increased or decreased, the level of employment supported by a given sector will rise or fall by some amount. In the case of the High Efficiency scenario, we want to know whether investing $835 billion over an 18-year period (1992 through 2010) yields enough energy cost savings to end up with significantly more jobs than might otherwise occur.

Given a pattern of efficiency investments and their resulting energy savings (Table II-4), the question can now be asked: "What are the *net benefits*, if any, from those efficiency investments?" One tool that can assist in the evaluation of the job and income benefits is known as input-output analysis, sometimes called multiplier analysis.

Input-output analysis can be used to evaluate the job and income benefits (i.e., the "outputs") which are likely to result from the changes in spending patterns (the "inputs") created by the investment in particular technologies or sectors. Changes in each sector will actively affect all other sectors that are linked to it. Using input-output analysis, the impact of a dollar spent in different sectors of the economy can be traced and measured.

For example, let us suppose (in a highly simplified example) that a 10-horsepower motor in a pulp and paper mill has burned out. By paying an extra $100 for a more efficient model, it is possible to save about $50 per year in lower electric bills. In purchasing the premium model, the first impact will be to pay the motor vendor an extra $100 for a new motor. The vendor will in turn pay the manufacturer a premium, possibly through an intermediate distributor. The manufacturer, in turn, will pay his or her parts suppliers, and, perhaps, an extra bonus to the salesperson. Those effects represent economic gains from the efficiency improvement.

In the meantime, until the pulp and paper mill recoups its initial investment, it will have 100 dollars less money to spend on other goods or services. That may be translated as a delay in the purchase of a new copier for the office, for instance. That $100 motor investment, while providing economic gains to the vendor and manufacturer, represents an interim economic loss to the paper mill.

But once the new motor is installed, the business will be able to spend about $50 each year for other goods, equipment and services. That $50 savings represents a second benefit to the local economy. At the same time, the local utility may lose $50 in revenues which represents a loss to the overall economic activity. At this point, then, we have identified four separate changes in normal purchase patterns. Two were positive and two were negative.

But there are more effects than simply those directly created, for example, by the money paid to a motor vendor for a high efficiency unit. To determine the total economic outcome of the efficiency investment, three separate effects must be examined:

Direct Effect: These are the on-site jobs created by an expenditure. In the case of installing a more efficient electric motor, the direct effect would be the on-site jobs of the electrical contractor hired to carry out the work as well as the vendor who sold the new motor to the paper mill.

Indirect Effect: When a contractor or motor vendor receives payment for goods or services delivered, he or she is able to pay others who support their businesses. This is the indirect effect and includes such people as the banker who finances the contractor, the accountant who keeps the books for the vendor, and the wholesale suppliers who keep both well-stocked with material goods.

Induced Effect: As the people who are directly and indirectly employed by the efficiency upgrade spend their weekly paychecks, they are said to "induce" other activity. This refers to money received by the grocer, for instance, who hires people to work in his or her store.

The sum of these three effects yields a **Total Effect** that results from a single expenditure, in this case the extra $100 spent to buy the more efficient motor. Even at this point the analysis is incomplete since it only deals with the direct, indirect and induced effects of the efficiency investment itself. To understand the full range of economic influences, a total of four impacts must also be examined for their direct, indirect and induced, or total effects. They are the:

Investment Impact: This is the efficiency investment, including both equipment and labor costs. In the case just described, it is the $100 additional cost for the purchase of the high efficiency motor.

Revenue Impact: This refers to the transfer of funds from one place to another which must be recorded as a loss in the overall set of transactions. In the case of the motor purchase, while the motor vendor receives an extra $100, the pulp and paper mill will initially have $100 less to spend elsewhere.

Substitution Impact: With the premium motor now installed, the efficiency improvements are effectively "substituted" for some amount of the energy use. If that amount generates a net savings, the result is increased local spending equal to some portion of the energy savings. In the motor example, the paper mill owner may have extra funds to complete other upkeep or maintenance. He or she may buy another piece of office machinery, or provide a Christmas bonus to employees.

Displacement Impact: Any money saved by the efficiency improvements may create a loss of income for the local energy supplier. If it occurs, such displacement may create an economic loss to the community, which will also have indirect and induced effects. Again, in the case of the motor efficiency improvements, a local utility may find revenues sufficiently reduced so that open jobs slots are unfilled, or that some employees are asked to retire early.

From a discussion of these terms, it can be seen that a complete multiplier analysis captures the direct, indirect and induced effects of each major change in local expenditure patterns. Thus, there are two major tasks in completing an employment and income analysis of this type. The first is to understand just how the expenditure patterns affect each of the sectors of the economy. The second is to identify and calibrate an appropriate economic model to reflect the total impacts of those four spending changes, both positive and negative.

There are many different analytical tools that can be used to estimate the full range of these spending impacts. One is the U.S. Department of Commerce's Regional Input-Output Modeling Systems (RIMS II), a 531-sector input-output model designed and used by the U.S. Bureau of Economic Analysis.[21] A number of state energy offices, for instance, have adapted the RIMS model for use in their own policy analysis.

A second analytical tool often used is the 528-sector IMPLAN model originally developed for mainframe computers by the U.S. Forest Service. It is now available for use in personal computers and has recently been used for such things as estimating the economic impacts of oil and gas exploration and the conversion of midwestern farmland into a national forest.[22]

Both models produce comparable results if the framework of analysis is properly established. However, the data provided by the RIMS model largely consists of just the multipliers themselves. IMPLAN, on the other hand, contains actual output, employment and income data as well as the input-output multipliers. This allows the user to more easily adapt it for use in a particular analysis. Therefore, the IMPLAN model was chosen for conducting this analysis.[23]

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21. For more information on the use of this database and model, see, Bureau of Economic Analysis, *Regional Multipliers: A User Handbook for the Regional Input-Output Modeling System (RIMS II)*, (Washington, DC: U.S. Department of Commerce, 1992).

22. IMPLAN is short for "IMpact Analysis for PLANning." Originally an analytical model used on the U.S. Forest Service's mainframe computers, it is now available for microcomputers from the University of Minnesota's Department of Agricultural and Applied Economics, 1994 Buford Avenue, St. Paul, MN 55108.

23. The I-O model used in this study is a "static model" because the multipliers are assumed to remain constant in the future (except for specific changes in multifactor productivity which the user can introduce at the time of analysis). Some of the limitations inherent with this type of model are discussed in section II-D. Dynamic I-O models have been developed and used to analyze issues such as how technological

With the baseline information downloaded from the IMPLAN model, the next step in the analysis was to make the information easier to manage. This was done by aggregating the 528 sectors down to a total of 25 sectors.

Since IMPLAN is benchmarked to a 1985 economic database, the second step in the analysis was to calibrate the model to fit within the 1990 framework referenced in Table II-3. This was done using 1990 employment and income information for each of the relevant economic sectors. With this step complete, a series of multipliers were generated for each of the 25 sectors (see Table II-5). While updated as much as possible to economic conditions in 1990, the multipliers shown in Table II-5 still represent underlying relationships within the U.S. economy as of 1985.[24]

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change has affected capital and labor markets in the United States. See, F. Duchin, "International Trade and the Use of Capital and Labor in the U.S. Economy," *Economic Systems Research*, 1(3), 1989, pages 345-350. Also, F. Duchin and G.M. Lange, "Technological Choices, Prices and Their Implications for the U.S. Economy, 1963-2000," *Economic Systems Research*, 4(1), 1992.

24. Technically, the 1985 IMPLAN model is updated from the 1977 benchmark tables developed by the U.S. Department of Commerce. The 1982 benchmark tables, the most recent available, were released in 1992 but have not yet been incorporated into IMPLAN. While the RIMS multipliers have been updated from 1977 using the 1982 tables, any results generated from the earlier tables will continue to provide useful insights at the level of U.S. policy analysis referenced in this study. As with any analytical tool like IMPLAN, however, a proper analysis must anticipate these shortcomings and make any needed adjustments. One example of such an adjustment is the annual increase in productivity. A variety of sources project a growth in productivity of between 1.0 and 1.5 percent for the next 20 years. Using an assumed productivity growth rate of 1.4 percent coupled with the projected 2.4 annual percent growth in GDP used in *America's Energy Choices*, the IMPLAN model forecasts a year 2000 employment level of 136.5 million jobs. BLS forecasts to 136.2 million jobs, which is reasonably close to the IMPLAN results.

Table II-5. Multipliers for the United States (1990)			
Industry	Output (Total Sales Per Dollar Spent)	Jobs (Total Per Million $ Expenditure)	Wages/Salaries (Total Earnings per Dollar Spent)
Agriculture	2.1198	26.86	0.3451
Other Mining	1.8170	13.51	0.5672
Coal Mining	1.8690	12.88	0.5431
Oil and Gas Extraction	1.3438	7.02	0.2546
Construction	1.9228	20.97	0.5674
Metal Durables	1.9390	17.28	0.6469
Food	2.4489	19.77	0.4650
Other Manufacturing	2.0310	20.75	0.5884
Paper	2.1011	14.29	0.5476
Chemicals	2.1282	13.06	0.5340
Refining	2.0209	7.14	0.2617
Stone, Glass, Clay	1.9051	17.25	0.5732
Primary Metals	2.0150	13.05	0.5489
Motor Vehicles	2.1871	13.70	0.5426
Transportation/Communication	1.5777	16.37	0.5487
Electric Utilities	1.7821	9.54	0.3341
Gas Utilities	1.9921	7.41	0.2442
Water/Sewer Utilities	1.5943	14.00	0.4163
Wholesale Trade	1.4668	20.43	0.6730
Retail Trade	1.5984	32.24	0.6590
Finance, Insurance, Real Estate	1.4220	10.10	0.2959
Hotels and Lodging Places	1.5815	36.13	0.6048
Other Services	1.3726	26.45	0.7048
Eating and Drinking Places	1.9766	37.78	0.5389
Health Services	1.5853	23.15	0.6740

Three types of multipliers are shown in Table II-5.[25] The first is referred to as **output multipliers**. This refers to the total change in economic activity generated for each dollar of final demand delivered to a given economic sector. In the case of electric utilities, for instance, each dollar of additional revenue collected by the utilities will generate, directly and indirectly, a total of $1.78 in total sales activity throughout the U.S. economy. Economic output contributes directly to GDP; in other words, expenditures that result in higher net output contribute to economic growth.

The second set of ratios refers to **jobs multipliers**. Here, the reference is to the total change in employment for each one million dollars of final demand delivered to a given economic sector. Again referring to electric utilities, a one million dollar increase in revenues will support a total of 9.54 jobs, both directly and indirectly. Beginning with its 1985 data, IMPLAN defines a job as a person-year equivalent.

Finally, the third set of ratios refer to employee compensation in the form of **wage and salary multipliers**. The reference, in this case, is to the total change in income for each dollar of final demand delivered to a given economic sector. Continuing with the previous example, each dollar of revenue collected by the electric utilities will increase employee compensation by a total of $0.33.

A quick review of the Table II-5 reveals an important point. When looking at the jobs column, the five energy-related sectors (coal mining, oil and gas extraction, refining, electric utilities and gas utilities) have some of the smallest employment multipliers. In other words, these traditional energy supply sectors are relatively capital intensive in contrast to more labor intensive businesses that might be found in the various service sectors. This insight offers an early hint of the likely results of the economic impact analysis to come — that is, by lowering energy bills in all sectors of the economy, the savings will likely be spent in a way that supports a stronger employment base for the country.

Changes in Final Demand

Two major steps in the input/output analysis have been completed — setting up the initial dollar amounts associated with the efficiency investments, and developing the initial set of multipliers. We can understand how these steps fit together within an analysis by setting up a simple problem to solve.

25. Strictly speaking, the multipliers on this page are what are known as Type I multipliers. That is, they include only the direct and indirect effects of a given expenditure. The induced effect is simulated by including changes in personal consumption expenditures as part of the final demand column rather than as part of the production process.

Let us again use the example of a purchase of a more efficient electric motor by a pulp and paper mill. In this case, the local planner wants to know what the net benefit would be to the economy — based upon the $100 incremental cost of the premium motor, and the anticipated energy savings of $50 per year.

The multipliers found in Table II-5 already reflect the direct and indirect effects of an expenditure made for each sector of the economy. At this point all we need to do is match the proper change in spending with the correct multiplier found in Table II-5. In this example there are four such calculations to be made and summed. The steps for the first year in which the efficient motor is purchased and operated are shown next:

(1) Investment Impact $=\$100_{\text{motor purchase}} * 2.0310_{\text{manufacturer}} = \$203.10_{\text{gain}}$

(2) Revenue Impact $=-\$100_{\text{budget loss}} * 2.1011_{\text{paper mill}} = -\$210.11_{\text{loss}}$

(3) Substitution Impact $=\$50_{\text{utility bill savings}} * 2.1011_{\text{paper mill}} = \$105.06_{\text{gain}}$

(4) Displacement Impact $=-\$50_{\text{revenue loss}} * 1.7821_{\text{electric utility}} = -\$89.11_{\text{loss}}$

Net Impact $= \$8.99_{\text{net gain in year one}}$

In this example, total economic activity will be strengthened by about $8.99 compared to buying a less-expensive and less-efficient motor. This includes both the direct and indirect effects of all four sets of expenditures. Similar calculations would be done for both employment and wage and salary multipliers to generate estimates of job and income benefits.

By year two, because of the assumption that the motor is paid for with current earnings, the net gain to the economy will be even larger since equations (1) and (2) would be dropped from the analysis. In that case, the year two net benefit would be $105.06 less $89.11, or $15.95. Thus, as energy savings begin to accumulate, the net gains to the economy also grow.

Each of the changes in spending shown in the calculations above represent changes in final consumer demand. Each change in the final demand, created by the efficiency upgrade, needs to be matched with its appropriate multiplier. The products are then summed to determine whether the upgrade produces net benefits or not.

As this point we move to the next step of the analysis — to determine the sector-by-sector changes in expenditures resulting from the efficiency investments summarized in

Table II-4. This becomes the basis on which to predict employment and income benefits in the U.S. using the modified IMPLAN model.

The assumption used here is that each sector that benefits from efficiency improvements will also carry the cost of paying for the improvements. In other words, there is no cross subsidy in utility bills or tax incentives. A further premise is that the savings enjoyed by each sector, proportionate to the level of investment made, will be respent in the same manner as other funds available to it.

For instance, if households dedicate five percent of their income to savings, then we assume five percent of the energy bill savings will be saved as well. Similarly, if a manufacturing sector spends about 25 percent of its revenues for employee compensation, then about 25 percent of the energy bill savings will end up as employee compensation. We do not assume that businesses would use energy bill savings to reduce overall price levels. If we did, there would be more indirect economic benefits in other sectors, which would still lead to substitution impacts.

C. Results

Table II-6 presents the results for the High Efficiency scenario in 1995, 2000, 2005, and 2010. Compared to the Reference scenario, primary energy use is reduced by 7.5 Quads (8 percent) in 2000 and 20.8 Quads (20 percent) in 2010. Absolute energy consumption rises slightly during 1990-2000 but then declines during 2001-2010 in the High Efficiency scenario. Energy use per unit of GDP declines by 2.4 percent per year on average during the twenty-year period, nearly matching the rate of energy intensity reduction in the United States during 1973-86.[26]

The IMPLAN model does not directly track consumption of different types of fuel on a primary basis. We can, however, estimate energy savings by fuel type and the corresponding reductions in pollutant emissions in the High Efficiency scenario by referring to the Market Case analysis in *America's Energy Choices*. Adjusting for the small difference in energy savings between the two analyses as well as the accelerated implementation of renewable energy sources in *America's Energy Choices*, we estimate that the 20.8 Quads of energy savings in our High Efficiency scenario in 2010 would be comprised of about 7.0 Quads of oil, 4.7 Quads of natural gas, and 9.1 Quads of coal. We also estimate about 1.7 billion tons of avoided carbon dioxide emissions in 2010 in the High Efficiency scenario, a 24 percent reduction relative to emissions in the Reference scenario. Likewise, NOx emissions would be reduced by about 14 percent and SO2 emissions by about 5 percent in 2010 in the High Efficiency scenario.

26. Projected energy use and energy intensity in 2010 are about three percent higher in the High Efficiency scenario as compared to the Market Case in *America's Energy Choices*.

Table II-6. Summary of Input-Output Analysis

	1990	1995	2000	2005	2010
Reference Case Scenario					
GDP (Billion 1990$)	$5,514	$6,205.6	$6,993.0	$7,889.7	$8,911.1
Jobs (Thousands)	122,600	129,273	136,494	144,273	152,650
Income (Billion 1990$)	$3,290	$3,712.4	$4,192.9	$4,741.0	$5,366.3
Energy (Quads)	85.02	90.49	95.61	101.20	106.10
Btu/GDP (1990$)	15,419	14,582	13,672	12,827	11,906
High Efficiency Scenario					
GDP (Billion 1990$)	$5,514	$6,206.6	$6,993.8	$7,891.2	$8,914.8
Jobs (Thousands)	122,600	129,566	136,965	145,049	153,737
Income (Billion 1990$)	$3,290	$3,719.0	$4,203.6	$4,761.2	$5,394.8
Energy (Quads)	85.02	87.14	88.07	87.06	85.35
Btu/GDP (1990$)	15,419	14,040	12,593	11,033	9,574
Net Efficiency Gains					
GDP (Billion 1990$)	n/a	1.0	0.8	1.5	3.7
Jobs (Thousands)	n/a	293.0	471.0	776.0	1,087.0
Income (Billion 1990$)	n/a	6.6	10.7	20.2	28.5
Energy (Quads)	n/a	-3.4	-7.5	-14.1	-20.8
Btu/GDP (1990$)	n/a	-542.0	-1,079.0	-1,794.0	-2,332.0

The High Efficiency scenario results in more jobs, higher personal income, and marginally higher GDP throughout the twenty year period. It is estimated that about 293,000 new jobs are created by 1995, 471,000 new jobs by 2000, and nearly 1.1 million new jobs by 2010 on a net basis. The net increase in jobs by 2010 represents about approximately a 0.7 percent rise in the projected employment level that year (see Figure II-1). Likewise, the rise in personal income during the twenty-year period reaches about 0.5 percent by 2010, while the increase in GDP is less than 0.1 percent that year.[27]

Table II-7 presents the sectoral changes in employment that are expected in 2010 in comparing the High Efficiency and Reference scenarios. The table shows both the anticipated job gains or losses as well as the percent change from the Reference Case scenario. Negative values are shown in parentheses. In the High Efficiency scenario, a total of 1.5 million new jobs are added in 2010 in the twenty "gaining" sectors, while about 0.4 million jobs are lost in the five "losing" sectors.

The construction, retail trade and service sectors gain the most new jobs in absolute terms in the High Efficiency scenario, while the motor vehicles and stone, clay, and glass industries also gain significantly in percentage terms. Energy efficiency technologies are installed by builders, vehicle manufacturers and electrical and special trade contractors. Building contractors will begin to use more architectural and engineering services and other technical skills in the construction of new homes and business, as well as in the renovation of the existing building stock. All of these activities will increase demand for manufactured goods such as energy efficient motors, lights and space conditioning systems. And as the energy bill savings begin to mount, consumers and businesses will have increased buying power that further adds to the job gains throughout the economy.

As might be expected from the drop in energy consumption, the energy sectors could face significant employment loss. It is important to recognize that the projected job losses in Table II-7 are based on comparison with the Reference scenario. Considering the projected change in the actual employment levels between 1990 and 2010, a total of about 200,000 jobs could be lost in the five energy sectors by 2010 in the High Efficiency scenario. This represents about a 12 percent drop in total employment in these industries between 1990 and 2010. These potential job losses are due primarily to expected productivity improvements, not to changes in absolute energy use during 1990-2010. In addition, individual companies may be able to reduce any adverse jobs

27. A study by the Energy Information Administration of the U.S. Department of Energy indicates that energy efficiency improvements on the scale envisioned in our High Efficiency scenario could have a somewhat greater impact on total economic output. By reducing primary energy consumption in 2010 by about 18 Quads compared to a base case, the "Very High Efficiency Scenario" developed by the EIA resulted in an 0.84 net increase in GNP by 2010. See, *Energy Consumption and Conservation Potential*, op. cit., pages 18-21.

Figure II-1
Net increase in jobs, personal income, and GDP
in the High Efficiency scenario

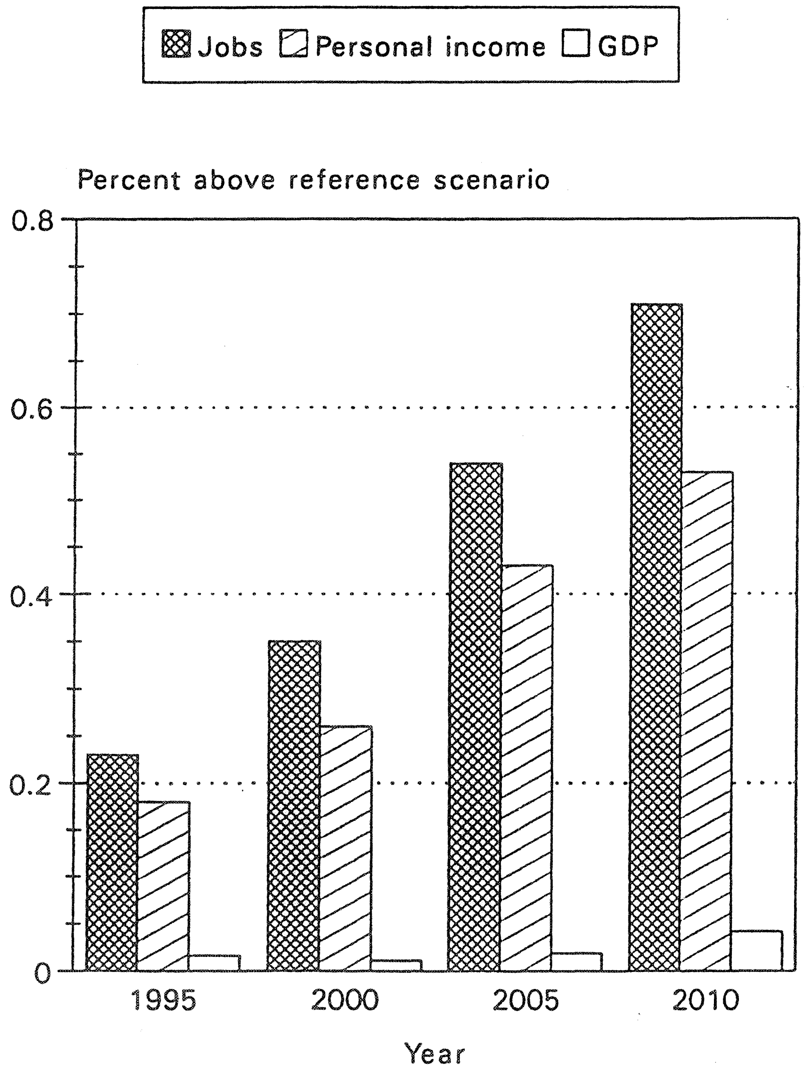

Table II-7. Differences in Employment Levels in 2010: High Efficiency vs. Reference Scenario

Sector	Net Job Changes	Percent Change
Subtotal Gains	*1,503,088*	n/a
Construction	342,101	4.4%
Retail Trade	197,491	1.1%
Services	152,264	0.3%
Agriculture	118,569	3.6%
Restaurants	105,259	1.3%
Health Services	91,651	0.8%
Finance, Insurance, Real Estate	77,931	0.8%
Non-Durable Goods	73,589	0.8%
Other Manufacturing	72,824	1.1%
Motor Vehicles	53,587	6.2%
Wholesale Trade	44,644	0.5%
Hotels and Lodging	34,404	1.4%
Food Processing	27,270	1.8%
Stone, Glass, Clay	26,403	4.1%
Primary Metals	23,417	2.3%
Transportation/Communications	22,873	0.4%
Chemicals	22,018	1.8%
Pulp and Paper	10,958	1.5%
Miscellaneous Mining	3,943	2.1%
Water/Sewer Utilities	892	0.4%
Subtotal Losses	*(416,309)*	n/a
Refining	(8,095)	(5.4%)
Coal Mining	(20,300)	(11.9%)
Gas Utilities	(71,090)	(31.0%)
Oil and Gas Extraction	(139,080)	(30.4%)
Electric Utilities	(177,744)	(21.6%)
Net Employment Gain	*1,086,779*	n/a

Table II-8. Source of Employment Changes for Year 2010			
Effect	**GDP (Billion 1990$)**	**Jobs**	**Income (Billion 1990$)**
Investment Impact	$64.62	1,093,000	$40.20
Revenue Impact	($63.33)	(1,009,000)	($34.32)
Substitution Impact	$153.84	2,471,000	$82.61
Displacement Impact	($151.43)	(1,468,000)	($59.99)
Net Impacts	$3.70	1,087,000	$28.50

impacts by diversifying into the energy efficiency field (e.g., if utilities hire workers to implement energy conservation programs).

Table II-8 offers yet another view of the dynamics of job creation associated with energy efficiency improvements. The net increases found in the High Efficiency scenario in 2010 are reviewed according to the four separate impacts — the investment, revenue, substitution and displacement impacts. The investment and substitution impacts are positive influences while the revenue and displacement impacts are negative influences.

Table II-8 indicates that the net job and income benefits of the High Efficiency scenario result largely from the energy bill savings. We can observe this influence by examining the net outcomes of the efficiency investment versus the net impact of the energy bill savings.

Combining the (positive) efficiency investment impacts and the (negative) efficiency revenue impacts for the year 2010 shows only a modest gain in GDP, jobs, and wage and salary income. In the case of jobs, for instance, the investment impact shows a gain of 1,093,000 jobs in 2010. But subtracting the 1,009,000 jobs lost through the revenue impact — the diversion of funds from other normal purchases to pay for the efficiency improvements — yields only a small gain of 84,000 jobs in that year.

Turning to the two impacts associated with the energy savings, the substitution impact, which represents the respending of the money saved through lower energy bills, will lead to an estimated 2,471,000 new jobs in 2010. On the other hand, the displacement impact, which represents lost revenues to energy supply companies, reduces overall employment by 1,468,000 jobs. The net jobs gain from the energy bill savings is, therefore, 1,003,000 jobs.

Adding the 84,000 job gains from the investment and revenue impacts to the 1,003,000 jobs supported by the energy bill savings leaves a total net increase of 1,087,000 jobs. In other words, the investments and revenue impacts yield about eight percent of the net employment creation, while the energy savings and respending impacts yield about 92 percent of the new jobs on a net basis. This result makes sense when we recall the earlier discussion about the large difference in job multipliers between the various energy sectors on one hand and all other sectors of the economy on the other. By diverting a large sum of money ($167 billion in year 2010 as shown in Table II-4) from energy spending with its small job multipliers, a positive net employment impact results. These considerations explain, for example, why there is a positive job gain in 1995 even though efficiency expenditures are larger than energy bill savings that year. While the investment impact is largely offset by the revenue impact, the substitution impact produces the net positive jobs gain through the respending of the energy bill savings in 1995.

D. Issues Affecting the Results

The results of this analysis are not surprising given the cost effectiveness of energy efficiency improvements and the low labor intensity of energy production. Nevertheless, it is important to review the limitations of this type of input-output analysis in order to place the results in perspective. There are five areas that merit particular attention.

Static, Scale Independent Modeling

Input-output models such as the IMPLAN model are based upon an accounting of the nation's economic activity at a given point in time. These are termed *static* models of economic activity. This notion refers to the premise that the relationships among the many different businesses and industries in one year will remain unchanged over the time period analyzed. In the case of IMPLAN, the data is "benchmarked" to the 1977 national I-O tables available from the U.S. Department of Commerce. The tables are then adjusted to the 1985 economic profile for the U.S.[28]

For this project, 1990 data was substituted in the IMPLAN model for the 1985 data. This includes actual sectoral data for output, GDP, jobs and employment compensation

28. For a discussion of how the adjustments are made to the "benchmark" tables, see, M. Planting, "The History and Development of the U.S. Annual Input-Output Accounts," Interindustry Economics Division, Bureau of Economic Analysis, U.S. Department of Commerce, Washington, DC, March 1988.

(i.e., wages and salaries and associated benefits). To establish a Reference scenario for 1990-2010, each of the sectors was grown or contracted according to the projected annual growth rates for GNP found in *America's Energy Choices*. The assumption in AEC was that through the year 2010 the economy would grow at about 2.4 percent annually. Implicit in this approach is the premise that the relationships among the sectors through the year 2010 would be adequately represented by the relationships that existed in 1990. This assumption appears to be reasonable given that the U.S. economy is relatively stable; i.e., relationships among sectors are not changing very rapidly.[29]

Input-output models such as IMPLAN also assume that the average relationships among the industries are independent of the scale of investment. This means that the relationships apply equally to both very small and very large changes in spending. For example, let's assume that, on average, it takes $250,000 worth of labor to produce $1,000,000 worth of a specific type of manufactured good. A static input-output model assumes that the same labor ratio of 25 percent will apply to a $1,000 purchase or to $100,000,000 purchase throughout the time period analyzed.

A strict I-O model, such as IMPLAN, also does not analyze how the assumed pattern of investments and expenditures affect other macroeconomic parameters such as interest rates or inflation. There should be some interaction between these parameters and the effects that are estimated by IMPLAN (i.e., GDP, jobs, and employment compensation). However, the magnitude of the changes in GDP, employment and income due to greater energy efficiency in this study are moderate enough that significant changes in other variables are unlikely. For example, unemployment by the year 2010 is projected to run at about five or six percent of the labor force. That means about 8-10 million people will be unemployed in that year. It is unlikely that the introduction of about one million new jobs from efficiency improvements will significantly increase the average wages and thus raise the rate of inflation.

Nonetheless, for the reasons described above, static models cannot precisely forecast changes in future employment and income levels from particular actions over a long period of time. The strength of the input-output model as it is used here is that it provides useful insights about how different investment strategies can expand the nation's

29. One economist recently examined the differences between the two sets of benchmark tables and concluded that, at the level applied in this analysis, there was very little change between 1977 and 1982. Personal communication, Peter Blair, Energy and Materials Program, Office of Technology Assessment, Washington, DC, September 1992. Similarly, 1989 RIMS multipliers for the U.S. based either on the 1977 or the 1982 benchmark tables also showed little overall difference. Finally, an analysis done for the Electric Power Research Institute, comparing a 1972 benchmark table to a dynamically created table for the year 2000, concluded that only relatively small changes occurred in the resulting multipliers. See, Resources for the Future, Inc. *An Energy-Oriented Input-Output Model*, EPRI EA-3625, Electric Power Research Institute, Palo Alto, CA, August 1984, page 4-21.

overall employment and income opportunities, and which sectors of the economy will be affected either positively or negatively.

The conclusion that should be drawn from this analysis is not that the High Efficiency scenario will provide exactly 1.1 million jobs in the year 2010, but that energy efficiency can provide significantly greater employment opportunities while continuing to meet other critical economic and environmental needs. In fact, there are other positive impacts in the High Efficiency scenario which indicate that the resulting analysis may actually understate the employment and income benefits.

The multipliers used in this study are based upon the import levels in the 1985-1990 time period. Because of the static model and related assumptions, any oil savings due to energy efficiency improvements are assumed to reduce both domestic and imported oil consumption in proportion to their use in 1990. But in reality, oil savings at the margin primarily lead to less imports, rather than less domestic production. Thus, by investing in technologies that reduce the nation's dependence on petroleum, especially imported oil, the tendency will be to increase the average sectoral multipliers compared to those generated by the IMPLAN model for this analysis. In this sense, the results presented here tend to understate the economic gains of the High Efficiency scenario.

Energy Prices

This analysis primarily relies on the energy prices published in the *Annual Energy Outlook* to estimate the monetary values of anticipated energy savings. While these prices form a reasonable starting point, there are two issues which will significantly alter how those prices translate into energy bill savings.

The first issue is the problem of fixed costs. For all fuels, and especially for electricity, reduced consumption means that there are fewer units of energy over which to recover previous investments in power plants, transmission lines, pipelines, production wells, and the like. This leads to price increases, at least in the short run.

To correct for the problem of fixed capacity, the analysis assumes that electricity prices have a fixed cost component equal to about 40 percent of the published DOE prices.[30] Information on the fixed cost components for natural gas and petroleum, while less capital-intensive than electricity, is difficult to generate. The premise used here is that they have a fixed cost component of 20 and 10 percent, respectively. The implication

30. Information from the U.S. Department of Energy indicates a 1990 capital cost component of 44 percent of the average electricity price, dropping to 31 percent in 2010. The 40 percent figure was used throughout the analysis as a conservative estimate. See, *Annual Energy Outlook 1992: With Projections Through 2010*, DOE/EIA-0383(92), Energy Information Administration, U.S. Department of Energy, Washington, DC, January 1992.

of these assumptions is that energy bill savings will, in fact, be equal only to the non-capital costs of energy.

The second issue affecting energy prices is how reduced energy consumption in the High Efficiency scenario will affect the price of energy. DOE reports indicate that all energy prices are reasonably sensitive to significantly reduced demand. In other words, as demand falls, there will be a downward pressure on energy prices. There is not a consistent body of published literature that supports one response rate over another. For purpose of this analysis, therefore, it was assumed that the variable (non-capital) cost component of all energy prices would have an elasticity of 0.4 with respect to demand. More specifically, for every 10 percent drop in consumption, the premise was adopted that the variable energy costs would drop by four percent over their otherwise published values.[31]

Utility and Other Energy Investments

As the High Efficiency scenario begins to show significant energy savings, reduced energy use either postpones or eliminates the need for a variety of future energy supply investments. While there is a strong database on how electricity investments will be affected, notably through the work of Tellus Institute, there is little information on the investment patterns for the other major fuels.

Because of this uncertainty, it was decided to hold at zero the energy investment factor in the analysis presented here. In other words, the analysis assumes no savings from a lower investment in other energy resources such as new oil and gas wells or new power plants. However, a number simulations were run to test the influence of reduced energy investments on the overall employment picture.

It turns out the energy savings from lower energy investments did not appreciably affect the overall outcome. For example, in the year 2010, employment levels generated in scenarios which reflected the investment savings remained within three percent of those scenarios which did not include the investment savings. The reason appears to be that as the savings are reallocated back to the other sectors, their weighted labor intensities

31. In estimating the impacts of the Very High End-Use Conservation Excursion on energy prices and costs, the Department of Energy notes that in the year 2010 world oil prices will drop 7.2 percent (in real terms) compared to the reference scenario. Similarly, wellhead natural gas prices will drop 26.1 percent and average electricity prices will also drop 5.7 percent in real terms. This implies a long-run elasticity of 0.32 for petroleum, 1.25 for natural gas and 0.36 for electricity. See, *Energy Consumption and Conservation Potential*, op cit, pages 18-21. To maintain a consistency in the analysis, this study adopts an average elasticity of 0.4. Since this applies only to the non-capital portion of the energy costs, the effective elasticities are, therefore, 0.24 for electricity, 0.32 for natural gas, and 0.36 for petroleum.

were approximately equal to the construction multipliers. Nonetheless, this issue should be refined in future studies, particularly as it affects the non-electric investment patterns.

Consumer Decisions

An important question that needs to be explored is how businesses and consumers will respend any savings realized through their lower energy bills. In other words, how much of the savings will households use to buy more goods, how much will they add to savings, how much will be spent out of the country, and how much will they use to retire debt. The literature is not especially strong concerning this issue. For purposes of this study, it was assumed that households would spend their savings in the same pattern as their personal consumption expenditures. It was further assumed that businesses would spend their savings much as they would any additional revenues earned through their normal course of doing business. In other words, additional inputs would be purchased and investments made, thereby enabling output to grow.[32] Absent better information, the premise was adopted that savings would be respent in an average rather than marginal fashion.

Making different assumptions about how consumers spend or use energy bill savings could lead to moderately different results from those reached in this study. While the implications of different assumptions should be examined, we are confident that our fundamental results will not be altered because: a) saving energy is more labor intensive than supplying energy; b) increasing energy efficiency will increase overall economic efficiency and raise multi-factor productivity; and c) the savings will be respent eventually in ways that tend to employ more people than supplying energy.

Expensing Versus Financing

The issue of expensing versus financing energy efficiency improvements is not addressed in this study. The assumption used is that the investment would be expensed (i.e., paid for immediately). However, financing all or part of the investment is possible. Making this assumption should yield similar if not more positive results because the banking and finance industries have reasonably high multipliers. By taking money from businesses and consumers in the form of interest payments, a similar level of employment would be created as leaving the money in the hands of the consumer. Nonetheless, since there are numerous ways to underwrite and finance the High Efficiency scenario, this issue should be explored in subsequent studies.

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32. The energy bill savings computed in *America's Energy Choices* already reflect a so-called "rebound" effect — that is, the fraction of energy savings that is sacrificed for increased levels of comfort or service. An example of this effect is a household which previously kept its indoor temperature at 68 degrees during the winter but after adding insulation, decides to maintain a 72 degree indoor temperature.

III. Vehicle Efficiency Scenario

Light duty vehicle (car and light truck) efficiency improvements were identified as one of the major opportunities for cost-effective fossil fuel (namely, petroleum) energy savings in the *America's Energy Choices* study. Vehicle efficiency improvements account for 4.1 Quads (20 percent) of the overall 20.8 Quads reduction in primary energy use obtained in the High Efficiency scenario relative to the Reference scenario.

The issue of potential employment impacts has been frequently raised in the course of policy discussions regarding vehicle efficiency improvement, for example, through strengthened Corporate Average Fuel Economy (CAFE) standards. To directly address the issue, we developed a scenario including only vehicle efficiency improvements in order to isolate the employment impacts associated with these measures.

A. Economic Parameters for the Vehicle Efficiency Scenario

Light vehicles (including only cars and light duty trucks such as pickups and vans) now represent about 89 percent of motor vehicle sector output in the U.S. economy.[33] The average price increase for an automobile obtaining 40 miles per gallon instead of 28 miles per gallon is about $600 relative to current new car prices. At this level of improvement, the average incremental cost of conserved energy is $0.53 per gallon.[34] These estimates are based on a detailed analysis of the fuel economy improvements and costs of a wide range of available vehicle efficiency measures.[35] Fuel economy improvement cost estimates vary; the automotive industry in particular has cited much higher costs. Important determinants of cost include assumptions regarding the scale of production and whether efficiency improvements cause premature plant or equipment retirement (i.e., requirements for new retooling investments prior to the end of the useful

33. Total 1990 vehicle output is estimated at $202 billion based on figures of truck and car sales published by the *Survey of Current Business*, Bureau of Economic Analysis, U.S. Department of Commerce, Washington, DC, August 1992. Cars have a 70 percent share and light trucks have a 30 percent share of the light vehicle market, based on R.M. Heavenrich, J.D. Murrell and R.K. Hellman, *Light-Duty Automotive Technology and Fuel Economy Trends through 1991*, EPA/AA/CTAB/91-02, U.S. Environmental Protection Agency, Ann Arbor, MI, May 1991. Assuming a light truck-to-car price ratio of 88 percent yields an 89 percent share estimate for light vehicles in the motor vehicle sector. Heavy trucks and buses account for the remaining 11 percent of motor vehicle output on a dollar basis.

34. *America's Energy Choices*, op. cit., Table C-8 of the technical appendixes.

35. M. Ross, M. Ledbetter, and F. An, *Options for reducing oil use by light vehicles: an analysis of technologies and policy*, American Council for an Energy-Efficient Economy, Washington, DC, December 1991.

life of older tooling investments). The $600 estimate is adopted here under assumptions of a full scale of production and avoidance of premature plant retirements.

In order to increase fuel economy beyond 40 miles per gallon during 2001-2010, we assume the cost of automotive efficiency improvements will rise further. However, we do not assume static technology and so the additional price increase is modest, with the average incremental cost of $700 per vehicle (1990$) for an increase in fuel economy from 28 miles per gallon to 50 miles per gallon.[36] In effect, we assume that innovation will allow a rightward shift of the conservation supply curve, so that greater energy savings are achieved at a given level of avoided fuel costs. However, the efficiency investments made in vehicles in the beginning years of the scenario must be repeated in later years to account for vehicle replacement. Thus, the investment costs shown in Table III-1 rise sharply after 2000, but most of the rise is due to replacement costs, not higher incremental vehicle costs.

Table III-1. Summary of Annual Investments and Energy Savings of the Vehicle Efficiency Scenario (Billions of 1990 Dollars)

Expenditure	1995	2000	2005	2010
Technology Investment	4.8	4.8	17.3	17.3
Fuel Savings	5.5	14.0	33.4	53.8

As with the main analysis described in Chapter II of this report, the Vehicle Efficiency scenario is based upon the projected annual efficiency investments and energy bill savings. These values for 1995, 2000, 2005 and 2010, are shown in Table III-1. By 1995, the fuel savings are comparable in magnitude to annual investments in fuel economy for new cars and light trucks. However, the annual savings grow as the improved vehicles come to dominate the on-road vehicle stock. Thus, by 2010, the fuel cost savings exceed annual investments by a factor of three.

The cumulative energy cost savings during the period 1992 through 2010 amount to $415 billion while the cumulative vehicle efficiency investments are about $204 billion.

36. Based on an average added cost of conserved energy of $0.63/gallon, for increasing from 40 MPG to 50 MPG. See *America's Energy Choices, op. cit.*, pp.C-26,27 and J-2.

Consumers and businesses directly realize a net savings of $211 billion.[37] This stream of investments and savings for light vehicle efficiency, then; provided the economic drivers to evaluate changes in GDP, jobs and personal income compared to the Reference scenario.

B. Vehicle Efficiency Results

Table III-2 summarizes the results of the Vehicle Efficiency scenario for 1995, 2000, 2005 and 2010. As might be expected, the lower level of investment (29 percent of that in the complete High Efficiency scenario in 2010) yields a portion (32 percent) of the energy cost savings and therefore a smaller increase in GDP, jobs and income compared to the complete High Efficiency scenario. But because the investments are cost-effective and the savings still quite significant, and because there is a shift away from the petroleum supply sector with its very low labor intensity; there are net gains in employment in the Vehicle Efficiency scenario, rising steadily from 25,000 new jobs in 1995 to 244,000 new jobs in 2010 on a net basis.

Similar to Table II-7 in the main analysis, Table III-3 lists the net employment gains and losses by economic sector in 2010 for the Vehicle Efficiency scenario. Since vehicle efficiency improvement saves mainly petroleum, the petroleum extraction and refining industries face the largest percentage drops in employment. There is, however, one surprising result in Table III-3. Service sector job losses are the largest in absolute terms (although only 0.2 percent of the total sectoral employment). The reason is that government employees are aggregated within this sector. As oil consumption declines, so do the revenues associated with the various taxes on gasoline. Since our analysis incorporates no offset for the reduced tax revenue, the result is a projection of reduced employment within government agencies throughout the country.

All but three of the 25 sectors show job gains, primarily due to the redirection of expenditures away from the capital-intensive and import-dependent petroleum industry. The motor vehicle industry itself is projected to increase employment by as many as 47,000 jobs. The increase in employment is a function of the retooling needed to provide the more efficient vehicles, the increased costs and therefore larger sales revenues associated with light vehicles, and the significant respending effect resulting from the energy bill savings, which enables greater overall consumption of non-energy goods, including cars and light trucks.

37. As in the main analysis, all monetary values are expressed in 1990 dollars with the net present value established using a three percent real discount rate.

Table III-2. Summary of Input-Output Analysis for the Vehicle Efficiency Scenario

	1990	1995	2000	2005	2010
Reference Scenario					
GDP (Billion 1990$)	$5,514	$6,205.6	$6,993.0	$7,889.7	$8,911.1
Jobs (Thousands)	122,600	129,273	136,494	144,273	152,650
Income (Billion 1990$)	$3,290	$3,712.4	$4,192.9	$4,741.0	$5,366.3
Energy (Quads)	85.02	90.49	95.61	101.20	106.10
Btu/GDP (1990$)	15,419	14,582	13,672	12,827	11,906
Vehicle Efficiency Scenario					
GDP (Billion 1990$)	$5,514	$6,205.7	$6,993.5	$7,890.5	$8,912.8
Jobs (Thousands)	122,600	129,298	136,566	144,424	152,893
Income (Billion 1990$)	$3,290	$3,713.4	$4,194.7	$4,745.7	$5,372.8
Energy (Quads)	85.02	89.96	94.43	98.57	102.03
Btu/GDP (1990$)	15,419	14,496	13,502	12,492	11,448
Net Efficiency Gains					
GDP (Billion 1990$)	n/a	0.1	0.5	0.8	1.7
Jobs (Thousands)	n/a	25.0	72.0	151.0	244.0
Income (Billion 1990$)	n/a	1.0	1.8	4.7	6.5
Energy (Quads)	n/a	-0.5	-1.2	-2.6	-4.1
Btu/GDP (1990$)	n/a	-86.0	-170.0	-335.0	-458.0

Table III-3. Differences in Employment Levels in 2010: Vehicle Efficiency vs. Reference Scenario		
Sector	Net Job Changes	Percent Change
Subtotal Gains	*410,645*	n/a
Retail Trade	80,372	0.5%
Agriculture	59,090	1.1%
Motor Vehicles	47,216	5.5%
Restaurants	34,373	0.4%
Health Services	31,921	0.3%
Metal Durable Goods	25,188	0.3%
Finance, Insurance, Real Estate	24,182	0.3%
Construction	23,240	0.3%
Other Manufacturing	19,994	0.3%
Hotels and Lodging	11,997	0.5%
Food Processing	10,168	0.7%
Transportation/Communications	8,634	0.1%
Chemicals	7,390	0.6%
Wholesale Trade	6,989	0.1%
Primary Metals	6,500	0.8%
Electric Utilities	3,790	0.5%
Stone, Glass, Clay	3,704	0.6%
Pulp and Paper	2,565	0.4%
Gas Utilities	1,210	0.5%
Coal Mining	851	0.5%
Water/Sewer Utilities	654	0.3%
Miscellaneous Mining	619	0.3%
Subtotal Losses	*(167,660)*	n/a
Refining	(6,275)	(4.0%)
Oil and Gas Extraction	(68,543)	(15.0%)
Services	(92,842)	(0.2%)
Net Employment Gain	*243,985*	n/a

C. Sensitivity to Vehicle Imports

Automobile imports now account for about 30 percent of the total sales of new cars in the United States.[38] Projections by the Bureau of Labor Statistics indicate that this relationship is unlikely to change over the next decade.[39] A constant import share was assumed in the analysis presented in Tables III-2 and III-3. But what if the level of imports were to change, either positively or negatively, over the 20-year time frame of our analysis? This issue was examined through a series of sensitivity analyses. Table III-4 presents the net change in jobs in the economy as a whole in 2010 with imports increasing or decreasing by 15 and 30 percent from their current levels together with the vehicle efficiency improvements explained above.

We do not believe that measures to promote vehicle efficiency improvement are likely to affect the import market share one way or the other. The level of imports is primarily dependent on broader competitiveness considerations and is further complicated by the significant and growing inter-relationships among automakers. U.S. automakers are presently competitive in all vehicle classes. There are continuing negotiations and agreements regarding motor vehicle trade levels and supply arrangements, particularly for imports from and exports to Japan and within North America. These factors have far greater bearing on net vehicle imports than U.S. domestic energy and environmental policies. Because these competitiveness and trade factors could induce volatility in market shares, an import share sensitivity analysis is of interest.

Under the scenario of a 30 percent rise in imports (that is, automobile import market share rising from 30 percent to 39 percent) together with the assumed efficiency improvements, employment in the U.S. could drop by 6,000 jobs in 2010. On the other hand, reducing the level of imports from 30 percent to 21 percent could increase the employment gain from 244,000 jobs to 492,000 jobs by 2010. A similar beneficial impact might result if the improved efficiency of domestically produced cars enables an increase in U.S. automotive exports to regions (e.g., Latin America) where efficient vehicles are likely to be more competitive than the less efficient cars typical of the present U.S. market.

The results in Table III-4 indicate that unless there is a further large shift towards imported vehicles, there are net U.S. job gains because of the energy savings that accrue

38. L.S. Williams and P.S. Hu, *Highway Vehicle MPG and Market Shares Report: Model Year 1990*, ORNL-6672, Oak Ridge National Laboratory, Table 4, April 1991.

39. *Outlook 2000*, op. cit.

from vehicle efficiency improvements. Furthermore, if energy efficiency improvements occur throughout the economy as in our High Efficiency scenario, the employment and income benefits resulting from the even larger nationwide energy savings would more than offset any such job losses from a hypothetical shift towards imported vehicles.

Table III-4. Employment Impacts in 2010 Associated with Different Automobile Import Levels

Automobile Import Assumption	Import Market Share	Net Job Gain
30% rise over Baseline	39.0%	(6,000)
15% rise over Baseline	34.5%	118,000
Baseline Vehicle Efficiency Scenario	30.0%	244,000
15% drop from Baseline	25.5%	368,000
30% drop from Baseline	21.0%	492,000

D. Sensitivity to Vehicle Sales Levels

Motor vehicle manufacturers have expressed a concern that, if new car prices rise because of efficiency improvements, then sales will decline. This could, in turn, lead to reduced employment. This concern about lower automobile sales became the focus of a second sensitivity analysis conducted with the modified IMPLAN model.

There are two reasons why a price increase from technology improvement may not result in a proportionately-sized loss of jobs. First, the price rise reflects value added: jobs are involved in supplying the technology used to improve efficiency. Second, the price increase associated with efficiency improvement does represent a value to consumer, namely, that of lower operating costs.

There could, nevertheless, still be a drop in sales from consumers responding to the assumed price increase. A consensus estimate of the long-run light vehicle sales price elasticity is a value of -1.0; that is, for each percentage increase in the price of a car, sales could decline by one percent.[40] A price elasticity of -1.0 generally implies that a supply-side price increase results in no change in the overall consumer expenditures on vehicles (that is, the marginal revenue for manufacturers is zero). With new automobiles prices averaging about $16,000,[41] the extra $600 per vehicle needed to raise average fuel economy from 28 miles per gallon to 40 miles per gallon corresponds to a price increase of about four percent. This means, in turn, new car sales would decline by about four percent with a price elasticity of -1.0. A four percent sales decline forms the boundary for this sensitivity analysis.

A more moderate response also is examined because price increases associated with higher vehicle efficiency reflect real value to the consumer in the form of future energy savings. In other words, rational consumers would be willing to pay a certain amount more for an efficient car because of the future fuel savings. A review of econometric studies indicates that there is indeed some willingness to pay for efficiency improvement, although the apparent value to consumers is quite uncertain and the discounting of the future operating cost savings can be quite high.[42] For example, the present value of fuel savings for a 40 mpg car versus a 28 mpg car, discounted at 30 percent, is $336. This is just over one-half of the $600 incremental cost for the car. Thus, the average consumer purchase decision would be based on a net incremental cost of only $264, or about two percent of the initial price. Thus, a two percent decline in sales is also tested in this sensitivity analysis.

Table III-5 presents the results of this sensitivity analysis. While the added cost of technology-based vehicle efficiency improvements might result in lower vehicle sales, the effect on jobs is not large enough to negate the overall job gains associated with the investments in efficient vehicle technology and the resulting energy savings. Even if consumers have no willingness to pay more for a car to save fuel (as in the 4 percent sales decline case), there are still net job gains for the economy as a whole relative to the Reference scenario.

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40. D.L. Greene and K.G. Duleep, *Costs and Benefits of Automotive Fuel Economy Improvement: A Partial Analysis*, Report ORNL-6702, Center for Transportation Analysis, Oak Ridge National Laboratory, Oak Ridge, TN, March 1992.

41. *MVMA Motor Vehicle Facts and Figures 1991*, Motor Vehicles Manufacturers Association, Washington, DC, 1991.

42. D.L. Greene, "A note on implicit consumer discounting of automobile fuel economy: reviewing the available evidence," *Transportation Research* 17B(6):491-499, 1983.

Table III-5. Employment Impacts in 2010 Associated with Different Sales Levels	
Assumption	**Net Job Gain**
Baseline Vehicle Efficiency Scenario	244,000
Two Percent Decline in Sales Over Baseline	171,000
Four Percent Decline in Sales Over Baseline	98,000

IV. Comparisons to Other Studies

There have been several regional or state analyses of the employment and income effects of energy efficiency programs. The models used for regional or state-based studies vary widely. But all of these studies point in the same direction — that improved energy and resource efficiency can strengthen local employment and income opportunities.

In part this conclusion is reached because most studies pertain to energy-importing regions where some of the job losses in the energy sectors occur outside the boundaries considered. Yet, these studies also illustrate some general points of interest, such as the relationship between direct, indirect and respending effects, or the relative impacts from specific energy efficiency and energy supply projects.

To better understand the results that have been obtained by this project, we reviewed the results of six regional or state studies.

A. Bonneville Power Administration

In 1984, the Bonneville Power Administration (BPA) wanted to evaluate the employment effects of residential weatherization programs compared to the construction of a major power plant in the Pacific Northwest. The study used an input-output model to simulate the employment effects of saving or supplying one million kWh through either weatherization of electrically-heated homes or construction of new coal-fired or nuclear power plants.[43]

The study found that conservation produces more direct jobs and much more favorable employment impacts when all effects are accounted for. Both coal-fired and nuclear power production results in a net loss of jobs because they lead to rate increases and, thus, less consumer spending for other goods and services. The resulting job losses more than offset the job creation in power plant construction and operation, including indirect and induced jobs. For example, the study found that for each million kWh provided over a 30-year period by nuclear power, 31 jobs would be lost.[44]

Efficiency improvements as represented by residential weatherization also lead to rate increases according to this study, but the resulting job loss is less than the total job creation resulting from conservation activities. Therefore, the overall employment impacts from energy efficiency is slightly positive — 2 jobs created over a 30-year period per million kWh saved.

This example shows that "supplying power" through conservation has a more favorable impact on employment than supplying power through building power plants. The absolute job impact from conservation is not very significant, however, because conservation measures in this study are viewed as a cost to society, leaving less money for spending on other goods and services. If conservation were viewed as an alternative to capacity expansion, and thus a way to reduce total expenditures on energy services, the positive effect on employment would appear to be much larger.

B. British Columbia

In a 1991 study, two Canadian economists reviewed the employment effects of energy efficiency and hydroelectric power in British Columbia.[45] A total of 17 residential, commercial and industrial conservation programs initiated by BC Hydro in 1988 were extrapolated over a 20-year period. The impacts of these programs were then compared

43. Charles River Associates, *Employment Effect of Electric Energy Conservation*, prepared for the Bonneville Power Administration, Portland, OR, May 1984.

44. It should be noted that this study assumed relatively low power production costs from coal-fired power plants (42 mills per kWh) and nuclear power plants (50 mills per kWh). Use of higher costs would lead to even greater net job losses from these options.

45. Mark Jaccard and David Sims, "Employment Effects of Electricity Conservation: The Case of British Columbia," *Energy Studies Review*, volume 3:1, 1991, pages 35-44.

to a proposed hydroelectric facility known as the Site C Dam using a static I-O model for British Columbia.

This study concludes that the efficiency programs would increase net employment over the next 20 years by about 11,000 job-years, or about 600 jobs a year for the next 20 years. The investments in conservation measures (direct, indirect, and induced) provide an estimated 6,400 job-years, the displacement impact from not building the hydro plant is an estimated loss of 3,600 job-years, while the substitution impact from respending energy bill savings is an estimated 9,100 job-years of additional employment in British Columbia.

In this example it was assumed that saving electricity cost society 1.9 cents per kWh on average while the cost of supplying electricity from the new hydro plant would be 5.0 cents per kWh. Even without considering the respending effect, electricity conservation would create nearly twice as many jobs as hydropower production for an equivalent amount of energy produced or saved.

C. Long Island, NY

In 1979, the Council on Economic Priorities (CEP) completed an analysis of the employment impacts for various energy options for Long Island, New York.[46] The study examined the effects of 32 residential energy conservation and solar energy measures implemented at a cost of $4.0 billion over a 38-year period. It compared these options to the construction of a new nuclear power plant proposed for the region. It also compared the impacts from conservation and solar energy measures and the equivalent energy output from the use of oil, natural gas and conventional electricity sources. Employment impacts were estimated for both the region and the U.S. economy as a whole.

The CEP study used two different I-O models to evaluate the overall impacts of each scenario, the RIMS model and the national Economic Growth Model developed by the Bureau of Labor Statistics. The study found that the conservation and solar options would create up to 1.4 times as much national employment, and 2.2 times as much regional employment per unit of energy supplied or saved, compared to the proposed nuclear power plant. Moreover, the study indicated that conservation and solar technologies would create 2.4 to 2.7 times more employment nationally than would the equivalent use of oil, natural gas and electricity. The net effect would be the creation of 10,000 to 13,000 more jobs nationally with about 90 percent of the added employment occurring in the Long Island region.

46. S. Buchsbaum, et al., *Jobs and Energy*, Council on Economic Priorities, New York, NY, 1979.

D. California Energy Commission

The California Energy Commission (CEC) conducted a study to determine total state and national employment created by investments made in a variety of energy technologies.[47] These included the use of nuclear, coal and oil-fired power plants, as well as solar water heating systems and a conservation program involving building insulation. The study also contrasted the total statewide employment from these energy options with their resulting national impacts.

An I-O model was used for the analysis with the direct labor requirements derived from detailed cost estimates for each of the energy alternatives. The impacts were described in terms of both jobs per million dollars of expenditure and jobs per billion kilowatt-hours of energy produced or saved.

In comparing the labor requirements for the construction and operation of different energy facilities, the study found that fewer workers are employed in California for power production than for providing an equivalent amount of energy through building insulation or solar water heating. This result is due to the fact that California imports more of the goods and services associated with power plants than those associated with conservation and renewable energy technologies. At the national level, however, where differences in the import levels among the major energy options vary only slightly, all energy facilities produce a comparable level of employment per unit of energy saved or supplied according to the CEC study.

When the energy options were compared on the basis of expenditures rather than energy saved or produced, none of the technologies supported more employment than the "average dollar" spent for personal consumption, investment or government expenditures (see Table IV-1). The reason for this result, the study noted, was that much of the "average dollar" is spent in the service sectors which employ relatively large numbers of people per dollar.

Table IV-1 summarizes the jobs impacts from expenditures on the construction and operation of the energy facilities (i.e.; without considering substitution and displacement impacts). When looking at the respending effect, the study found that energy bill savings from building insulation would create five times as many jobs as would be created by power plant expenditures. This finding underscores the importance of pursuing least-cost energy strategies since, by definition, lower utility bills would facilitate respending.

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47. California Energy Commission, *The Comparative Effects of Energy Technologies on Employment*, Sacramento, CA, 1979.

Table IV-1. Job-Years Per Million Dollars of Expenditure according to the California Energy Commission		
Energy Facility	**California**	**United States**
Power Plants	14-51	101-105
Insulation	56-60	99-102
Solar Water Heating	56-69	113-134
Average Consumer Expenditures	77	150

The CEC study reached the same conclusion as our study; namely that the respending of energy bill savings from energy efficiency improvements would be the dominant factor behind significant increases in local or national employment.

E. Missouri's Economic Matrix

In mid-1992, the Missouri Environmental Improvement and Energy Resources Authority completed a seven volume report on the links between energy production and consumption and the Missouri environment and economy. As part of this in-depth review, Economic Research Associates evaluated the cost, employment and environmental impacts associated with more than 140 different energy technologies, including energy efficiency technologies in all end-use sectors, renewable energy options, as well as more traditional supply-side alternatives such as coal-fired power plants.[48] Input-output analysis was performed as part of this study.

Using only conservation resources that are cost-effective, the analysis indicated that Missouri has the potential to reduce its energy consumption by 100 trillion Btus in the year 2000. This represents an eight percent reduction over the projected energy demand for that year, or about a two percent reduction compared to energy use in 1990. The total investment in energy efficiency measures would be on the order of $5 billion, but

48. See, S. Laitner, "The Missouri Energy Matrix Model: A User's Guide," Economic Research Associates, Eugene, OR, March 1992.

this would be less than the fuel and capital costs that would be needed if the conservation measures are not adopted.[49]

The analysis also concluded that the conservation measures would actually strengthen the state's employment base, providing between 8,000 and 13,000 new jobs for the state, if the conservation target is reached. Wage and salary earnings were projected to rise by as much a $300 million annually. The study also found that the quicker the payback, the stronger the economic benefits to the state. Conversely, the study also indicated that new conventional energy supply technologies would result in a net reduction in employment statewide.

F. Maine DSM Programs Versus a Coal-Fired Power Plant

In 1991, the Conservation Law Foundation and the Natural Resources Council of Maine sponsored a study to compare the employment impacts of a proposed coal-fired power plant with demand-side management (DSM) programs.[50] The plant was to provide 1,183 gigawatt-hours of electricity annually. The study concluded that for an equivalent amount of electricty supplied or saved, the DSM programs would support substantially more employment than the power plant.

Based upon a survey of DSM programs and other data, the Maine study estimated that DSM programs would result in two to five times more jobs than the proposed power plant. Over the life of the DSM programs, the energy efficiency measures would create about 227 jobs in Maine, compared to the power plant which would provide an average of only 75 jobs over its 30-year lifetime.

G. Macroeconomic Studies Using Other Modeling Techniques

Some recent energy-economic studies examine the overall macroeconomic impacts from widespread energy efficiency improvements in the United States. One study that is underway is analyzing the employment and income impacts from electricity conservation measures using a combined input-output and general equilibrium model.[51] This study

49. S. Laitner, "Missouri's Two-Percent Solution: Energy Efficiency for Economic Development and the Environment," Summary Report, Economic Research Associates, Eugene, OR, November 1991.

50. See, The Goodman Group, "A Comparison of the Employment Creation Effects of the AES-Harriman Cove Coal-Fired Generating State and Maine Demand-Side Management," Boston, MA, May 1992.

51. For further information, contact Eric Heitz, The Energy Foundation, San Francisco, CA.

also uses the data on energy efficiency measures developed for the *America's Energy Choices* report.

Other studies have examined the implications of greater energy taxes and/or lower greenhouse gas emissions on GDP. These studies employ general equilibrium models or macroeconomic forecasting models.[52] Such studies usually find that higher energy taxes lead to energy efficiency improvements as well as a net **reduction** in GDP. For example, one model estimates that a carbon tax of $17 per ton would reduce fossil fuel use significantly and lower carbon emissions in 2020 by 20 percent, but would also lower GDP that year by 0.5 percent.[53] Some macroeconomic studies consider much larger taxes and conclude that there would be even a greater drop in GNP if such taxes are adopted.[54] However, studies that assume the carbon tax revenue is used to offset other taxes (e.g., payroll or income taxes) conclude that there is a negligible or even positive impact on GDP.[55]

The macroeconomic studies discussed above have certain critical flaws, namely that they do not account for the net economic savings that result from energy efficiency improvements. They usually do not explicitly consider technological change in energy efficiency options or other areas; and they do not quantify the environmental and social benefits associated with reducing energy consumption.[56] The first point is a fundamental difference with our study. Although we do not look explicitly at carbon or other energy taxes, we do recognize the net economic savings that result from energy efficiency improvements. In fact, this aspect of the analysis is essential for realizing positive employment, personal income, and GDP impacts.

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52. For a discussion of the different types of models, see M.B. Zimmerman, "Assessing the Costs of Reducing Greenhouse Gas Emissions: Comparing Modelling Approaches," Alliance to Save Energy, Washington, D.C., July 1992.

53. Dale W. Jorgenson and Peter Wilcoxen, "Reducing U.S. Carbon Emissions: The Cost of Different Goals," Center for Science and International Affairs, Harvard University, Cambridge, MA, October 1991.

54. Alan S. Manne and Richard G. Richels, "CO2 Emissions Limits: An Economic Cost Analysis for the USA," *The Energy Journal* 11 (2), April 1990. Also, Richard A. Bradley, Edward C. Watts, and Edward R. Williams, "Limiting Net Greenhouse Gas Emissions in the United States," U.S. Department of Energy, Washington, D.C., December 1991.

55. Roger C. Dower and Mary Beth Zimmerman, "The Right Climate for Carbon Taxes: Creating Economic Incentives to Protect the Atmosphere," World Resources Institute, Washington, D.C., August 1992.

56. Ibid.

V. Conclusion

The United States now uses about 85 Quads of primary energy annually which translates to a national energy bill of over $500 billion per year. The U.S. Department of Energy projects that with "business-as-usual" trends and policies, primary energy use will increase to about 106 Quads per year by 2010. With rising energy consumption and energy prices, our national energy bill in 2010 is projected to reach about $950 billion.[57] Increasing energy use presents a host of other problems besides higher energy bills, including greater oil imports (DOE forecasts a 68 percent increase between 1990 and 2010) and greater pollutant emissions (DOE forecasts a 23 percent increase in carbon dioxide emissions between 1990 and 2010).

Vigorous energy efficiency improvements would lower consumers' energy bills and reduce the cost of energy services, cut oil imports, reduce pollutant emissions, and provide other benefits. Studies such as *America's Energy Choices* document the specific energy conserving technologies that are available and the favorable direct impacts they could have.

This study adds a new dimension to the case for improving energy efficiency. By shifting economic activity away from energy supply and by saving consumers and businesses money that will be respent throughout the economy, energy efficiency improvements will result in a net increase in jobs and personal income. We estimate that efficiency improvements consistent with a 2.4 percent annual reduction in national energy intensity could create nearly 500,000 new jobs 2000 and nearly 1.1 million new jobs by 2010 on a net basis.

A rate of energy intensity reduction similar to that in our High Efficiency scenario was achieved in the United States during 1973-86. This rate of energy intensity reduction can be achieved again. However, it is not occurring now and it will not occur without new policies aimed at increasing energy efficiency in all regions and end use sectors. The policies needed to reduce national energy intensity by nearly 40 percent during the next eighteen years are beyond the scope of this study, but such policies have been described elsewhere.[58]

Substantial improvements in the efficiency of cars and light trucks, without considering other efficiency improvements, also could result in a net increase in jobs and personal

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57. See *Annual Energy Outlook 1992*, op. cit.

58. *America's Energy Choices*, op. cit., pp. 97-122; "Getting America Back on the Energy-Efficiency Track: No-Regrets Policies for Slowing Climate Change", op. cit.

income. In this case, we estimate that 70,000 new jobs could be created by 2000 and about 240,000 new jobs by 2010, all on a net basis. By incorporating energy efficiency measures into their products, vehicle manufacturers could employ nearly 50,000 additional workers by 2010 and could realize the largest percentage increase in employment among sectors of the economy. These gains in employment could be moderated somewhat if increasing efficiency is accompanied by either a shift towards imported vehicles or a reduction in vehicle sales, although we do not believe that increasing vehicle efficiency need raise import levels.

Before concluding, a few caveats are necessary. In particular, this study deals with complex economic relationships, it is based on many data and modeling assumptions, and it looks eighteen years into the future. For these reasons, our results should be viewed as indicative rather than precise estimates of future impacts. But despite these caveats, all indicators point towards positive results. Energy efficiency improvements save consumers money, reduce pollutant emissions associated with energy production, and result in a net increase in jobs. Given the economic, energy, and environmental challenges facing our nation, can we afford not to act?