ENERGY EFFICIENCY AND ECONOMIC INDICATORS: CHARTING IMPROVEMENTS IN THE ECONOMY AND THE ENVIRONMENT

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February 1995

Report Number ED952

Prepared for the
U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy

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PREFACE

This paper reviews a set of 14 different energy-related indicators of economic, social and environmental progress. Some are new to the energy policy arena. Some merely have been reformatted and updated. The aim to is suggest a complementary set of indicators that might be regularly tracked and evaluated by the U.S. Department of Energy in order to better track how the United States is doing in terms of energy efficiency and economic/environmental well-being.

The U.S. Department of Energy's Office of Energy (DOE) Efficiency and Renewable Energy provided funds which allowed the American Council for an Energy-Efficient Economy (ACEEE) to develop initial data and to examine a variety of preliminary indicators. A working paper was submitted to DOE and to a large review panel in August 1994. Based upon that scrutiny and from ACEEE's own review of the working draft, it was clear that additional analysis would be needed. The supplemental work which resulted in this document would not have been possible without the support of both the Energy Foundation and the Joyce Mertz-Gilmore Foundation.

A number of people have given generously of their time in helping me find the information needed, and in commenting on previous versions of this paper. A heartfelt thanks goes to Larry Bean, Penelope Canan, Jerry Dion, Mindi Farber, Howard Geller, Bill Golove, Eric Hirst, Alice Hubbard, John Morrill, David Roodman, Lee Schipper, Mike Sheehan, Tom Tietenburg, Claudette Young-Hinds, and Steve Wiel. I also offer a personal note of thanks to the many statisticians and analysts at the Energy Information Administration who work hard at providing the bulk of data used in this paper. Without their daily collection of information, this paper certainly would never have been possible.

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I. INTRODUCTION

Over the course of the next century energy will become an increasingly critical resource in our nation's effort to enhance its overall economic well-being, and at the same time to mitigate environmental impacts. But for most households and businesses the only visible aspect about the nation's energy policy is the utility bill or the cost of gasoline.

Much of this limited view of energy policy and its impact stems from what social scientist Barbara Farhar refers to as "a roller coaster" of energy events since the 1973-1974 Arab oil embargo. In more recent years there is evidence the early roller coaster gains in energy efficiency, for example, "may have been eroded as consumers relax their vigilance about the energy situation."[1]

Farhar indicates there is a "profound lack of 'systems' thinking" about the links between energy consumption and environmental impact. To regain the initiative and capture the economic and environmental opportunities associated with energy efficiency technologies, she suggests a need for information and education for "an informed electorate that supports intelligent public policy." Basic energy facts "need to be provided frequently and broadly."[2]

At the same time, the National Performance Review directed by Vice-President Al Gore has been encouraging federal agencies to actively reinvent the way they do business with both the American taxpayer and private industry. For the U.S. Department of Energy this has meant redefining both its mission and its strategic plan to promote sustainable energy technologies.[3]

David Rejeski notes that most people operate in a "culture of risk aversion" which focuses attention on negative rather than positive outcomes. He asks the question: "Can we alter the risk analysis process to more fully capitalize on human imagination — creating visions of the worlds we could inhabit and then examining the environmental

1. Barbara C. Farhar, *Trends in Public Perceptions and Preferences on Energy and Environmental Policy* (Golden, CO: National Renewable Energy Laboratory, NREL/TP-4857, February 1993), page 1. This point is underscored, at least in part, by examining the trend of the nation's energy intensity. In the period 1973 through 1986, the nation's energy intensity declined by an average annual rate of 2.3 percent. From 1986 through 1994, it appears the decline in energy intensity is falling by only 0.5 percent annually. The point is discussed more fully in the subsequent section of this report.

2. Ibid., page 257.

3. See, for example, "Draft Strategic Plan for the Office of Energy Efficiency and Renewable Energy" (Washington, DC: U.S. Department of Energy, June 1994).

risks *avoided* by moving down certain paths of social, technological, and economic development?"[4]

In each of their respective contexts, Vice-President Gore, Barbara Farhar, David Rejeski and others have raised concerns about the lack of a national vision to shape the nation's energy future in a way that promotes positive economic and environmental outcomes. In effect, there is a need for a compelling idea of how energy resources can be managed to enhance environmental quality, increase employment and income opportunities, and promote sustainable economic development.

Rejeski cites economist Kenneth Boulding's observation that "images of the future are the keys to choice-oriented behavior."[5] Among those "images of the future" are indicators and performance benchmarks which help decisionmakers and members of the public alike better understand how public policies and marketplace activities affect the well-being of the economy and the environment.

At the same time, there is no single measure that encompasses all of the values associated with the nation's use of energy and its other natural resources endowments. The diversity of values within the marketplace, and in the many social policy arenas, offers a compelling case for what Richard Norgaard calls methodological pluralism in the evaluation of outcomes associated with current energy trends and prospective energy strategies.[6]

This paper reviews a set of 14 different energy-related indicators of economic, social and environmental progress. Some are new to the energy policy arena. Some merely have been reformatted and updated. Still others represent efforts to monitor progress in the development of a sustainable energy future.

The 14 indicators contained in this anthology of energy-related benchmarks are an effort to encourage active discussion and promote new ways of thinking about energy in our everyday lives. The aim to is to suggest new indicators that might be regularly tracked and evaluated by the U.S. Department of Energy, state energy offices, and energy efficiency advocates throughout the country.

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4. David W. Rejeski, "Exploring Future Environmental Risks," in C. Richard Cothern and N. Philip Ross, editors, *Environmental Statistics, Assessment, and Forecasting* (Boca Raton, LA: Lewis Publishers, 1993).

5. "Exploring Future Environmental Risks," op. cit., page 272.

6. Richard B. Norgaard, "Linkages between Environmental And National Income Accounts," in Yusuf J. Ahmad, Salah El Serafy, and Ernst Lutz, editors, *Environmental Accounting for Sustainable Development* (Washington, DC: The World Bank, 1992), page 56.

This report is divided into six sections. The first is the introduction. The second offers a background perspective. It examines the kind of indicators now published by the Energy Information Administration (EIA), among others. These generally relate to what might be termed "energy intensity" indicators which measure the amount of energy consumed per dollar of output or economic activity.

The third section contains a more detailed examination of energy intensity indicators. Among other things, it decomposes the changes in energy intensity into different factors that can help policymakers understand those changes. It builds on the work of Lee Schipper, Joe Roop, and others.[7] A total of three indicators are reviewed in the third section.

The fourth section contains a set of four "Performance Benchmarks" that allow policy makers to monitor progress toward achieving the goals set for the Energy Policy Act of 1992 and the Climate Change Action Plan. In this way, existing policies can be modified or new ones adopted as it becomes clear whether policy objectives are being achieved.

The fifth section contains a final set of seven measures referred to as "Economic and Environmental Welfare" indicators. The hope is that these new measures will help policy makers and the general public evaluate whether the material flow of energy goods and services are sustaining the nation's economic well-being, and whether the use of energy resources fully supports the immaterial flows of satisfaction that we are seeking in our personal, cultural and social lives.[8]

The sixth and last section provides a series of recommendations based upon the full set of indicators. It underscores the point that this paper is clearly a "work-in-progress." The American Council for an Energy-Efficient Economy (ACEEE) seeks a review of this and other similar publications in the hope that a lively discussion among a diversity of experts will improve the indicators identified in this study, or lead to the development of a better set of metrics.

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7. See, for example, Lee Schipper, Richard Howarth and Howard Geller, "United States Energy Use from 1973 to 1987: The Impacts of Improved Efficiency," *Annual Review of Energy 1990*, Volume 15, pages 455-504; and, Joe Roop, "Energy Implications of Structural Change in the United States Economy," *IEA Energy Demand Analysis Symposium: Proceedings* (Paris, France: Organisation of Economic Cooperation and Development, 1987).

8. For a brief discussion on the purpose of economic activity and economic development from an environmental perspective, see generally, Skip Laitner, "Ricardian Land: The Forgotten Piece of the Economic Development Puzzle," *The Journal of Consumer Affairs*, Volume 27, Number 2, 1993, pages 212-226.

II. BACKGROUND

Currently there are a large number of periodicals and annual reports which provide data on a variety of energy trends. The *Washington Post*, for example, regularly publishes statistics on local utility sales. In addition, *Business Week* and other industry publications offer regular data on crude oil refining and coal production. The *Monthly Energy Review* (MER) and the *Annual Energy Review* (AER) contain many useful data sets that are often incorporated into policy analysis.[9]

Perhaps the most obvious indicators of economic well-being are changes in energy prices and energy intensity. The latter refers to the amount of energy required to support a unit of economic output within the United States.

Figures 1 and 2, on the next page, show these trends in the period 1973 through 1994.[10] Figure 1 plots the changes in residential energy prices in dollars per million Btu (using constant 1982-84 dollars). Prices for gasoline, natural gas and electricity peaked in 1981, 1983, and 1985, respectively. With the exception of natural gas, they have substantially declined since that time. In 1994, for example, electricity is at its lowest price since 1974. Prices for both commercial and industrial users have followed a similar pattern as shown in Figure 1.

Figure 2 provides an insight into how the nation's overall energy intensity has changed since 1973. Energy intensity is benchmark that compares the number of Btus consumed per dollar of real Gross Domestic Product (GDP). It is currently measured in 1987 dollars and is often referred to as E/GDP. In 1973, for example, it took an estimated 22.7 thousand Btus (kBtus) of energy consumption to support a dollar of GDP. By mid-1994 the intensity ratio declined to 16.2 kBtus per dollar.

9. See, for example, Energy Information Administration, *Monthly Energy Review* (Washington, DC: U.S. Department of Energy, DOE/EIA-0035(94/10), October 1994); and *Annual Energy Review 1993* (Washington, DC: U.S. Department of Energy, DOE/EIA-0384(93), July 1994). Also helpful sources of data from EIA are the annual *State Energy Data Report 1992*, DOE/EIA-0214(92), June 1994; and *State Energy Price and Expenditure Report 1992*, DOE/EIA-0376(92), November 1994.

10. The data for 1994 are preliminary values that have been estimated by the Energy Information Administration through the second quarter of 1994.

FIGURE 1. COST OF ENERGY TO END-USERS

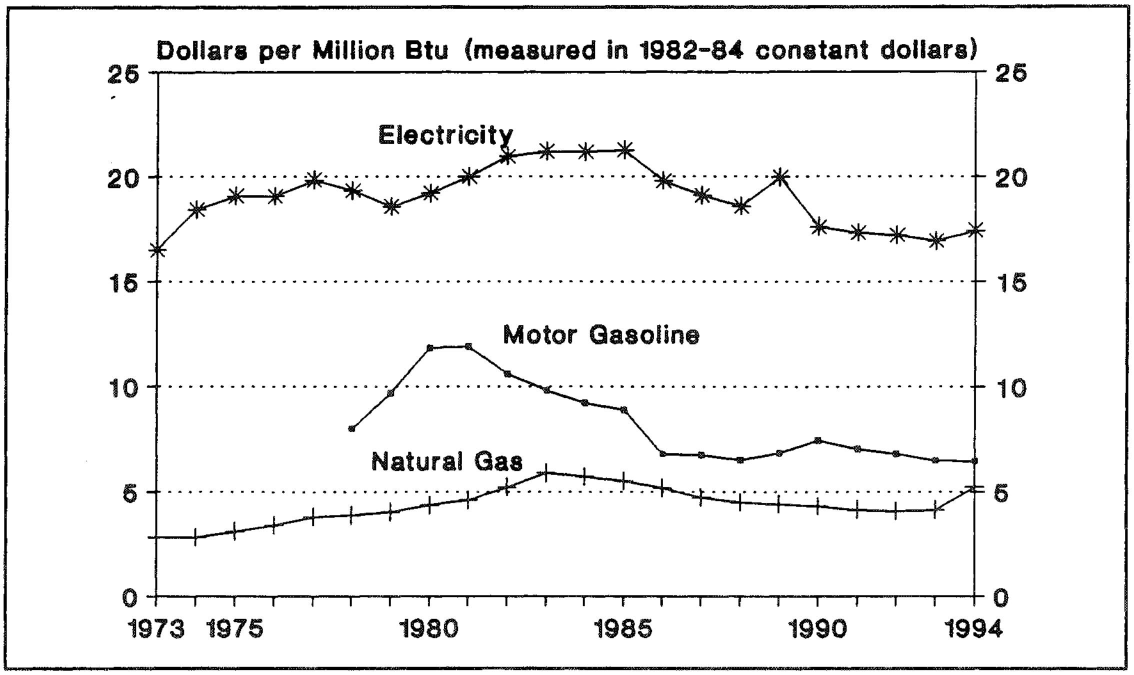

FIGURE 2. ENERGY CONSUMPTION PER DOLLAR OF GROSS DOMESTIC PRODUCT

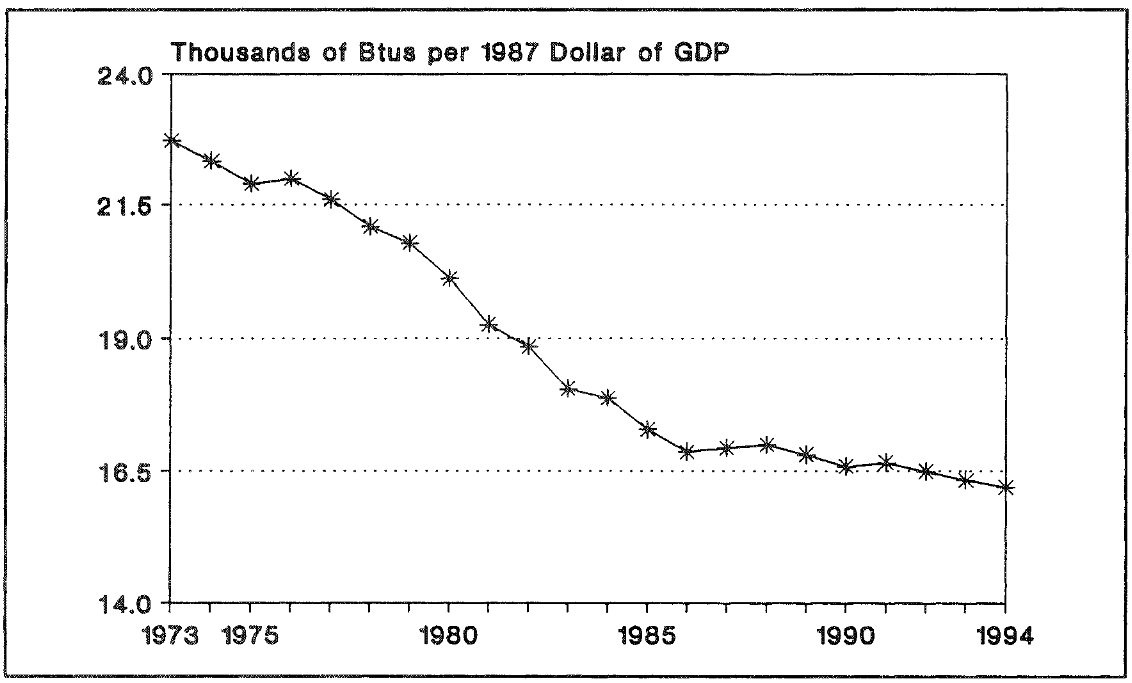

Table 1 shows more detailed data regarding the energy consumption per dollar of GDP. As in Figure 2, the E/GDP ratio declines from 22.7 kBtus in 1973 to 16.2 kBtus in mid-1994. In reviewing the full time series data through 1994, however, there actually are two distinct periods in the annual rate of decline. In the period 1973-1986 the E/GDP ratio dropped by an average annual rate of 2.3 percent. This sharp decline in energy intensity allowed the nation's GDP to expand by 35 percent (in real terms) from 1973 to 1986 without an increase in total energy use.

From 1986 through 1994, the change in energy intensity fell by only 0.5 percent annually. As a result, energy consumption grew almost in lock-step with the growth of GDP. Most analysts attribute the sharp decline in energy intensity from 1973 through 1986 as a response to the significant price hikes in the late-1970s through the mid-1980s (see Figure 1). Other factors which contributed to this change were concerns about petroleum supply disruptions and a variety of state and national legislation enacted within this period. In contrast, as energy prices and concerns about supply disruptions began to moderate after 1986, the rate of decline in energy intensity dropped from 16.9 kBtus to the just-referenced 1994 value of only 16.2 kBtus.

TABLE 1. ENERGY AND GDP DATA FOR SELECTED YEARS

Year	GDP	E/GDP	Energy
1973	$3,268.6	22.7	74.3
1986	$4,404.5	16.9	74.3
1994	$5,314.1	16.2	86.1
1994 alternative	$5,314.1	14.0	74.6

Notes: The data for 1973, 1986, and 1994 are taken from the *Monthly Energy Report*, referenced in the text. The alternative energy scenario for 1994 assumes the same rate of decline in the energy intensity rate (E/GDP) as occurred in the years 1973 through 1986. GDP is measured in billions of 1987 dollars. E/GDP is measured in kBtus. Finally, energy is measured in quadrillion Btus of primary energy.

To illustrate the importance of this change in E/GDP on the nation's energy use, Table 1 also provides an estimate of what consumption levels might be today had the United States sustained its early trend toward less energy-intensive economic activities. Continuing a 2.3 percent drop in the annual energy intensity from 1986 implies that by 1994, the E/GDP ratio might have been as low as 14.0 kBtus per dollar of GDP. Total energy consumption, therefore, would have been about 74.6 quads — 13 percent less than otherwise indicated. Thus, continuing the historical trend in declining energy intensity would again have allowed the economy to grow without increasing energy consumption over the 1973 totals shown in Table 1.

It is important to understand that it is technically and economically feasible to continue a 2.3 percent rate of decline in the nation's E/GDP ratio.[11] Thinking only in terms of E/GDP ratios is not "systems thinking," however. For that reason it may be even more important to recognize how "intensity" benchmarks such as E/GDP might be developed to provide additional insights into the links between energy production and consumption and their resulting economic and environmental impacts.

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11. This is the major insight in the nationally-recognized study, *America's Energy Choices*. In the market efficiency scenario of that 1991 analysis — the least aggressive of the three efficiency scenarios presented in that study — it was shown to be economically possible to lower E/GDP by an average annual rate of 2.5 percent in the period 1988 through 2010, and 1.9 percent through 2030. While such a trend was projected to cost $1.2 trillion over that period, it would save homes and businesses $3.1 trillion (with all values in 1990 constant dollars). Hence the benefit-cost ratio of the market efficiency scenario is a positive 2.58. See, Alliance to Save Energy, et al., *America's Energy Choices: Investing in a Strong Economy and a Clean Environment* (Cambridge, MA: Union of Concerned Scientists, 1991), pages 44-49.

III. Intensity Indicators

There is large body of literature that provides useful insights about changes in the way energy resources are used throughout the economy. The core of much of this analysis is data gathered and reproduced by the Energy Information Administration in its regular publications, including the *Monthly Energy Review* or the *Annual Energy Review* (previously cited).

In addition to these two mainstay publications, EIA also publishes a series of triennial surveys which contain data on a variety of end-use consumption patterns. These include the Residential Energy Consumption Survey (RECS), Commercial Buildings Energy Consumption Survey (CBECS), Residential Transportation Energy Consumption Survey (RTECS), and Manufacturing Energy Consumption Survey (MECS).[12]

In the past EIA has also published *Energy Conservation Indicators*, a short-lived series of annual publications. This was essentially a summation of conservation statistics from other regularly available documents.[13] But the data from these types of publications do not provide much insight into "systems thinking" about energy. They tend to provide a limited analysis of energy intensity and output.[14]

This section of the report builds on EIA's highly useful data to explore additional insights about energy efficiency versus energy intensity. In addition, it examines the influence of weather on consumption, and carbon emissions associated with energy use.

A. Efficiency Versus Structural Change

As noted in the background section, the popular measure of increased energy efficiency is the change in E/GDP. It is certainly the easiest to measure with the data that is now available through the various federal publications. But does the E/GDP ratio measure real efficiency improvements, or merely changes in the nation's energy intensity?

12. For more information these surveys, or for information about other energy statistics available from the Energy Information Administration, call EIA's National Energy Information Center, (202) 586-8800.

13. Energy Information Administration, *Energy Conservation Indicators 1986* (Washington, DC: U.S. Department of Energy, DOE/EIA-0441(86), February 1988.

14. As an example of industry's use of EIA data, see, Lisa Hofmann and Russell Jones, *Energy Consumption/Gross State Product Ratios in the United States* (Washington, DC: American Petroleum Institute, Research Study #061, October 1991).

As we shall see, comparing the changes in Btus per dollar of GDP overlooks the contribution of the many structural economic changes to the decline in energy overall intensity. Included in the set of structural changes are variations in the mix of fuels being used and the transition from a goods to a service economy.

The best example of how structural changes affects energy intensity is the accelerated growth of services in the economy compared to the production of goods. In 1993, it took about 24 kBtus to generate a dollar of GDP in the goods producing industries. Service industries, on the other hand, required about 14 kBtus per dollar of GDP. Thus, simply by moving the economy away from the production of goods to providing less services which are less energy-intensive, the E/GDP ratio will drop. But does that "structural" change signal real improvements in "efficiency?"

Two analytical techniques are used in the following section to decompose E/GDP into structural changes and efficiency improvements. These include use of the Divisia Index used in a two-sector analysis, and the Laspeyres Index used in a seven-sector analysis.

1. A Two-Sector Decomposition Analysis

To illustrate use of the divisia index, we compare the periods of change: (a) 1970 through 1987, and (b) 1987 through 1993. The former allows us to include data from the decade year (1970) just before the Arab oil embargo (1973). By including 1987 as the middle year of comparison we have a one-year period following the last year of significant price-induced changes in E/GDP (1986). The second comparison includes 1993, the last year for which reasonable information is available to disaggregate GDP into goods and services.

The data needed to construct these measures is contained in Table 2, on the following page. They are taken from recent publications of the Department of Commerce and the Energy Information Administration.

From the data shown in Table 2, energy use rose by 26.5 percent in the period 1970 to 1993. The value can be found directly by the following calculation: (83,893 / 66,334 - 1) * 100 = 26.5 percent (rounded). This can also be thought of as a product of the growth in economic activity (measured by GDP) and energy intensity (shown by E/GDP). Thus, the growth in GDP (1.787) times the change in E/GDP (0.708) equals 1.265, or an increase of 26.5 percent in total energy use. In effect, the economy expanded by 79 percent, but the energy intensity (E/GDP) fell by 29.2 percent (calculated as 1 - 0.708 times 100).

TABLE 2. ENERGY AND ECONOMIC DATA FOR SELECTED YEARS			
Data	**1970**	**1987**	**1993**
Goods			
GDP (Bln 87$)	1,003	1,262	1,257
Energy (TBtus)	28,593	27,828	30,732
E/GDP (kBtus)	28.51	22.05	24.45
Services			
GDP (Bln 87$)	1,871	3,278	3,878
Energy (TBtus)	37,741	49,066	53,161
E/GDP (kBtus)	20.17	14.97	13.71
Total			
GDP (Bln 87$)	2,874	4,540	5,135
Energy (TBtus)	66,334	76,894	83,893
E/GDP (kBtus)	23.08	16.94	16.34
Energy Weights			
Goods	43.1%	36.2%	36.6%
Services	56.9%	63.8%	63.4%

With a preliminary analysis of the data in Table 2, we might conclude that the economy is 29 percent more efficient from an energy perspective in 1993 than in 1970. However, energy efficiency accounts for only part of the drop in energy intensity. Using one form of the divisia index (described next) we can effectively decompose the change in energy intensity into: (a) energy efficiency effects; and (b) structural changes in the economy. In this case, structural changes are limited to the rate of increase in the value-added of service sectors relative to goods-producing industries.

The divisia index, I, is a weighted sum of growth rates. In logarithmic format, the formula is as follows:

$$\Delta Ln(I) = \sum [w_i * \Delta Ln(E_i) + w_i * \Delta Ln(O_i)]$$

where w_i is the share of energy used in sector i, E is the energy intensity of sector i measured in Btus per dollar of GDP (1987$), and O is the share of GDP maintained by sector i. The percent change for each variable is shown as the change in logarithmic values (ΔLn) for the two different years that are being compared.

Adopting a chaining technique between the two periods of time, the energy share weights are the simple average of the same two years being compared. Applying the data from Table 2 to the formula above yields the results shown in Table 3, below.

TABLE 3. COMPARING ENERGY EFFICIENCY VERSUS STRUCTURAL CHANGE

Period of Analysis	Intensity Index (BaseYear=1.000)	Efficiency (%)	Structural Change (%)
1970-1987	0.734	91.5%	8.5%
1987-1993	0.964	51.4%	48.6%
1970-1993	0.708	85.0%	15.0%

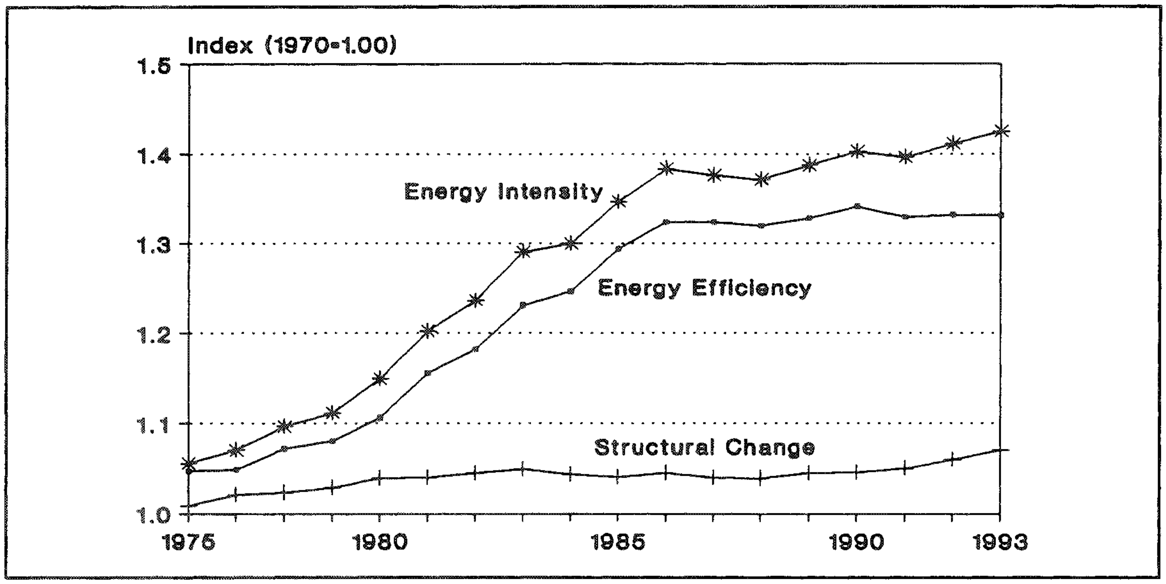
Table 3 allows us to make a number of interesting comparisons based upon different periods of analysis. First, the biggest gains in energy intensity was in the period 1970 through 1987. The 1987 level of energy intensity was 73.4 percent of the 1970 value. This implies an annual 1.8 percent decrease in energy intensity for that period.[15] On the other hand, the 1993 index of 0.964 (where 1987=1.000) suggests an annual decrease of only 0.6 percent in the period 1987-1993. The average annual drop in energy intensity for the entire period (1970-1993) was 1.5 percent.

15. Recall from an earlier discussion that during the critical years following the oil embargo (1973-1986), the average annual rate of decline was 2.3 percent.

Using the divisia index as the means to estimate energy efficiency versus structural change, we note that efficiency accounted for up to 85 percent of the change in E/GDP over the period 1970-1987. The movement away from goods to service industries (i.e., structural change) was responsible for 15 percent of the change in energy intensity. The results change dramatically when we compare the years 1987-1993. In those later years structural change appears to be responsible for about half of the overall drop in E/GDP.

The apparently larger contribution of structural change makes more sense when we examine Figure 3, below. Indexed to 1970 with the data inverted to a show rising (positive) trend, the chart shows the changes in energy intensity, efficiency, and structural change. The data suggest that the contribution of structural change has been relatively stable over the entire period of analysis. But the gains in energy efficiency drop off significantly after 1986. Thus, as the contribution of energy efficiency dropped in the later period and its contribution relative structural change grew smaller. As indicated in the table of results, efficiency was responsible for only 51.4 percent of the modest reduction in E/GDP from 1987-1993 while structural changes were responsible for 48.6 percent.

FIGURE 3. CHANGES IN U.S. ENERGY INTENSITY



These results assume that energy consumed in the goods producing sector reflect the totals reported by the EIA's industrial end-use categories, currently about 37 percent of primary energy use. The goods-producing industries include agriculture, fishing, mining, construction and manufacturing. The service-producing industries include the balance of the economic sectors — including households. The energy use in the service sector reflects all non-industrial energy consumption. In effect, we are treating households as part of the production process rather than as consumers of goods and services.

While this provides a useful benchmark to stimulate better public understanding of changes in energy efficiency over time, the highly aggregated results mask other influences which need to be identified in developing policies specific to end-use sectors.

There have been shifts in the manufacturing sector, for example, which stem from structural changes in the production process in addition to energy efficiency improvements. Moreover, the higher level of imported manufactured goods means that we are importing embodied energy. To accommodate a more detailed examination of structural changes, we next explore the influence of structural changes adapting a seven-sector analysis as used by Howarth, Schipper, and Andersson.[16]

2. A Seven-Sector Decomposition Analysis

Using more detailed information in the period 1970 to 1991, we can decompose total energy consumption into three separate effects: (a) economic activity by sector, (b) structural changes within each sector, and (c) energy intensity of each structural change.[17]

It is a straight-forward process to analyze the contribution of economic activity on energy use. Holding all else constant, a growth in output would be expected to increase the demand for energy — whether the output is measured by changes in GDP or vehicle-miles travelled. The other two components (i.e., structural change and energy intensity) are more difficult to track, however.

In the case of structural change, for example, there are two levels of analysis. The first deals with the relative importance of each of the economic sectors reviewed (listed below). As the service sector (with a less energy-intensive output) becomes more important to the nation's economy compared to manufacturing, for example, the nation's overall energy intensity will decline regardless of real efficiency improvements. This point was made in the previous two-sector decomposition.

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16. Richard B. Howarth, Lee Schipper, and Bo Andersson, "The Structure and Intensity of Energy Use: Trends in Five OECD Nations," *The Energy Journal*, Volume 14, Number 2, 1993, pages 27-45.

17. The detailed data used for this analysis was provided by Bill Golove, a graduate student working under the direction of Lee Schipper.

But there are sub-sector shifts which must be counted as well, notably the relative contributions from more energy-intensive industries as chemical and pulp and paper production to less-intensive industries which make optical instruments or computers. Finally, one must measure the energy intensity of all activities whether at the sectoral or subsectoral level.

Formatting the data into a Laspeyres index, the contribution of each separate effect on total energy consumption is found by holding the other two effects constant at their 1970 levels, and varying only the actual changes in the desired effect over time.[18] The remaining two effects are calculated in a corresponding fashion. The total change in energy use is the sum of these individual effects.

The sectors and effects analyzed here include:

> Manufacturing — including all 2-digit SIC sectors except petroleum and coal products which are included in the energy sector. Activity is represented by GDP while structure is shown by the percent of total manufacturing GDP represented by each of the major subsector's GDP;
>
> Other Industry — agriculture, non-energy mining, and construction. Activity is represented by GDP. Structure is also shown by the percent of other industry GDP represented by each subsector;
>
> Services — wholesale and retail trade, finance, insurance, real estate, and all other services, except utilities which are included in energy. Activity is represented by GDP. Because of a lack of data in this area, no structural variable is defined;
>
> Freight Transportation — the total ton-miles of goods shipped by each mode. Structure is shown as the percent of modal shipments in ton-miles to total shipments;
>
> Passenger Transportation — passenger-miles travelled on each mode. Structure is shown as the percent of modal travel compared to total passenger-miles;

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18. The term Laspeyres analysis refers to the use of 1970, the earliest year, as the base-year of analysis. In other words, 1970 = 1.00. Had we chosen to use an index where 1993 = 1.000, we would have generated a Paasche analysis. The two resulting estimates would be similar, although not necessarily the same. While switching the analytical methodology from the Divisia to a Laspeyres index, it is the greater level of detail in a 7-sector analysis that changes the results compared to a 2-sector analysis. For a useful side-by-side comparison of the two indexes, see, Richard B. Howarth, et al., "Manufacturing energy use in eight OECD countries, *Energy Economics*, April 1991, Appendix 2, page 142.

Residential — all consumption in residential buildings where activity is represented by population, and structure is shown as dwelling area per person.

Energy - coal, petroleum and utilities. Activity is represented by GDP and structure is the percent of GDP contributed by each major energy form.

Table 4 summarizes the results of this more disaggregated approach to energy consumption for two different periods: 1973-1987 and 1987-1991. This allows a comparison in the years in which E/GDP declined rapidly with the most recent period for which data is available. The comparison shows average annual changes in each of the three effects by major economic sector.

By examining the combined effects on the total economy (shown toward the end of Table 4) we can see that the activity effect grew at an average rate of 2.03 percent in the period 1973 to 1987. It slowed to only 1.33 percent in the subsequent period from 1987 to 1991. Despite the economic growth, energy use rose by only 0.24 percent in the first period. During the second period, however, it closely tracked economic activity by rising 1.36 percent annually. The difference in the two periods lies in the structural and energy intensity effects.[19]

In the former period, the structural effect was -0.06 percent while the intensity effect was -1.53 percent. These two effects combined to slow energy use to only 0.24 percent despite the increased economic activity. On the other hand, the more recent data shows a positive contribution to energy consumption of 0.90 percent while the intensity effect was less pronounced at -0.14 percent. Thus, despite the weaker economic growth in the later period, energy use grew more rapidly.

Perhaps the more interesting story in this analysis is found at the very bottom of Table 4. Schipper and others have suggested that a better measure of real energy efficiency can be found by taking the change in energy intensity for the total economy and dividing it by E/GDP.[20] In the data shown in Table 4, this suggests that about 70 percent of the decline in E/GDP can be attributed to energy efficiency improvements in the period 1973 to 1987.

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19. Several comments should be made at this point. First, in this technique there is also an interactive term which is not shown. Second, the term "intensity effect" could be renamed "efficiency effect" since it is what remains after the activity and structural effects have been backed out. However, to maintain the naming conventions used to this point, we continue with the term "intensity effect" in this analysis.

20. See, "United States Energy Use from 1973 to 1987: The Impacts of Improved Efficiency," op. cit.

TABLE 4. IMPACTS OF ACTIVITY, STRUCTURAL, AND INTENSITY CHANGES ON SECTORAL U.S. PRIMARY ENERGY USE, 1973-1991

Category of Effect	Annual Rate of Change	
	1973-1987	1987-1991
Manufacturing		
Actual Final Energy Consumption	-1.51%	0.76%
Activity Effect	2.24%	0.96%
Structure Effect	-1.24%	0.09%
Intensity Effect	-2.00%	-0.94%
Other Industry		
Actual Final Energy Consumption	-0.42%	2.54%
Activity Effect	0.66%	-0.07%
Structure Effect	-0.42%	2.54%
Intensity Effect	-1.08%	2.62%
Services		
Actual Final Energy Consumption	0.37%	1.88%
Activity Effect	2.93%	2.23%
Structure Effect	0.37%	1.88%
Intensity Effect	-2.49%	-0.33%
Freight Transportation		
Actual Final Energy Consumption	2.67%	-0.06%
Activity Effect	1.98%	1.12%
Structure Effect	0.28%	1.68%
Intensity Effect	0.25%	-2.92%

TABLE 4. IMPACTS OF ACTIVITY, STRUCTURAL, AND INTENSITY CHANGES ON SECTORAL U.S. PRIMARY ENERGY USE, 1973-1991

Category of Effect	Annual Rate of Change	
	1973-1987	1987-1991
Passenger Travel		
Actual Final Energy Consumption	0.48%	0.46%
Activity Effect	1.46%	1.94%
Structure Effect	0.37%	-0.11%
Intensity Effect	-0.93%	-1.47%
Residential		
Actual Final Energy Consumption	-0.40%	0.21%
Activity Effect	1.01%	0.89%
Structure Effect	0.97%	1.13%
Intensity Effect	-2.35%	-1.79%
Energy Sector (Net)		
Actual Final Energy Consumption	1.69%	2.32%
Activity Effect	3.43%	2.04%
Structure Effect	0.01%	-0.28%
Intensity Effect	-1.74%	0.44%
Total Economy		
Actual Final Energy Consumption	0.24%	1.36%
Activity Effect	2.03%	1.33%
Structure Effect	-0.06%	0.90%
Intensity Effect	-1.53%	-0.14%

TABLE 4. IMPACTS OF ACTIVITY, STRUCTURAL, AND INTENSITY CHANGES ON SECTORAL U.S. PRIMARY ENERGY USE, 1973-1991

	Annual Rate of Change	
Category of Effect	**1973-1987**	**1987-1991**
Gross Domestic Product	2.44%	1.73%
E/GDP	-2.15%	-0.36%
Efficiency Share of E/GDP	70.90%	38.40%

By 1991 the contribution of energy efficiency changes in the E/GDP ratio has fallen to only 38 percent, however. In other words, more of the decline in E/GDP in later years is attributable a variety of structural changes rather than energy efficiency improvements.[21]

The results shown in Table 4 generally support the results found in the two-sector, two-effect analysis illustrated in Table 3. However, the less disaggregated approach of the two-sector analysis appears to overstate the contribution from energy efficiency. Thus, the seven-sector decomposition appears to capture more of the influence of all structural changes than the two-sector analysis in the preceding section. This result appears to support Schipper's contention that the first step in realistic modeling is a more complete disaggregation of activities and major economic sectors.[22]

B. Weather-Adjusted Energy Intensity

One other possible adjustment to the standard E/GDP analysis is a modification based upon weather patterns. This is particularly helpful for a short-term analysis to see how

21. As measured by data from the *Monthly Energy Review*, the rate of decline in E/GDP for 1973-87 and 1987-91 is about 2.3 and 0.5 percent, respectively. The values shown in Table 4 are the result of slightly different data on GDP and the use of net rather than total energy requirements

22. Personal communication with Lee Schipper, Energy and Environment Division, Lawrence Berkeley Laboratory, University of California, Berkeley, CA, September 1994.

the nation's energy intensity changes when annual weather patterns in a given year are normalized to the 30-year period 1961-1990.[23]

Based upon data published by Brookhaven National Laboratory, about 33 percent of a building's total energy requirement is sensitive to heating load while 12 percent is sensitive to cooling needs.[24] To make an adjustment based upon weather patterns, the first step is to isolate building energy consumption from total primary energy use. In 1990, for instance, about 35 percent of the nation's total energy needs was devoted to building consumption. Also in 1990, heating degree days were about 13 percent below normal while cooling degree days were about five percent above normal.

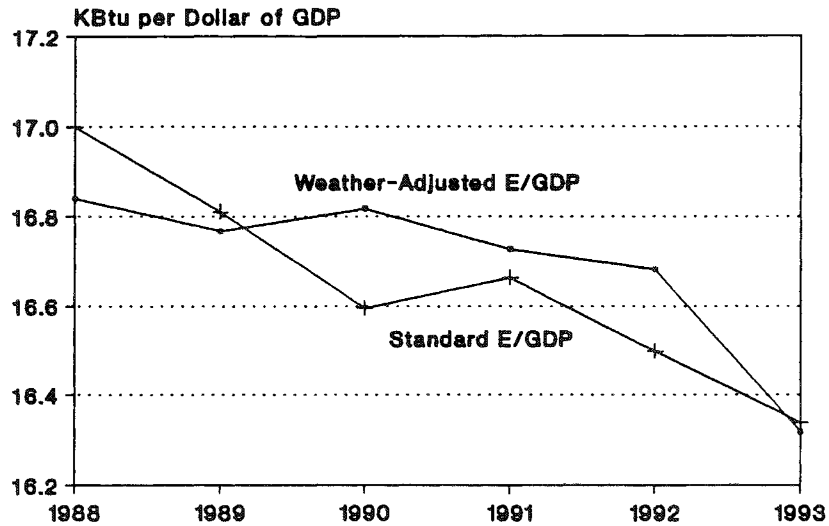
Adjusting building consumption to reflect normal weather patterns shows an increase of about 1.5 percent more energy would have been used in buildings in 1990 under normal weather conditions. The standard E/GDP ratio suggests a value of 16.6 kBtu per dollar of GDP while the weather-adjusted measure is 16.8 kBtu. As shown in Figure 4, on the following page, rather than a 1.3 percent decline in standard energy intensity from 1989, adjusted E/GDP value rose by 0.3 percent. The trends are shown more fully for the years 1988 through 1993.

Over the long-term these weather adjustments will make very little difference in the E/GDP trend as long as there are relatively large long-term changes in E/GDP. In fact, weather normalization usually represents a one percent or less modification in the actual E/GDP in any given year. This is evidenced by a quick review of Figure 2. In the short-term, however, such adjustments can help policy makers better understand recent energy intensity trends and the near-term impact of recent policy decisions.

23. Degree days are the number of degrees per day that the daily average temperature is above or below 65 degrees fahrenheit according to DOE practice. When the degrees are measured above 65 degrees, it is a measure of cooling needs in buildings. When measured below 65 degrees, it is a measure of heating needs. See Tables 1.11 and 1.12 in the *Monthly Energy Review*, op. cit., for further information.

24. The heating and cooling thermal load requirements are drawn from, Barbara Pierce, *Office of Building Technologies Evaluation and Planning Report*, (NY: Brookhaven National Laboratory, BNL-52426, June 1994), pages A-20 and A-21.

FIGURE 4. WEATHER-ADJUSTED ENERGY INTENSITY INDEX



C. Carbon Intensity

In June 1992 representatives from more than 140 countries met at the United States Conference on Environment and Development in Rio de Janeiro, Brazil. Participants in the so-called "Earth Summit" agreed that, among other things, industrial nations should reduce their total greenhouse gas emissions to 1990 levels by the year 2000. The agreement stemmed from a concern that the release of greenhouse gases — including carbon dioxide, methane, and nitrous oxide — contribute to global warming and global climate change.

The agreement was embodied in an international global climate change treaty known as the Framework Convention on Climate Change. Following the conclusion of the Earth Summit in June, the U.S. Senate ratified the treaty on October 7, 1992.

Because fossil fuel consumption is responsible for a large share of anthropogenic greenhouse gas emissions, there has been a rising interest in tracking energy-related carbon emissions. Toward that end, for example, the EIA published a report titled, *Energy Use and Carbon Emissions* in March 1994.[25]

25. Energy Information Administration, *Energy Use and Carbon Emissions: Some International Comparisons* (Washington, DC: U.S. Department of Energy, DOE/EIA-0579, March 1994).

Typical of the information contained in that 1994 report is the data shown in Figure 5 which continues the trend of intensity indicators by contrasting U.S. carbon emissions with growth in GDP and energy consumption. Figure 6 provides another look at the carbon trends by indexing (1950 = 1.00) total energy use, carbon emissions and carbon intensity through 1993. Carbon intensity, in this case, is the ratio of energy-related carbon emissions per unit of energy consumed in the United States.

As revealed in Figure 6, carbon intensity has steadily declined over time. There are two primary influences behind this trend. First, there is a systematic decline in the use of carbon-intensive coal in favor of the less carbon-intensive natural gas. In the period 1950 through 1993, for example, the contribution of coal to the nation's overall energy consumption declined from 37 to 23 percent while natural gas increased its share from 18 to 25 percent. Petroleum held onto its 40 percent share over that same 43-year period. Second, coal resources have also been displaced by nuclear energy with some contribution from renewable energy resources. The share of non-fossil energy supplies grew from 5 to 12 percent of total energy consumption from 1950 to 1993.[26]

26. The data are taken from the *Annual Energy Review 1993*, op. cit., Table 1-3.

FIGURE 5. GDP, ENERGY CONSUMPTION AND CARBON EMISSIONS IN THE U.S.

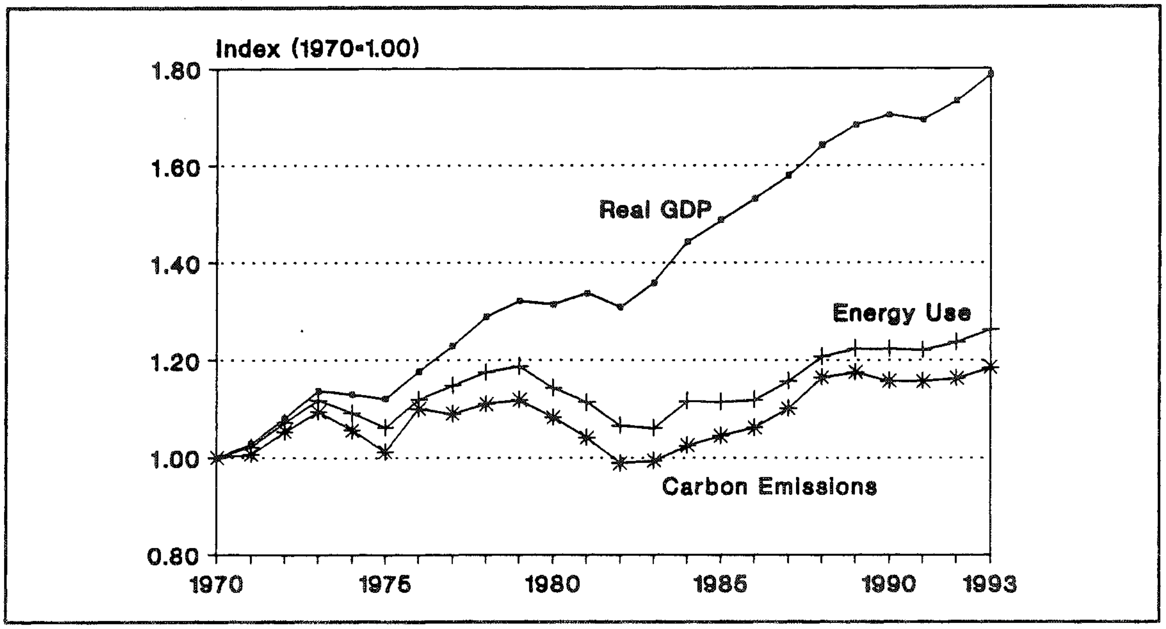
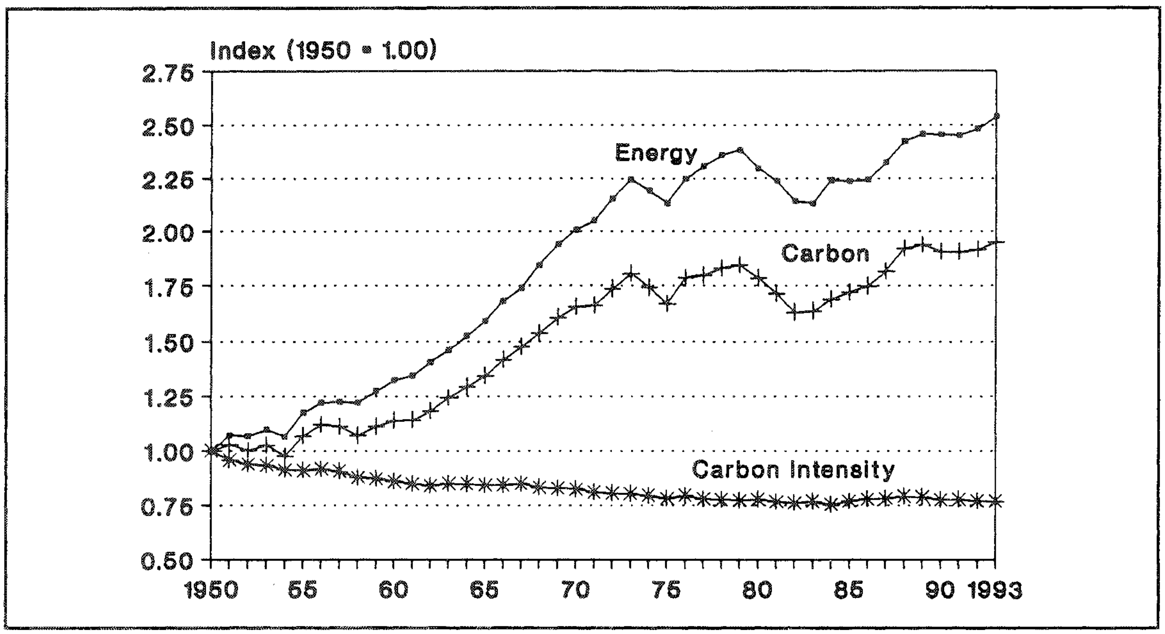


FIGURE 6. U.S. CARBON INTENSITY TRENDS, 1950-1993



This increase in non-fossil fuel (and, therefore, non-carbon) resources and the move away from coal to natural gas has all contributed to an overall decline in the level of carbon emissions per unit of energy. At the same time the U.S. economy has steadily expanded.

The expanded economic activity — despite the decline in E/GDP — has pulled energy use up by 254 percent from 1950 through 1993. While carbon intensity has declined to 77 percent of its 1950 value, the net result is still a 195 percent increase in fossil-fuel related carbon emissions (2.54 * 0.77 = 1.95).

Although this type of information shows a clear trend of increasing carbon emissions for the United States, there is nothing to help the policy maker or members of the public understand the possible link between carbon emissions and climate change.

Figure 7, on the other hand, offers at least one alternative perspective by charting the global average temperatures (in degrees celsius) and the atmospheric concentrations of carbon dioxide (in parts per million). The temperature data are from 1950 while the carbon dioxide levels are first plotted in 1959.[27]

Figure 7 indicates that while the average global temperature follows a volatile path, it appears to be on an upward trend, following the rise in carbon dioxide emissions. Indeed, regressing the temperature on the level of carbon dioxide concentrations shows that the build-up of such emissions "explains" about 52 percent of the temperature rise.[28]

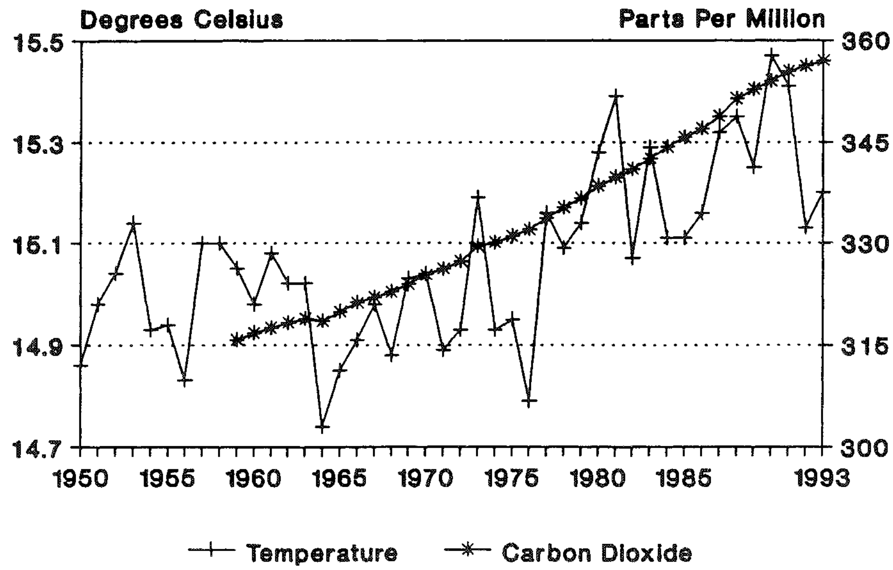
27. The temperature data is taken from, J. Hansen and S. Lebedeff, "Global Trends of Measured Surface Air Temperature," *Journal of Geophysical Research*, November 1987; Helene Wilson and James Hansen, Goddard Institute for Space Studies, New York, private communication and printouts, January 21, 1994 and February 18, 1994. The carbon dioxide data is from Charles D. Keeling and Timothy Whorf, Scripps Institute of Oceanography, La Jolla, California, private communications, February 26, 1993 and February 14, 1994. For further information, see, *Vital Signs 1993* and *Vital Signs 1994* (Washington, DC: Worldwatch Institute, 1993, 1994).

28. Over the period 1959 through 1993, the regression yields the following expression:

$$\text{Temperature} = 11.77 + 0.01 * \text{Concentration}.$$

Both the equation's constant and the concentration coefficient are statistically significant at the one percent level, with T-statistics of 21.8 and 6.2, respectively. The F-statistic of 38.2 is also statistically significant at the one percent level for 35 observations and one constraint. The "unexplained" contribution to the global temperature rise includes increased emissions of other greenhouse gases and the general build-up of total greenhouse gases. Of course, the volatility of weather patterns in general would also be part of the unexplained contributions to temperature.

FIGURE 7. GLOBAL TEMPERATURES AND CARBON DIOXIDE CONCENTRATIONS



In yet another look at the link between carbon emissions and temperatures, we might note that since 1950 there should have been about four years of record temperatures. This assumes a normal pattern of weather.[29] In reviewing the table of data used to construct Figure 7, we would find that there are, in fact, eight record-breaking years which suggests non-normal weather patterns.

This point is further confirmed when we realize that 9 of the 10 hottest years on record have occurred since 1980. In this light, it seems helpful in the development of meaningful public policy to provide indicators that express cause and effect relationships (both positive and negative). A step in that direction begins to open up the "systems" perspective suggested by the introduction to this report.

29. The actual value is closer to 3.8 rather than 4. This is the result of the unique properties of the number e which is approximately equal to 2.7182818285. It is no coincidence that the 3.8th root of 44 (i.e., the number of years in the temperature data) is roughly equal to the number e. Rounded to the nearest integer provides the normally expected 4 record temperature years in the 44 year period of observations.

IV. Performance Benchmarks

Current EIA publications, notably the *Annual Energy Review* and the *Monthly Energy Review* provide an excellent source of historical energy consumption data. But there is currently no means to track the performance of the economy with respect to existing public policy goals. This section of the report offers four possible benchmarks which might be easily measured.

The first benchmark tracks how closely the United States is meeting the suggested efficiency goals of the Energy Policy Act of 1992.[30] The second benchmark tracks progress toward meeting the goals of the *Climate Change Action Plan* (CCAP).[31] The third measures efficiency progress toward what might be termed an economically achievable goal as set forth in the 1991 study, *America's Energy Choices*.[32] Finally, a fourth benchmark identifies a means to track the historical investment in energy efficiency. Each is discussed in turn.

A. Tracking the EPACT Objectives

The Energy Policy Act of 1992 (EPACT) set forth a number of targets designed to promote a national least-cost energy strategy. Aside from several references in the more technical publications issued by the U.S. Department of Energy, there has been little public review of the progress toward meeting those targets.

Title XVI of EPACT, entitled "Global Climate Change," sets forth a number of suggested policy objectives,[33] including:

(a) a 30 percent increase in energy efficiency by 2010, based upon 1988 levels;

(b) a 75 percent increase in the use of renewable energy by 2005, based upon 1988 levels;

30. Public Law 102-486, H.R. 776, 102nd Congress, October 24, 1992.

31. President William J. Clinton and Vice-President Albert Gore, Jr., *The Climate Change Action Plan* (Washington, DC: Executive Office of the President, October 1993).

32. Op. cit.

33. There are two other EPACT targets in addition to the three that are reviewed in the text above. None of the five are actual mandates, however. Rather, they are policy objectives designed to guide the development of a least-cost energy policy for the United States.

(c) a reduction in US oil consumption from 40 percent to 35 percent of total energy use by 2005.

Using historical data found in the *Monthly Energy Review* (MER), we can track the progress toward each of these goals. Actual progress toward meeting the overall efficiency goal is shown in Figure 8. Using a rising index that is the inverse of E/GDP (where the base-year 1988 equals 1.00), the chart shows the actual progress toward meeting the EPACT goal through 1994. This 1994 figure is based upon preliminary data found in the November 1994 issue of the MER.[34] The chart also shows the level of efficiency as forecasted by the *Annual Energy Outlook 1994* (AEO94).[35]

The 1988 energy intensity index, E/GDP, was 17.0 kBtus per 1987 dollar of GDP. One interpretation of a 30 percent increase in efficiency by 2010 implies that the E/GDP ratio should be 11.9 kBtus.[36] This, in turn, implies an average annual decrease of 1.6 percent in energy intensity between the years 1988 and 2010. By 1994, therefore, the level should be down to 15.4 kBtus.

In fact, the preliminary data for 1994 suggests that the E/GDP value will be as high as 16.2 kBtus per dollar of GDP. As benchmarked to a rising index in Figure 8, the United States is already falling short of where it needs to be in order to achieve the EPACT target for the year 2010.

As further indication of a possible shortfall, the AEO94 reference case suggests that by 2010 the nation's E/GDP ratio will be 13.4 kBtus per dollar of GDP. Converted to the index values reflected in Figure 8, the U.S. benchmark for 2010 will be 1.27. On the other hand, if we index EPACT to the same 1988 benchmark, the target for 2010 is 1.43. This suggests that the nation as a whole will be about 11 percent short of meeting the suggested efficiency goal as defined here.

Some analysts have suggested that because E/GDP is a measure of energy intensity rather than energy efficiency, a better measure of efficiency ought to be the inverse of energy intensity — or GDP/E. In keeping with this efficiency measure, it has been suggested that the 30 percent improvement should be benchmarked against GDP/E. In effect, they

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34. See, *Monthly Energy Review*, November 1994, Table 1.9.

35. Energy Information Administration, *Annual Energy Outlook 1994 with Projections to 2010* (Washington, DC: U.S. Department of Energy, DOE/EIA-0383(94), January 1994).

36. The measure of E/GDP cited in the *Monthly Energy Review* does not include a number of renewable energy resources. Correcting the E/GDP ratio to reflect a reasonable estimate for all renewable resources would raise the ratio from 17.0 kBtus to about 17.6 kBtus. However, by referencing the analysis in terms of a rising index where 1988 equals 1.00, the magnitude of the 1988 starting point is less important to the discussion than is the comparison of the overall trends.

argue, the EPACT goal should be calculated as an index of 1.3 times the GDP/E ratio rather than the alternative presented in this analysis which is calculated as 0.70 times E/GDP.

By definition, if we adopt this less aggressive definition of efficiency improvement as the intended EPACT target, then the EPACT trend line in Figure 8 would rise to only 1.30 by the year 2010 instead of 1.43. This implies that the 1.27 index of the AEO94 reference case would very nearly meet the redefined EPACT efficiency objective. In citing this possible interpretation, however, three things militate against its adoption by DOE.

The first reason against this interpretation of an efficiency benchmark (for purposes of meeting the EPACT objective) is that neither GDP/E nor E/GDP makes a distinction between efficiency improvements and structural changes in the economy. In the period 1970 to 1991 only about 70 percent of the decline in E/GDP can be attributed to energy efficiency.[37] Hence, the EPACT target should be based upon this more complete measure of energy efficiency.

The second reason is that the widely-cited report, *America's Energy Choices*, establishes an energy efficiency potential which exceeds even the more aggressive interpretation of the EPACT objective. This point is more fully reviewed later part C of this section. Third, the Department of Energy has established other important economic objectives such as increasing the nation's employment by 1.1 million more jobs in 2010 through increase energy efficiency improvements. This target, based in part upon a 1992 ACEEE study,[38] is clearly achievable. But to reach that level of additional employment, the United States will need to adopt an objective that reduces E/GDP much closer to the 11.9 kBtus target that is referenced in this analysis.

Sometimes lost in the discussion is a second EPACT target that suggests the United States should achieve a 75 percent increase in the use of renewable energy by the year 2005. Using a variety of EIA data as a basis of comparison, this implies a 3.3 percent average annual growth rate in the use of renewable energy resources in the years 1988 through 2005. However, data from the AEO94 reference scenario suggests only a 2.0 percent growth rate within that same interval. The result is that renewable energy technologies will increase by only 40 percent by 2005 under current energy policies. Tracking progress in this area would provide another useful performance benchmark for the economy.

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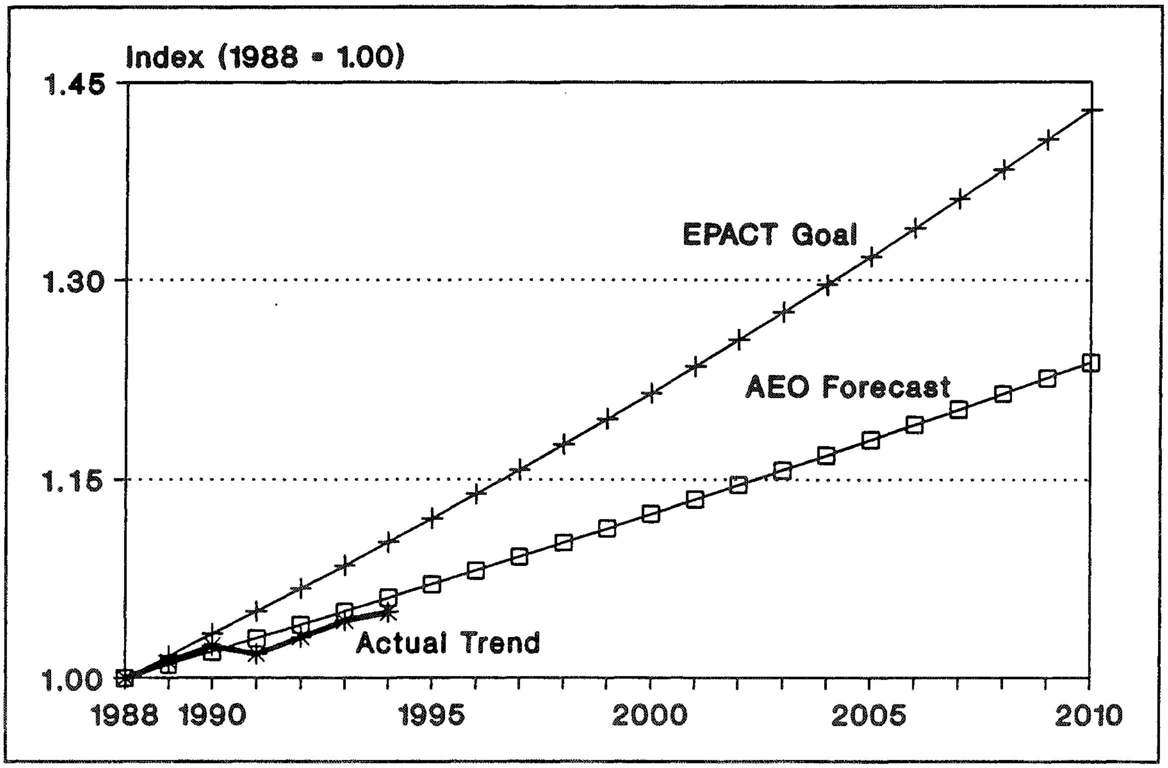
37. Section III(A)(2) of this report previously discussed changes only in the periods 1973-87 and 1987-91. When the entire period 1970 to 1991 is included, the results show that only 70 percent of the decline is E/GDP is explained by efficiency improvements.

38. See, *Energy Efficiency and Job Creation*, op. cit.

FIGURE 8. COMPARING ENERGY INTENSITY TRENDS WITH EPACT GOALS



A final benchmark among the three EPACT objectives reviewed here is tracking the use of petroleum resources. Recall that the EPACT objective suggests that U.S. oil consumption be reduced from 40 percent to 35 percent of total energy use by 2005. Despite that suggested mandate, oil resources still provide about 40 percent of the nation's total energy supply in 1994. According to the AEO94, in the year 2005 oil resources will continue to provide 40 percent of total energy needs. With existing trends the nation will, therefore, completely miss this benchmark.

B. Tracking CCAP Objectives

The United States has an international commitment to reduce its overall greenhouse gas emissions to 1990 levels by the year 2000. The commitment stems from the U.S. ratification of the Framework Climate Change Convention. Despite this agreement, energy-related carbon emissions in the U.S. have reached an all-time high. Emissions from the nation's use of fossil fuels climbed from 1,338 million metric tons (MMT) in 1990 to 1,412 MMT in 1994.[39]

In response to the growing concern about global climate change, the Clinton Administration issued a Climate Change Action Plan (CCAP) that proposed a series of 44 initiatives to reduce the overall greenhouse gases (GHG) to 1990 levels. In terms of fossil fuel-related emissions, the plan sets a target of 1,379 MMT by the year 2000. However, CCAP baseline projections suggest an emission level of 1,449 MMT by 2000; and the 1994 carbon emissions are already higher than the level projected for 1995 in the CCAP plan. Thus, annual milestones may be a useful tracking device to monitor the progress toward meeting the United State's international obligations.[40]

The primary source of information is the Energy Information Administration's *Emissions of Greenhouse Gases in the United States 1985-1990.*[41] A variety of carbon coefficients are applied to more recent data from the *Monthly Energy Review* to generate preliminary updates through 1994.

The methodology is straightforward. Once the energy consumption estimates are converted to estimates of carbon emissions, the annual levels can be compared to the projected CCAP policy scenario contained in the technical supplement to the climate plan.[42]

The results initially suggest, as displayed in Figure 9, that the United States may find it difficult to meet the 1990 benchmark. Rising from 1,241 MMT in 1985, the pattern of emissions has been fairly volatile en route to the 1994 high of 1,412 MMT.

Projected levels through the year 2000 (1,445 MMT) are then compared to the CCAP policy (1,379 MMT). Comparing the two trends suggests a potential gap of 66 MMT in the year 2000. Note that CCAP anticipates a higher energy-related emissions level in the year 2000, but this will be offset by greater levels of carbon sequestration and

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39. These preliminary estimates are based upon calculations by the author using recent data from the U.S. Department of Energy. They are likely to be revised once the final consumption figures are available for 1994.

40. Indeed, the Administration's *Climate Action Report* now acknowledges the strong likelihood of a shortfall in the nation's ability to meet its international obligation. See, *Climate Action Report: Submission of the United States of America Under the United Nations Framework Convention on Climate Change* (Washington, DC: Superintendent of Documents, 994), pages 186-189.

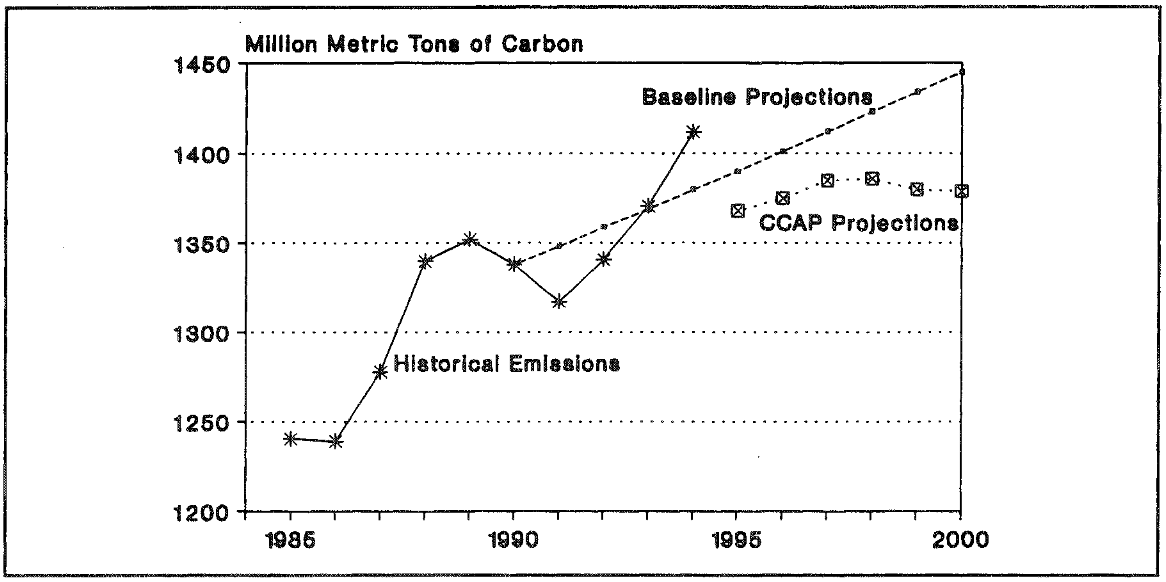
41. Energy Information Administration, *Emissions of Greenhouse Gases in the United States 1985-1990* (Washington, DC: U.S. Department of Energy, DOE/EIA-0573, October 1993). Note that this volume has been subsequently updated.

42. See, Office of Policy, Planning, and Program Evaluation, *Climate Change Action Plan: Technical Supplement* (Washington, DC: U.S. Department of Energy, March 1994).

other strategies. Should these benefits not materialize, then the carbon gap would increase from 1,338 MMT to 1,445 MMT, or a difference of 107 MMT.

Assuming the CCAP initiatives do not really kick in until 1995, the Administration has only five years to achieve its goal. Thus, monitoring emission levels on a quarterly basis and comparing them to the plan itself would help guide the modification and acceleration of programs which help achieve the CCAP goal. The rising emission levels and the admission that the plan may fail to reach the initial CCAP milestones indicate that such indicators should be developed immediately.

FIGURE 9. HISTORICAL AND PROJECTED CARBON EMISSIONS



C. Tracking Economic Efficiency Potential

The Energy Policy Act of 1992 provides useful targets to guide the development of U.S. energy policy. However, decision makers and members of the public may have difficulty conceptualizing something like E/GDP without a standard to help them understand the level of energy efficiency that can economically be achieved. The indicator suggested here would allow decision makers to track changes in the nation's annual energy intensity compared to the levels suggested by a detailed economic analysis found in *America's Energy Choices* (AEC).[43]

As described here, the benchmark adapts AEO94 reference case assumptions regarding changes in E/GDP. These assumptions are then compared to the energy intensity targets (E/GDP) established within the comprehensive AEC analysis. In monitoring the annual changes in E/GDP, the benchmark would presumably rely on EIA data found in the *Monthly Energy Review*. The MER data would need to be modified, however, to include all renewable energy resources.

In writing the AEC report, a consortium of leading energy and environmental organizations provided a series of detailed analyses to highlight economically achievable targets of energy efficiency and renewable energy in the year 2030. The information contained in the report originally reflected a baseline scenario in the *Annual Energy Outlook 1990*. This was modified to update the E/GDP data to provide a more consistent parallel to AEO94. The resulting targets for each of the three AEC scenarios include:

(a) Market Case: 11.0 kBtus per dollar of GDP in 2010;
(b) Environmental Case: 9.6 kBtus per dollar of GDP in 2010; and
(c) Climate Stabilization Case: 9.10 kBtus per dollar of GDP in 2010.

Using the AEO94 reference case forecast for 2010, and specifically including all renewables among all scenarios, we can examine the anticipated progress toward reaching the achievable levels of energy efficiency. Please note that because all scenarios include the full array of renewable resources, the E/GDP estimates are higher than would be found if we were to limit the analysis to those listed in MER.

As Figure 10 reveals on the following page, the AEO94 forecast suggests that the energy intensity in 1988 would fall from about 17.6 kBtus per dollar of GDP (measured in 1987 dollars) to 14.2 kBtus in the year 2010. This is a considerably higher ratio than the even the most conservative scenario developed in *America's Energy Choices* — the market case which suggested an achievable energy intensity level of 11.0 kBtus.

The difference among the three AEC scenarios and the AEO94 forecast implies a 23 to 36 percent energy intensity gap by the year 2010.[44] Unlike the discussion about the EPACT benchmarks, this gap would materialize regardless of whether the benchmark is calculated using energy intensity (E/GDP) or energy efficiency (GDP/E) as the index.

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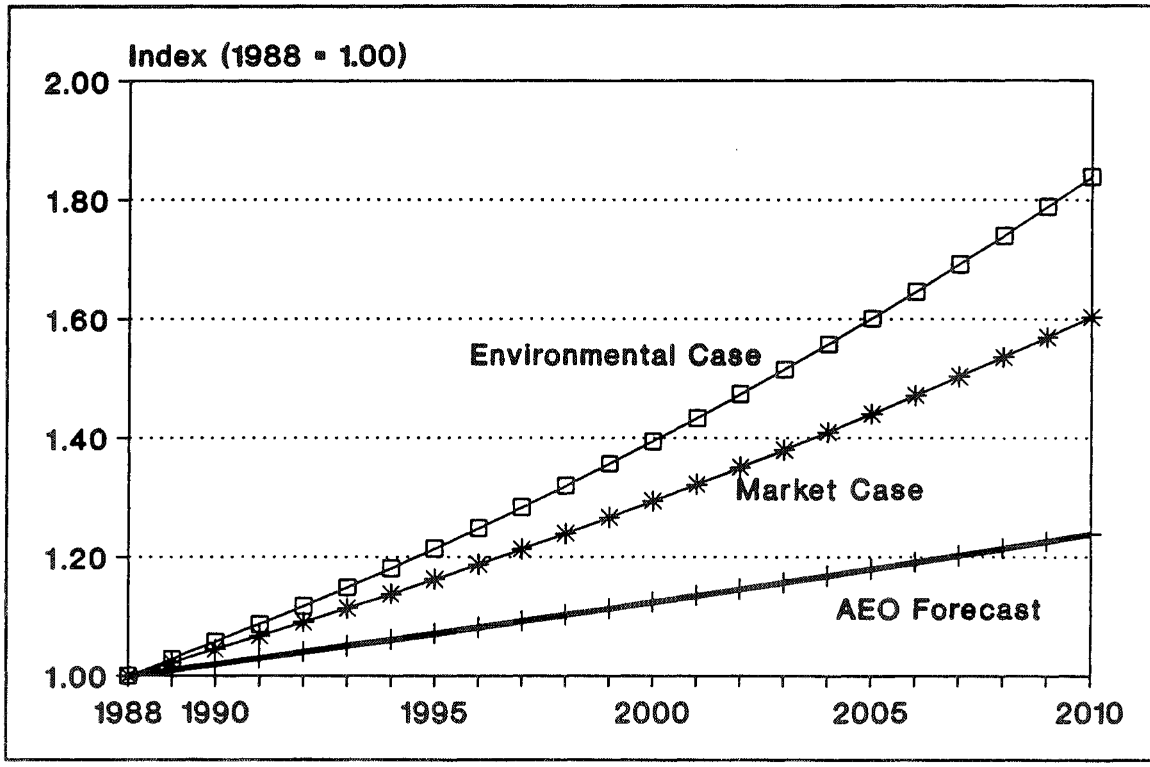
43. Op. cit. Plans are underway to update this analysis as a contribution to the President's 1995 National Energy Policy Plan (NEPP). For more information on this point, contact Howard Geller at ACEEE.

44. To improve the readability of Figure 7, the climate stabilization scenario is not shown since it so closely tracks the environmental case in AEC.

FIGURE 10. ENERGY INTENSITY TRENDS VERSUS AEC TARGETS



Since both the AEO94 and the AEC studies include renewables within their respective scenarios, a more complete review of overall energy efficiency improvement is possible. The projected 23-36 percent shortfall will have a significant impact. But when translated into total energy requirements in 2010, the difference among the scenarios become more pronounced.

According to AEO94 the nation's GDP is expected to grow (in real terms) by about 57 percent from 1988 through 2010. A difference of 23 percent in E/GDP effectively means that the United States will consume about 24 more quads of energy under the AEO94 scenario compared the AEC market scenario. Similarly, the AEO94 forecast suggests 34 and 38 more quads of consumption compared to the environmental and climate stabilization scenarios, respectively. At an average cost of $5.73 per million Btus for primary energy consumption, this implies additional energy expenditures of $138 to $218 billion per year by 2010.[45]

45. This figure is based upon the author's 1994 estimate for U.S. energy expenditures of $493 billion, and by a projected 1994 estimate for energy consumption of 86.1 quads.

D. Tracking Energy Efficiency Investments

Long-term efficiency gains are largely the result of technology investments. In that regard it would be helpful to have an indication of the trend and magnitude of efficiency investments in the United States. Unfortunately there is little data collected to help provide an assessment of the annual efficiency investment market. There is, however, an ad hoc collection of data on various individual technologies. Table 5, for instance, shows the worldwide growth in the use of compact fluorescent lamps collected by Evan Mills with the Lawrence Berkeley Laboratory, among others. Sales data for selected technologies as premium (high efficiency) motors and improved consumer appliances could also be tracked.

TABLE 5. SALES OF COMPACT FLUORESCENT LAMPS (IN MILLIONS)

Year	World	Western Europe	North America
1988	45	24	9
1989	59	30	11
1990	80	40	18
1991	115	49	29
1992	139	59	35
1993	168	69	49
1994	195	81	58

Source: Evan Mills, Lawrence Berkeley Laboratory, Berkeley, CA, private communication, January 1995.

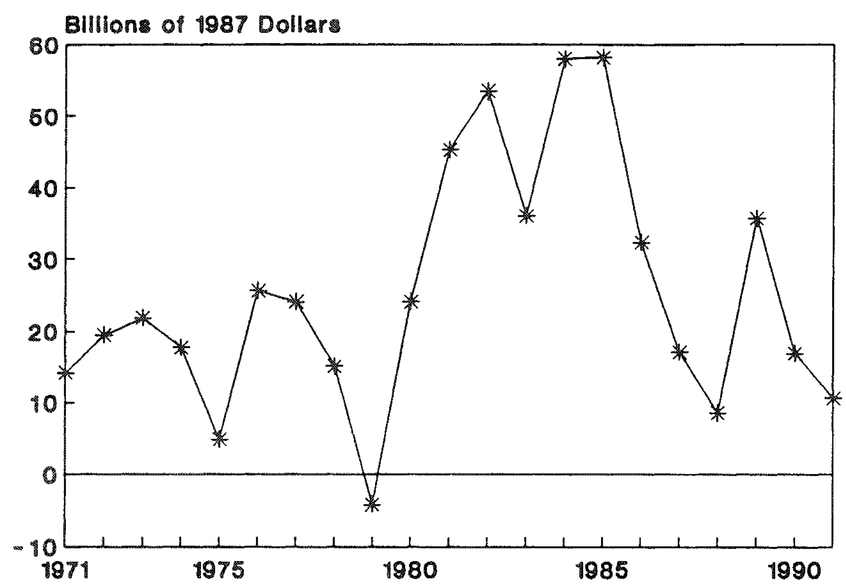
Yet, this kind of data alone does not provide either policy makers or investors with any sense of the larger sales trend for energy efficiency technologies. For that reason, a supplemental benchmark has been devised to generate at least one estimate of the energy efficiency investment trend over the period 1970-1991. It draws on the data and analysis presented in section III(A)(2) of this report. The result is a surrogate indicator to measure efficiency investment trends until such time as other and better survey data are collected.

The times series estimate for the efficiency investment market is developed in four steps. The starting point is the seven-sector decomposition analysis found in section III(A)(2). This is used to identify how much of the annual change in E/GDP is the result of efficiency improvements versus structural changes within the economy. The information is used in a second step to determine the magnitude of the incremental efficiency (rather than structural) savings as measured in trillions of Btus.

The third step is to identify the investment cost for efficiency investments. In the absence of hard data about the actual cost of efficiency technologies, it was assumed that the typical investment would have an average payback of five years. With the cost of primary energy holding at about $5.00 per million Btus (in 1987 dollars), this implies an investment of about $25 per million Btus of incremental gains in energy efficiency. Applying this investment rate to the efficiency gains projected for a given year generates an initial estimate of the annual investment in energy efficiency technologies.

Finally, the last step is to construct a three-year moving average of the investment totals. The reason for this procedure is to account for investments made in a prior year for which no savings are credited, and to provide a smoothing of annual changes that result in a loss of efficiency gains.[46]

FIGURE 11. EFFICIENCY INVESTMENT TRENDS



46. Drawing from the 7-sector decomposition analysis in section III(A)(2), there are four years in which efficiency impacts lost ground. They are 1976, 1979, 1987 and 1991. Net efficiency savings are about 21.2 quads while overall gains from efficiency and structural improvements are about 31.4 quads.

The results of these four steps are summarized in Figure 11. The above analysis is designed more to catalyze discussion about the efficiency investment trends than to provide an accurate estimate of the actual investment dollars. Despite the apparently volatility on the trend, and the lost efficiency investments in 1979, there are useful insights in Figure 11.

The first is that net investments over the period 1971 through 1991 are estimated to be about $530 billion (in 1987 dollars). Second, about 60 percent of the total investment appears to have been made in the seven-year period 1980 through 1987. Not coincidentally, this is in the period during the greatest gains in energy efficiency (see Figure 2). Finally, in recent years the magnitude of the investment appears to have fallen significantly. This corresponds to the rather flat change in the nation's energy intensity since 1987.

Figure 11 also suggests that if the United States is to meet either the EPACT or CCAP objectives, the level of investment will have to be significantly upgraded compared to current levels. In other words, what policy initiatives need to be instituted to catalyze the kind of investments seen in the years 1980 to 1987.

V. ECONOMIC WELFARE INDICATORS

Previous sections of this paper have focused on a rather narrow view of energy efficiency indicators. In this section we attempt to open up more of the "systems" view discussed by Barbara Farhar, David Rejeski, and others. By this we mean extending the review of indicators to measure larger productivity gains in the economy, track the influences of price and income on energy consumption patterns, and explore quality of life and environmental quality issues as they might be affected by energy consumption. In this section a total of seven possible indicators are reviewed.

A. Productivity Improvements

Policy makers in recent years have generally been tracking overall productivity within the American economy. There is general agreement that only greater levels of productivity can lead to greater increases in per capita welfare. William Baumol (and others) write, for example: "For real economic miracles one must look to productivity growth."[47]

There is broad agreement that energy efficiency can contribute to overall productivity increases. However, little has been done to specifically link energy efficiency improvements to positive changes in economic productivity. This section establishes a first look at possible benchmarks for productivity improvements.

Before examining the productivity benchmarks, it is helpful to review what is meant by such indicators. In general, productivity expresses a relationship between the quantity of goods and services produced by an economy and the quantity of labor, capital, energy, and other resources needed to produce those goods and services. There are two types of productivity measurements.

Single factor productivity is defined as output O per unit of input I, where output is usually defined as gross domestic product (GDP) — now measured in constant 1987 dollars. Input can be such things as a quantity of labor L (measured as either hours of work or jobs) or energy E, measured as Btus. The inverse of GDP-to-energy ratio produces the more familiar E/GDP index discussed in section III of this report.

Multifactor productivity, sometimes referred to as total factor productivity, is defined as output per unit of combined inputs of capital K, labor L, energy E, materials M, and

47. William J. Baumol, Sue Anne Batey Blackman, and Edward N. Wolff, *Productivity and American Leadership: The Long View* (Cambridge, MA: The MIT Press, 1989), page 9.

purchased services *S*. The aggregate of combined inputs is sometimes referred to as *KLEMS*.

The measure of multifactor productivity (MFP) can be thought of as the growth of output less the growth of combined inputs. For example, if total input grew by an average of two percent but total output grew by three percent, then multifactor productivity is said to improve by one percent, or the difference between output and inputs.

More formally, the MFP growth rate can be calculated as the rate of output less the rate of input,

$$\Delta LnB = \Delta LnO - \Delta LnI$$

where ΔLn is the differences in natural logarithms, B is a benchmark or index of multifactor productivity, O is an index of output, and I is an index of combined inputs. The measure I is an index of the five major categories of inputs calculated as,

$$\Delta LnI = \Sigma_i w_i \, \Delta LnX_i$$

In this case, ΔLn is the difference in successive logarithms, X_i refers to quantity indexes where i = *KLEMS*, and w_i refers to the average of the factor shares (measured in dollars) of each input used in the calculation of the MFP index.[48]

1. National Productivity Trends

The productivity chart (Figure 12) shows both single and multifactor productivity trends for the United States in the period 1970 through 1992.[49] What may be most surprising is that capital productivity moved in such a volatile and downward course over the period of time examined here. Employment, generally showed both a positive and consistent productivity gain.

Energy productivity (measured as the inverse of E/GDP) generated the strongest benefit for the economy, moving to an index value of 1.40 by 1992. Since energy represents

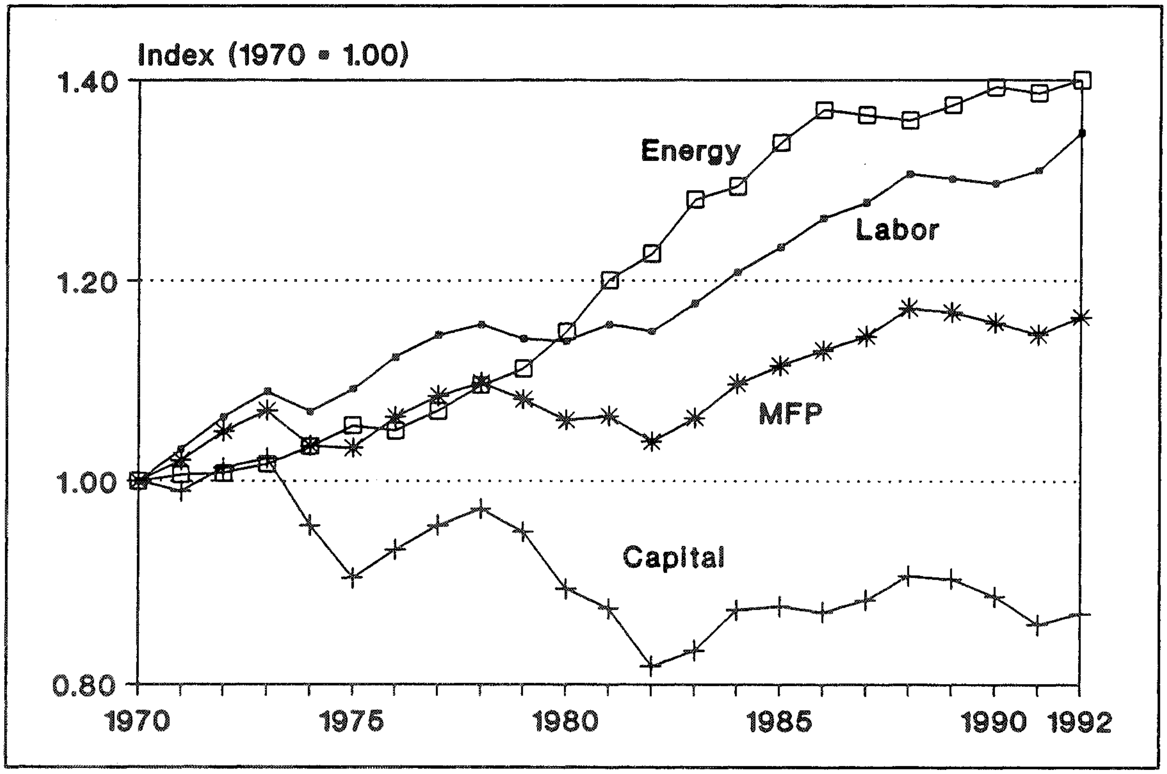
48. For more discussion about the development of MFP indexes, see Bureau of Labor Statistics, *Productivity Measures for Selected Industries and Government Services* (Washington, DC: Superintendent of Documents, Bulletin 2440, March 1994).

49. The MFP, labor, and capital data from 1970 to 1990 are taken from, Bureau of Labor Statistics, *Productivity and the Economy: A Chartbook* (Washington, DC: U.S. Department of Labor, Bulletin 2431, September 1993); and updated with 1991-92 data using, Bureau of Labor Statistics, *Monthly Labor Review* (Washington, DC: U.S. Department of Labor, September 1994).

such a small share of the combined inputs (about five percent of total input resources), its impact on multifactor productivity is small. Moreover, the gains have been generally small since 1986. This attests to the influence of declining real energy prices and a stagnating E/GDP ratio since 1986.

Although energy inputs are a relatively small influence on multifactor productivity, energy efficiency investments can indirectly strengthen the return on the nation's capital investment. For example, rather than focusing solely on energy efficiency gains within the various sectors of the economy, policy makers may want to explore how energy efficiency investments can lead to increases in overall process efficiency. In that way, the benefits of energy efficiency technologies can be extended throughout the larger economy.[50]

FIGURE 12. NATIONAL PRODUCTIVITY TRENDS



50. Although not a definitive analysis, when MFP data from 1970 through 1990 is regressed on the GDP/E ratio for the same period, it appears that changes in energy intensity explains about 66 percent of the changes in MFP. Moreover, the MFP has an elasticity of 0.30 with respect to GDP/E. The t-statistic for this coefficient is significant at the one percent level of confidence.

To illustrate this point, let us compare the productivity gains from unrealized efficiency opportunities. For example, had the E/GDP declined at the same rate in the late 1980s as through 1986, the energy index shown in Figure 12 would have risen from 1.40 to 1.57 by 1992 (where 1970 = 1.00). Admittedly, this appears to be a only a modest 12 percent improvement in the nation's energy efficiency index. Yet, this difference implies the savings of about nine quads of energy, or a savings of about $50 billion in the nation's annual energy bill.

Using a simple calculation implies the prospect of a larger benefit in the form of a higher overall economic productivity. In 1992 the MFP index stood at 1.164. Had the index of energy inputs risen from 1.40 to 1.57, the MFP index would have rise to 1.171.[51] This is a GDP gain of about $30 billion, or about $117 per person in the United States. It is in this context that it becomes important to track energy efficiency as it positively or negatively impacts multifactor productivity.

2. Productivity Gains Among Energy Resources

The productivity discussion up to this point has been confined to a review of what might be termed the "demand-side" of the productivity equation. But what is the "supply-side" productivity of the major energy resources themselves? In other words, how efficiently do the nation's suppliers process and distribute the nation's energy resources? This section examines some initial ways to answer this question.

Figure 13 offers an opening insight into the productivity trends of petroleum, natural gas and electricity in the years 1970 through 1992. Three sources of information are required to generate this initial MFP index for energy resources. The first is the EIA's *State Energy Price and Expenditures Report* which provides total annual revenues for each resource. The second is EIA's *State Energy Data Report* which provides total sales of energy in physical units: kilowatt-hours of electricity, barrels of oil and cubic feet of natural gas. The final is the GDP deflators for the desired time series data. These can be found in the latest *Annual Energy Review*.[52]

As used here within this sector, the MFP index is computed as the ratio of the index of energy output (measured in physical energy units) to the index of aggregate inputs (measured in constant 1987 dollars), or Y/I. In other words, the MFP index is simply the inverse of energy prices where inputs are assumed to be the same as total

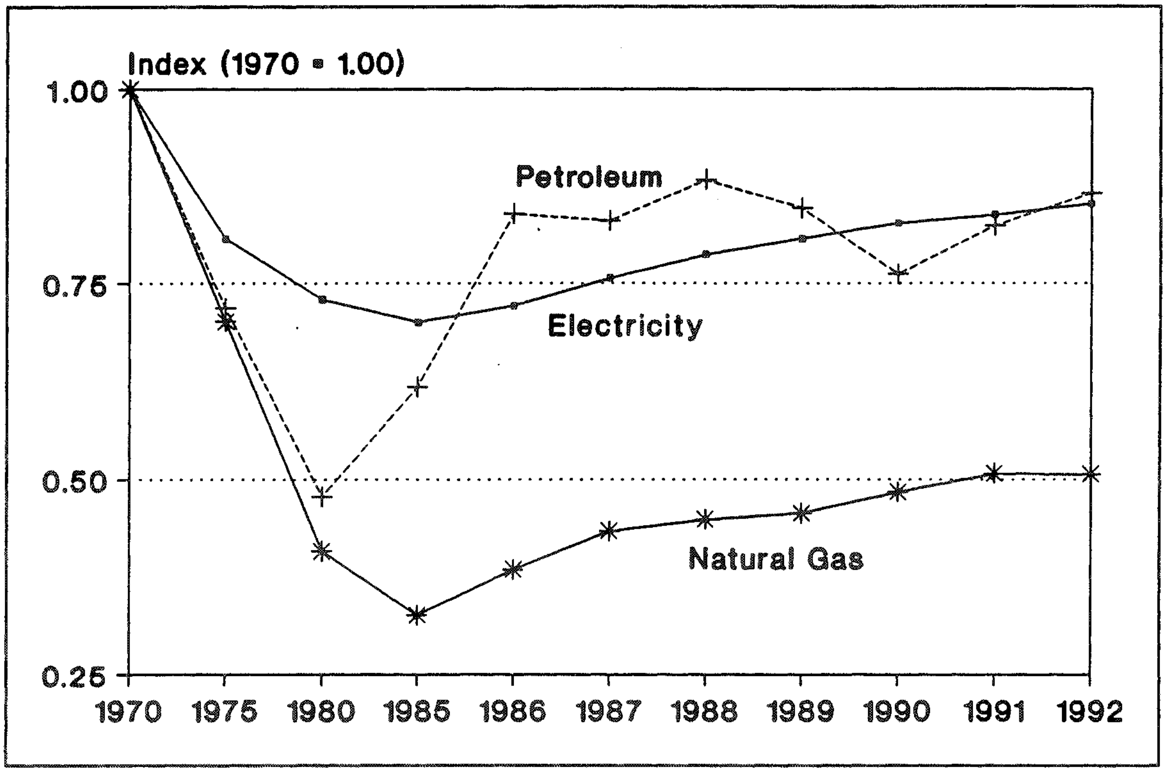
51. This result is based upon calculations made by the author. It assumes that energy is about five percent of the aggregate KLEMS input for 1992.

52. All three are cited in section II, the background narrative of this report.

expenditures in a given year. As before, the measure is based upon an index where 1970 equals 1.00.

Figure 13 shows each of the three resources appears to be less "productive" in 1992 than is the case in 1970. As might be expected, the precipitous price increases in the 1970s prompted a slowdown in sales. The twin effects of higher prices and reduced sales dropped productivity by a substantial margin through the 1970s.

FIGURE 13. MULTIFACTOR PRODUCTIVITY AMONG ENERGY RESOURCES



Natural gas shows the steepest decline while electricity appears to be more stable. Petroleum resources seem to be more volatile. All three energy resources recovered somewhat in the 1980s although none have returned to their 1970 performance level. By 1992, the indexes for electricity and petroleum were just above 0.80. Natural gas, however, has regained only about one-half of its 1970 performance level with an index at just over 0.50.

While Figure 13 presents a useful index to track the performance levels of the nation's energy suppliers, this yardstick is not a true measure of multifactor productivity. Among other things, there is a significant amount of double-counting such as the purchase of intraindustry fuels. Moreover, since output is measured as unweighted energy sales, true productivity gains or losses would not be measured if consumption shifts either to or from the relatively low-cost industrial sales (in the case of electricity or natural gas, for example).

The Bureau of Labor Statistics recently introduced a more sophisticated measure of multifactor productivity for the utility services industry, including electric, gas, water and sanitary services. As explained in its 1993 analysis, the measure tracks output compared to inputs of capital, labor, energy, materials and purchased services.[53] The results of that analysis are summarized in Table 6.

TABLE 6. COMPOUND ANNUAL RATES OF CHANGE IN PRODUCTIVITY MEASURES FOR UTILITY SERVICES, 1948-1988

	Multifactor and Singe-Factor Productivity (Percent)					
Period	MFP	Capital	Labor	Energy	Materials	Services
1948-73	3.6	3.4	6.2	1.2	3.6	0.9
1973-88	0.4	-0.8	-0.2	1.4	1.9	0.1

Multifactor productivity in utility services grew at an average rate of 3.6 percent annually in the period 1948 to 1973. This is significantly better than the 1.4 per year growth for the entire nonfarm business sector. Following the 1973 oil embargo, however, the growth in the utility MFP index dropped to 0.4 percent while the nonfarm business sector slipped to only 0.6 percent. The biggest reasons for this turnaround appears to be the negative productivity in the use of both capital and labor following the 1973 embargo.

While there is evidence that the nation's utilities have improved their labor productivity, especially in the 1990s, the return to pre-1973 levels of productivity in the utilities service sectors may still lag the nation as a whole.

For example, a review of data from the investor-owned electric utilities suggests that in the years 1992 and 1993, labor productivity improved significantly. Employment fell by

53. John L. Glaser, "Multifactor productivity in the utility services industry," *Monthly Labor Review*, May 1993, pages 34-49.

about 2.8 percent while sales to ultimate electric utility customers increased by 3.4 percent. At the same time, capital assets increased by about 6.6 percent and the purchase of materials and services increased by about 7.1 percent. A preliminary estimate of the overall change in multifactor productivity for 1992-93 suggests a drop in the MFP index of about 0.9 percent.[54]

B. Price and Income Elasticities

One of the constants in any discussion about the nation's energy policy is the role of energy prices on anticipated future consumption. Less attention is paid to the role of income on shaping future energy demand. Yet, the more policy makers and the public understand about the dynamic tension between changes of income and prices on energy consumption, the better they can positively direct the course of future energy policy.

One way to measure the influence of price and income on energy consumption is through the use of price and income elasticities. These are values which express a relationship between the amount of a commodity demanded and the variables which shape that demand.

Price elasticity refers to the effect of a commodity's own price on its demand. For that reason, it is sometimes referred to as the *own price elasticity*. This is defined as the percentage change in the use of a given commodity when the price of that same quantity changes by one percent. Mathematically, this is shown as follows,

$$E_p = \frac{\frac{Q_t - Q_{t+1}}{Q_t}}{\frac{P_t - P_{t+1}}{P_t}}$$

where Q refers to the quantity of energy consumed in a give period to time, t, and P refers to the price of energy.

Income elasticity refers to the impact of income changes upon a specific commodity; or, the percentage change in the quantity demanded when income changes by one percent. In the equation above, we would substitute the amount of income I for the price values.

Price elasticity usually has a negative value to show that as the price increases, demand decreases; or as the price decreases, the demand increases. Income elasticity, on the other hand, usually shows a positive value since demand for a product usually increases

54. Author's calculations based upon data published in the *Statistical Yearbook of the Electric Utility Industry 1993* (Washington, DC: Edison Electric Institute, October 1994).

as income increases. If a commodity has an elasticity that is greater than 1.0 (in absolute value) — meaning that if the change in demand is greater than one percent for a one percent change in price or income — then it is said to have an elastic demand.

If a commodity has an elasticity of less than one, it is said to have an inelastic demand. If a one percent change in price induces a one percent change in demand, the demand is said to be unitary elastic. Finally, an elasticity of zero implies a perfectly inelastic demand; that is, a change in price has no impact on consumption.

From a policy perspective it would be useful to track the changes in price and income elasticities over time. Using time series data from the *Annual Energy Review*, we can set up an index of elasticities in the period 1970 through 1994.[55] The index was established using a three-step process with the results illustrated in Figure 14.

The first step was to estimate how energy consumption changes given annual energy prices and levels of income. The equation below shows the resulting demand function for the period 1970 through 1994:

$$\text{QUADS} = \alpha + \beta_1 * \text{PRICE}_t + \beta_2 * \text{GDP}_t + \text{AR(1)}$$

where:

Quads	=	U.S. Energy Consumption in Quadrillion Btus
α	=	Constant Term
β_1	=	Short-Run Price Coefficient of Demand for Primary Energy
β_2	=	Short-Run Income Coefficient of Demand for Primary Energy
Price	=	Real Price of Primary Energy in constant dollars
GDP	=	Real Gross Domestic Product in constant dollars
AR(1)	=	Autoregressive error coefficient for first order serial correlation.

The second step was to estimate the equivalent of an annual price elasticity, *Elasp*, and an income elasticity, *Elasi*, in period *t* using the following expressions:

$$\text{ELASP}_t = \beta_{1,t} * \text{PRICE}_t \ / \ \text{QUADS}_t$$

and

$$\text{ELASI}_t = \beta_{2,t} * \text{GDP}_t \ / \ \text{QUADS}_t.$$

The year-by-year results for short-run price and income elasticities are shown in Table 7, on the next page.

55. *Annual Energy Review 1993*, op. cit., Tables 1.7 and 3.6. The data for energy expenditures extend only through 1991. The expenditure data for 1993 and 1994 were estimated by the author using data from the *Monthly Energy Review*, op. cit.

TABLE 7. U.S. INCOME AND PRICE ELASTICITIES		
Year	**Income**	**Price**
1970	0.280	-0.395
1971	0.281	-0.391
1972	0.282	-0.377
1973	0.284	-0.363
1974	0.289	-0.370
1975	0.295	-0.388
1976	0.294	-0.369
1977	0.299	-0.360
1978	0.307	-0.353
1979	0.311	-0.348
1980	0.321	-0.363
1981	0.336	-0.378
1982	0.343	-0.400
1983	0.358	-0.406
1984	0.362	-0.385
1985	0.374	-0.389
1986	0.383	-0.391
1987	0.382	-0.377
1988	0.380	-0.361
1989	0.385	-0.357
1990	0.390	-0.357
1991	0.388	-0.360
1992	0.392	-0.328
1993	0.395	-0.311
1994	0.399	-0.298

The final step was to index the annual values shown in Table 7 (where 1970 = 1.00). The results are shown in Figure 14 below.[56]

FIGURE 14. AN INDEX OF PRICE AND INCOME ELASTICITIES

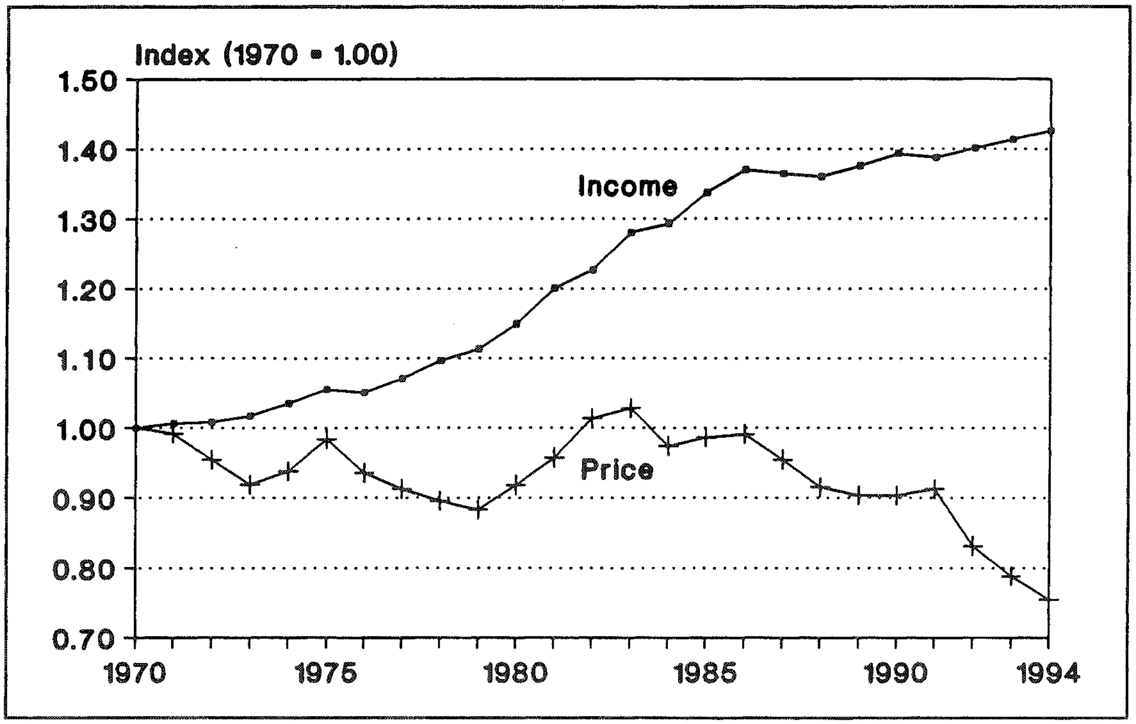


Figure 14 tells an interesting story. While much of the discussion about future energy demand focuses on the effect of energy prices, it is the effect of changes in income that may have a greater impact on consumption in the future.

Using the methodology described above, the 1970 price elasticity for primary energy was -0.395. Following the volatile path reflected in Figure 14, by 1994 it appears the price elasticity has fallen to about -0.298. In contrast, the 1970 income elasticity at 0.280 was smaller (in absolute terms) than the 1970 price elasticity. Following a steady upward change it appears to have risen to about 0.399 in 1994.

56. All independent variables in the equation are statistically significant in terms of their T-statistic where $\alpha = 4.11$, PRICE = -1.68, GDP = 4.50, and AR(1) = 4.81. Moreover, total adjusted R-squared is 89.03 percent. The Durbin-Watson statistic is 1.24 while the F-Statistic is 63.19. The critical F-value for a one percent level of confidence where there are four explanatory variables, including the constant, price, gdp and ar(1), and 24 observations is 4.50. Since the computed F-value is greater than 4.50, the equation is statistically significant at the one percent level of confidence.

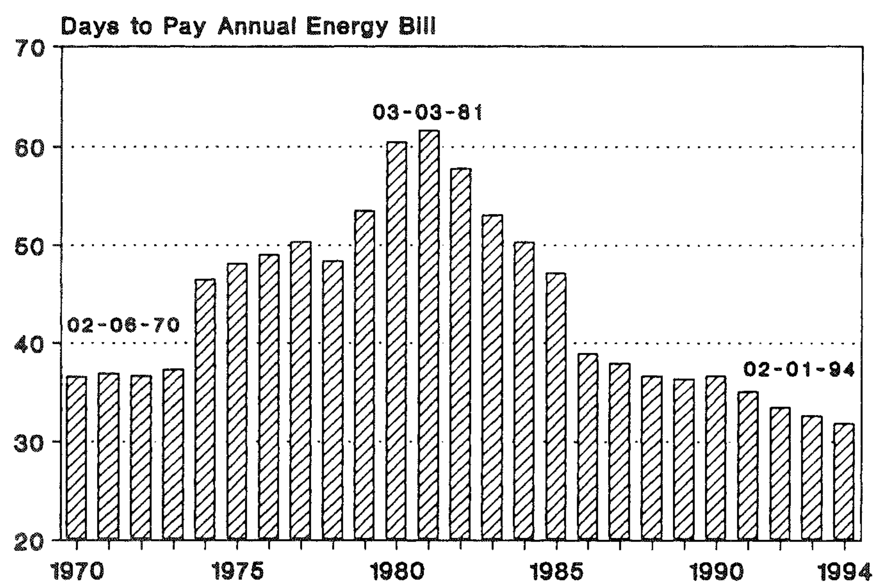
Based upon the data in Table 7, 1987 appears to be the crossover year in which income elasticity (in absolute terms) becomes greater than price elasticity. The results make intuitive sense when we realize that 1987 is also the first year in which the nation's energy intensity (measured as the E/GDP ratio) remains relatively unchanged (as shown earlier in Figure 2).

It is generally accepted that the drop in prices after 1986 had a big impact on energy demand. But these results suggest that the growing national income were at least as important as prices. In effect, consumers and businesses are responding to growing income opportunities rather than worrying about either energy price or energy supply disruptions. Policies which promote energy efficiency may need, therefore, to pay more attention to ways of overcoming the income effect than merely to changes in energy prices as such.

C. Energy Freedom Day

Similar to the Tax Foundation's copyrighted "Tax Freedom Day," the American Council for an Energy-Efficient Economy has estimated what it refers to as "Energy Freedom Day." The measure provides a simple benchmark to track the single day each year when personal income in the United States is equivalent to the nation's annual energy bill. ACEEE estimates that, in 1994, Energy Freedom Day occurred on or about February 1st. This is shown in Figure 15, below.

FIGURE 15. A HISTORICAL REVIEW OF THE U.S. ENERGY FREEDOM DAY



Only two pieces of information are needed for this calculation: (1) total personal income in the United States; and (2) total energy expenditures (both measured in billions of current dollars).[57] In 1994, U.S. personal income is estimated to be $5,653 billion. The average daily income will be, therefore, $15.5 billion for 1994. Based upon ACEEE's preliminary estimates, the 1994 energy expenditure in the U.S. will be about $493 billion.

The data imply that the U.S. energy expenditures would have been "paid for" in the first 32 days of the year. The U.S. "Energy Freedom Day", therefore, falls on or about February 1, 1994.

For historical reference, the chart on the previous page also shows the trend for the period 1970 to 1994. As shown in Figure 14, the nation's 1970 total energy bill was retired on February 6th. In 1981 the energy bill was not paid until March 3rd. This gap was largely the result of the influence of the OPEC cartel on overall energy prices.

While it looks as though the trend is now declining due to falling energy prices, had the U.S. continued the efficiency trends of the late 1970s and early 1980s, the energy bill might be $66 billion less than now projected. Efficiency improved at a rate of 2.3 percent annually from 1973 through 1986, but only 0.5 percent from 1986 to 1994. Under the continued efficiency trend, the 1994 Energy Bill Freedom Day might have been January 27, 1994, about 4 days earlier in the year.[58]

At first, a four-day difference may not seem like a significant event. But the difference of four days implies the use of 11.5 less Quads of energy for roughly the same level of domestic economic activity (as measured by Gross Domestic Product). Had we used that much less energy, for example, carbon emissions would be down by about 190 million metric tons (depending upon the precise mix of fuels under that scenario). Based upon ACEEE's 1992 employment study, a January 27, 1994 Energy Freedom Day would have meant about 578,000 more jobs for the American economy.[59]

57. While personal income and energy consumption data are available in a preliminary format from the U.S. Department of Commerce for the first two quarters of 1994, complete energy expenditure data are available only through the year 1991 as of this writing. The 1994 estimates of total energy expenditures were calculated by the author using a variety of data published by the U.S. Department of Energy.

58. Or it might be somewhat earlier if lower energy use also resulted in lower energy prices.

59. The employment estimate is drawn from an earlier report published by ACEEE entitled, *Energy Efficiency and Job Creation*, op. cit.

D. Consumption of Natural Resources

Economic activity that is sustainable requires that the consumption of natural resources be replaced by other assets. Some economists refer to this notion as "keeping capital intact." Sir John Hicks noted that if "a person's receipts are derived from the exploitation of a wasting asset, liable to give out at a future date, we shall say that his receipts are in excess of his income."[60] Within energy policy it would be useful to have a means to evaluate and understand the erosion of the nation's energy capital.

Salah El Serafy, an economist at the World Bank has proposed a simple formula to estimate what he refers to as the "user-cost" associated with natural capital — in this case, associated with energy resources. This cost must then be subtracted from GDP to determine a net value of the economic activity in a given year.[61] The methodology is as follows:

$$X = R * [1 - 1 / (1 + r)^{n+1}]$$

Where:

X	=	Sustainable (Hicksian) income
R	=	operating surplus from sale of natural resources
R-X	=	user cost, or the capital whose cumulative investment at interest rate, r, during n years would create a permanent income stream of X
r	=	public discount rate
n	=	remaining life of resource in years

Although complete data are not available to properly apply this methodology, we can develop surrogate data to show the magnitude of impact.[62] Value-added production of oil and gas mining are estimated to be $55.2 billion in 1987. The operating surplus appears to be about 65 percent of total value-added. The current life of remaining reserves shows a weighted average of about 44 years for both oil and gas reserves. GDP in 1987 estimated at $4,572.8 billion. The assumed real discount rate is 3.0 percent.

60. Sir John Hicks, *Value and Capital* (Oxford, England: Oxford University Press, 2nd edition, 1946), page 187.

61. Salah El Serafy, "The Proper Calculation of Income from Depletable Natural Resources," *Environmental Accounting for Sustainable Development* (Washington, DC: The World Bank, 1989).

62. The data that follows in this narrative is derived by the author using a variety of sources, including the 1987 input-output benchmark tables published by the Bureau of Economic Analysis, the *Annual Energy Review 1993*, op. cit., and the 1990 U.S. data from the *Implan* modelling system.

Applying this information to the methodology described above, we find the following results:

$$X = \$36.1 * [1 - 1 / (1 + 0.03)^{44+1}] = \$26.6$$
$$R\text{-}X = \$36.1 - 26.6 = \$9.5$$

Using El Serafy's accounting definitions, the sustainable income is only $26.6 billion. The user cost — that is, the amount of capital that would have to be invested to generate an income stream equal to $26.6 billion at a 3.0 percent discount rate — is $9.5 billion. The implication of this discussion is that, from the standpoint of oil and gas resources, the 1987 GDP is about $9.5 billion too high. If we make a downward adjustment to reflect this "user-cost" the GDP would decline by 0.2 percent. Although a small effect, the numbers suggest that from an energy perspective, the economy is not on a sustainable path.[63]

E. Population, Energy Consumption and Carbon Emissions

Fossil-fuel related carbon emissions increased by 21.1 percent since 1970 to a record high of 1,412 million metric tons in 1994.[64] This result was largely driven by a 27 percent population increase and a 46 percent increase in per capita GDP (measured in 1987 dollars) in that period. Despite the growing worldwide concern about the link between carbon emissions and global climate change, there is little discussion of how changes in population and per capita income affect overall carbon emission. This set of indicators addresses those twin effects.

The information used in this analysis was drawn entirely from EIA documents.[65] The key data is summarized in Table 8.

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63. For a review of how this concept is applied to a state economy, see, George E. Foy, "Accounting for Non-Renewable Natural Resources in Louisiana's Gross State Product," *Ecological Economics*, Volume 3, No. 1, March 1991, pages 25-41.

64. This figure is a preliminary estimate for 1994 energy-related carbon emissions. It will undoubtedly change as more complete data for 1994 becomes available.

65. See, *Annual Energy Review* and the *Annual Energy Outlook 1994*, op. cit. The 1994 estimates of energy consumption and GDP were based upon the December 1994 issue of the *Monthly Energy Review*. Carbon intensity and carbon emissions, expressed as million metric tons equivalent (MMT) were estimated by the author for 1994. Finally, the 1994 population estimates are based upon an assumed growth of 0.9 percent since 1993.

TABLE 8. TABLE ENERGY AND ECONOMIC DATA FOR SELECTED YEARS				
Indicator Data	**1970**	**1980**	**1990**	**1994**
Population (millions)	205.1	227.7	249.9	260.5
GDP Per Capita (1987$)	$14,015	$16,583	$19,596	$20,398
Energy Intensity (btus/GDP87$)	23,082	20,122	16,570	16,210
Carbon Intensity (tons/quad)	17.58	16.61	16.49	16.39
Total Carbon (MMT)	1,166	1,262	1,338	1,412

The analysis of population and income on carbon emissions stems from a straightforward relationship as follows:

$$CARBON = POP * PCAPGDP * EOVERGDP * COVERE.$$

In this formula, CARBON refers to fossil-fuel related carbon emissions measured in million metric tons, POP is the U.S. population in millions of persons, PCAPGDP refers to per capita Gross Domestic Product (GDP) measured in constant 1987 dollars, EOVERGDP (or E/GDP) is the energy intensity of the U.S. economy in btus per dollar of GDP, and finally, COVERE (C/E) is the carbon emissions rate measured as tons per Quad (or 10^{15} btus) of primary energy.

At the same time as population and income pressures increased in the period 1970-1994, these upward pressures were offset by a decline in both energy and carbon intensities of 28 and 7 percent, respectively. The combination of these four factors — population, per capita income, energy intensity, and carbon intensity — resulted in the 21 percent increase in energy-related carbon emissions as noted above. The question then becomes how to understand the interaction of these influences in achieving various policy goals such as those found in the Climate Change Action Plan (CCAP).

CCAP initiatives are designed to reduce the year 2000's total greenhouse gas emissions to 1990 levels of about 1,459 MMT. Carbon emissions from fossil fuels amounted to about 1,338 MMT in 1990, but under CCAP, they are allowed to rise to 1,379 MMT. According to the plan, this increase will be offset by slightly larger reductions in other greenhouse gases.

We can adapt information from the AEO94 to project specific annual growth rates for the four variables to test their influence on energy-related carbon emissions through the end of the century. Based upon the AEO94 reference case, these annual changes are: Population, 0.90 percent; Per Capita GDP, 1.06 percent; Energy Intensity ratio (E/GDP), -1.20 percent; Carbon Intensity ratio (C/E), -0.25 percent. The influence of all four of these growth trends on the year 2000 energy-related carbon emissions is shown in Table 9.

TABLE 9. PROJECTED CARBON EMISSIONS IN THE YEAR 2000

Indicator Data	1994	Annual Change	2000
Population (millions)	260.5	0.90%	274.9
GDP Per Capita (1987$)	$20,398	1.06%	$21,730
Energy Intensity (btus/GDP87$)	16,210	-1.20%	15,077
Carbon Intensity (tons/quad)	16.39	-0.25%	16.15
Total Carbon (million metric tons)	1,412	n/a	1,454

With the assumptions outlined in Table 9, carbon emissions from fossil fuels are projected to increase 5.4 percent above the CCAP target of 1,379 MMT to 1,454 MMT in the year 2000. Assuming U.S. policy will have little control over population growth, and that increased GDP is desirable, this means that the energy and carbon intensities will need to decline by a greater degree than baseline forecasts.

To achieve the goal of the CCAP target, the data in Table 9 (as applied to the previously cited formula) implies that energy intensity will need to decline by 2.1 percent annually from 1994 through the year 2000. According to CCAP documents, the Administration forecasts an annual reduction in E/GDP of about 1.5 percent. Again, by way of comparison, the rate of decline in the years 1973-1986 was 2.3 percent annually.

As an alternative to the use of what might appear to be the unwieldy numbers associated with the various indicators data, an index of those values might be applied instead. This would lead to an easier computation of "what-if" analyses. As an example of how this might look, Table 10 contains the relevant variables needed to complete a what-if analysis for the years 2000 and 2030.

TABLE 10. INDEX OF ENERGY FACTORS AND SCENARIO RESULTS

Index (1990 = 1.000)	1994	Annual Change	2000	2030
Current Trends				
Population Index	1.042	0.90%	1.100	1.439
Per Capita GDP Index	1.041	1.06%	1.109	1.522
Energy Intensity Index	0.978	-1.20%	0.910	0.633
Carbon Intensity Index	0.994	-0.25%	0.979	0.908
Total Carbon Index	1.055	NA	1.087	1.260
CCAP Target Adjustment	0.970	NA	0.970	0.970
CCAP Index (CCAP Goal = 1.000)	1.024	NA	1.054	1.222
An Alternative Scenario				
Population Index	1.042	0.90%	1.100	1.439
Per Capita GDP Index	1.041	1.06%	1.109	1.522
Energy Intensity Index	0.978	-2.10%	0.861	0.455
Carbon Intensity Index	0.994	-0.70%	0.953	0.772
Total Carbon Index	1.055	NA	1.001	0.770
CCAP Target Adjustment	0.970	NA	0.970	0.970
CCAP Index (CCAP Goal = 1.000)	1.024	NA	0.971	0.747

The first column of data in Table 10 data shows the 1994 index for the critical variables affecting carbon emissions (where 1990 = 1.000). The total carbon index shows a value of 1.055 which means that total carbon is up by 5.5 percent over 1990 levels. Since the CCAP target is 1,379 MMT rather than the 1,338 MMT actually emitted, a CCAP index can be created by adjusting the carbon index to 97 percent of actual emissions. This implies that in 1994, carbon emissions were about 2.4 percent above the CCAP target.

By multiplying the 1994 values associated with each of the five critical variables by the anticipated (current scenario) growth rates over the six-year period to the year 2000, we note that total carbon emissions will exceed the CCAP target about 5.4 percent in that year, or

$$1.042*1.009^6 * 1.041*1.0106^6 * 0.978*(1-0.012)^6 * 0.994*(1-0.0025)^6 * 0.970 = 1.054.$$

Using a similar calculation for the year 2030, carbon emissions will be up 22.2 percent over CCAP target. From this point, we can then apply alternative energy and carbon intensity growth rates to see how carbon emissions might be affected.

The Alternative Scenario in Table 10 differs from current trends in that we have applied the annual rates of change for energy and carbon intensities from the market case of *America's Energy Choices*. These are -2.1 percent and -0.7 percent, respectively.[66]

With the reduced energy intensity in 2030, energy consumption would be about the same as the 1990 level — despite a higher population and a larger economy:

$$1.439 * 1.522 * 0.455 = 0.997.$$

With the carbon intensity index down to 0.772 in 2030 (largely the result of increased energy production from renewable energy resources), total carbon emissions would be nearly three-fourths of the actual 1990 levels:

$$0.997 * 0.772 = 0.769.$$

Additional analysis can be performed using different assumption about population and economic growth. But the critical insight from this analysis is that current trends strongly indicate a large increase in carbon emissions through the year 2030. By showing the different influences on the growth in these emissions, the public will better understand the need for increased efficiency and higher levels of renewable energy production than currently anticipated.

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66. Calculated from the table found on page 44 of *America's Energy Choices*, op. cit.

F. Quality of Life

To build a better understanding of how well people actually live as a result of energy consumption patterns, we can contrast a particular standard of living with energy usage. One measure of the standard of living is the Overseas Development Council's Physical Quality of Life Index (PQLI).

The PQLI is constructed from World Bank cross-sectional data of 110 countries using three individual reference points. These are: (1) a nation's literacy rate, (2) infant mortality rate, and (3) longevity.[67] As applied in this analysis, a simple quality of life (QoL) Index is first constructed using each of the three criteria. They are given equal weights with the combined scores for each country indexed to a scale of 100. The resulting QoL index is then compared to per capita energy consumption appropriate to that country.

Using a simple weighting and normalizing procedure, Table 11 summarizes the data for three different regional aggregates including the United States, Developed Countries and Undeveloped Countries. Also shown is a per capita estimate of energy consumption measured in kilograms of oil equivalent.

TABLE 11. QUALITY OF LIFE COMPARED WITH ENERGY USE

Region	Per Capita Energy (Kg Oil Per Capita)	Quality of Life (QoL) Index	Energy/QoL Ratio
United States	7,681	96.7	79
Developed Countries	4,713	92.2	51
Undeveloped Countries	445	57.0	8

For both the United States and the developed countries it appears that each point in the QoL index is supported by an equivalent of 79 and 51 kilograms of oil per capita, respectively. Not surprisingly, the energy requirement falls to as little as 8 kilograms of oil per capita for undeveloped countries.

67. See, *The World Bank Atlas 1994* (Washington, DC: The World Bank, 1993)

The QoL index for the United States is only five percent larger than for developed countries on average. Yet the 79 kilograms of energy consumption for each point in the index is 55 percent higher than for the average of all developed countries. In other words, when measured in terms of the quality of life, energy resources provide only marginal value for the economy compared to the average of developed countries.

The importance of energy to the development of a country's quality of life can be evaluated by using regression analysis to "explain" how much energy appears to influence the QoL index. For developed countries, it turns out that energy consumption accounts for only 14 percent of their QoL index as measured by the three indicators. For developing nations, on the other hand, energy consumption "explains" 58 percent of their quality of life.

This large difference in how energy contributes to the quality of life may be an indication that the United States, for example, could continue to maintain a high quality of life while reducing the nation's overall energy intensity.[68] If the reduction in energy intensity is pursued through gains in energy efficiency, this would, in effect, free up resources to help develop other nations.[69]

G. Economic and Environmental Well-Being

Much like the index of leading economic indicators, policy makers might better understand the opportunity for energy efficiency improvements if the appropriate energy-related trends affecting the nation's economic and environmental well-being were tracked on at least an annual basis. The measure proposed here is referred to as the National Energy, Economic and Environmental (N3E) Index which, in turn, is a composite of three separate indicators: Energy/GDP, Jobs/Energy, Carbon Emissions/GDP.

68. This point has been raised using a different methodology, noting that the "wealthiest countries exhibit a sharply diminishing real income response with respect to higher energy use." See, John R. Moroney, "Output and Energy: An International Analysis," *The Energy Journal*, Volume 10, Number 3, 1989, page 3.

69. This comparison might be strengthened by adding some form of purchasing power to the set of existing indicators. The conclusion is unlikely to change dramatically, however.

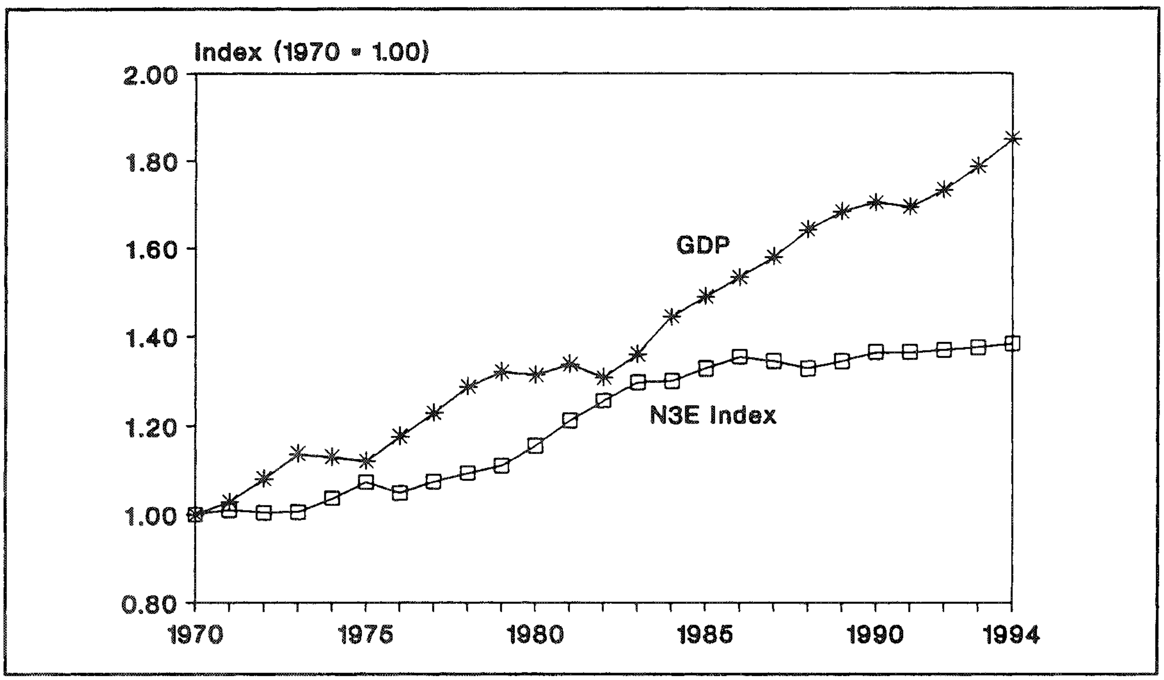
Table 12. Data Supporting the N3E Index				
Data Category	**1970**	**1980**	**1994**	**1994 Benchmark**
Primary Data				
Population (1000s)	203,799	227,255	260,500	260,500
Energy (Quads)	66.4	76.0	86.1	74.8
Jobs (1000s)	78,678	99,303	123,270	125,000
GDP (Bln 1987$)	$2,874	$3,776	$5,314	$5,367
Carbon (MMT)	1,156	1,252	1,412	1,227
Initial Ratios				
Jobs/Energy	43.26	47.75	52.30	61.02
GDP/Energy	43.26	49.71	61.72	71.73
GDP/CO2	43.60	52.92	66.02	76.73
Index Ratios				
Raw N3E Index	130.12	150.39	180.04	209.48
N3E 1970 = 100	1.00	1.16	1.38	1.61
GDP 1970 = 100	1.00	1.31	1.85	1.87

Only five discrete sources of time series data are needed for the N3E index as shown in Table 12. The population, employment and GDP estimates (measured in constant 1987 dollars) can be obtained from the U.S. Department of Commerce. Energy consumption and carbon estimates can be obtained from the Energy Information Administration. The data for selected years are shown in Table 12, together with the separate indicators which comprise the full composite index.

Once the database is established three initial ratios are calculated as shown in the table above: (1) Jobs to Energy, (2) GDP to Energy, and (3) GDP to Carbon Emissions. The raw N3E index assigns each ratio an equal weight based upon the base year results and then sums the total for a given year. The resulting values are then indexed so that 1970 = 1.00.

Both GDP and the N3E Index are compared in Figure 16 for the year 1970 through 1994.[70] The relationship between GDP and N3E remained reasonably close through 1982. Shortly after that time, however, GDP began to rise at a much faster clip the N3E index. By 1994 the N3E index had risen to only 1.38 while GDP climbed to 1.85.

FIGURE 16. COMPARING THE N3E INDEX TO GDP



70. The 1994 values reflect preliminary estimates generated by the author for this data series.

One possible insight from the above chart is that the system of human, capital, and natural resources have not been used as efficiently in recent years as in the past; or alternatively, that constraints on the use of all resources are beginning limit overall economic activity.

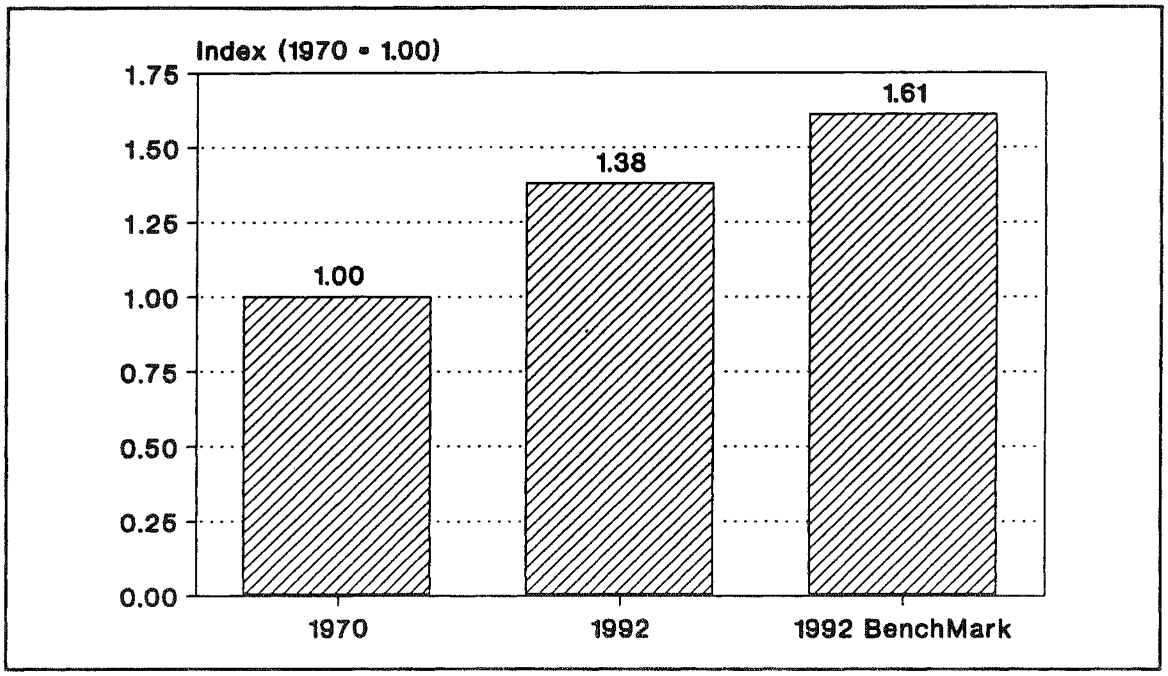
Although the issue needs to be examined more closely, an explanation may be that the larger the gap between GDP and the N3E index, the less sustainable the economic activity. This point seems to be reinforced in Figure 17, below, as well as the results shown in the data table that accompanies this section.

In Figure 17 the chart compares what might be termed a "benchmark" index for 1994 to the actual values for 1970 and 1994. The benchmark index of 1.61 is, in fact, an adjusted 1994 value based upon the energy efficiency trends experienced in the period 1973 through 1986.[71]

Further adjustments were made to account for the potential gains in GDP and jobs, as well as a reduction on overall carbon emission. In other words, by emphasizing a more energy-efficient economy, it is likely that the indicators which comprise the N3E index would have risen more rapidly compared to the historical trends. As a result, the N3E index would more closely track GDP. Presumably, the economy would therefore be on a more sustainable course.

71. As explained elsewhere in the report, the E/GDP ratio declined by 2.3 percent annually throughout this 13-year period. For purposes of establishing the 1994 benchmark index, it was assumed that the trend would continue through 1994. Other adjustments were made by the author to account for changes in employment, GDP, and carbon emissions. Much of the analytical support for these latter adjustments were taken from *Energy Efficiency and Job Creation*, op. cit.

Figure 17. A Benchmark N3E Index



The index might provide more insight by placing the various indicators on a per capita basis. And by definition, a different weighting scheme would yield a different set of results. One possible approach would be to using a chaining technique to weight the separate ratios as an average of the current year with the preceding year.

VI. RECOMMENDATIONS

The production and consumption of energy has a number of economic, social and environmental impacts that cannot be measured by E/GDP ratios alone. To build a better understanding of the many dimensions of energy consumption, a more diverse set of indicators should be regularly published.

The collection of indicators reviewed here is clearly a work in progress. Better data needs to be collected and reviewed. There needs to be a more rigorous examination of how that data should be formatted to establish meaningful links between energy consumption and the nation's economic and environmental well-being.

There are many other possible indicators which might be included in future reports but which time did not allow us to evaluate in any meaningful detail. For example, Cutler Cleveland and Robert Kaufmann have done some useful analysis on the energy return on (energy) investment (EROI). Their analysis suggests that it takes more energy to produce energy. This would be an extremely useful indicator to include in future public policy discussions.[72]

With these perspectives in mind, and building on the insights gleaned from the 14 indicators presented in this document, we make the following recommendations:

(1) The Department of Energy and the Energy Information Administration should regularly publish a mix of energy intensity trend data as well as broader economic, social and environmental indicators that relate to the production and consumption of energy in the United States. EIA is now preparing to issue a methodology for a broad range of efficiency indicators. This appears to be a complement and update of the previously published *Energy Conservation Indicators*.

Although this activity is of considerable value, it remains largely a review of energy intensity trends on a sector-by-sector basis. To inform policy makers and the public of the broader economic and environmental impacts associated with energy use, the new EIA report should be expanded to include additional benchmarks such as those found in sections IV and V of this study. At a

72. Much of this important work can be summarized in the following three articles: R.K. Kaufmann, "A biophysical analysis of the energy/real GDP ratio: implications for substitution and technical change," *Ecological Economics*, Volume 6, No. 1, July 1992, page 35; C.J. Cleveland, "An exploration of alternative measures of natural resource scarcity: the case of petroleum in the U.S.," *Ecological Economics* Volume 7, No. 2, April 1993, page 123; and finally, C.J. Cleveland, "Energy Quality and Energy Surplus in the Extraction of Fossil Fuels in the U.S.," *Ecological Economics*, Volume 6, No. 2, October 1992.

minimum, the set of indicators should be published annually in a chartbook format as is frequently done by the Bureau of Labor Statistics.[73]

(2) States and other federal agencies should be assisted in the development of their own indicators to allow their own policies and activities to be guided by the insights from these or similar benchmarks.

(3) The Department of Energy and the Energy Information Administration should convene an "expert review panel" to periodically assess and provide recommendations on how to improve such indicators. For example, the Department of Commerce is now in the process of refining and adding to the recently released Integrated Economic and Environmental Satellite Accounts.[74] The new accounts will contain useful data that should be helpful to EIA in the generation of these new benchmarks. In addition industry and energy efficiency research organizations have analytical skills that can contribute to a joint effort.

With these recommendations as starting points, American Council for an Energy-Efficient Economy believes the nation's energy policy's will be better guided and supported as policy makers and the public alike develop a better understanding about the economic and environmental outcomes associated with energy production and consumption.

73. See, for example, *Productivity and the Economy: A Chartbook*, op. cit.

74. See, "Integrated Economic and Environmental Satellite Accounts," *Survey of Current Business* (Washington, DC: Bureau of Economic Analysis, U.S. Department of Commerce, April 1994), page 33.