Trends in Building-Related Energy and Carbon Emissions: Actual and Alternate Scenarios

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ABSTRACT

Eighty-two percent of all greenhouse gas emitted by human activity is energy-related carbon dioxide. Since 1990, 48 percent of the increase in U.S. carbon emissions can be attributed to increasing emissions from the building sector.

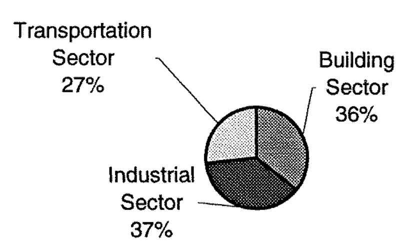
In this paper, trends in energy use and energy prices for the building sector are followed by explanations of some of the factors underlying these trends such as: (1) energy-efficiency changes, (2) change in the fuel mix, (3) income and wealth, and (4) demographics. Next is a discussion on carbon trends as related to the use of energy in the building sector.

Finally, two types of scenarios are presented. The first scenarios show the trends if energy and carbon intensities, fuel mix, and electricity energy and carbon intensities are held constant (1980). The second set of scenarios deal with the "what ifs"—such as how energy use and the related carbon emissions would change if we replaced all the 1997 refrigerator stock with 1997 new refrigerators.

Introduction

In the United States, the building sector (residential and commercial) uses more energy than the transportation sector, and almost as much as the industrial sector (Figure 1). Moreover, the building sector emits more carbon than either the industrial or the transportation sectors. In 1998, the building sector used 36 percent (33.7 quadrillion Btu) of the primary energy and emitted 35 percent (523 million metric tons) of the carbon.

Figure 1. Total Primary Energy In the U.S., by Energy Source,1998



Source: Energy Information Administration, *Annual Energy Review 1998,* Table 2.1.

This paper begins by looking at the trends in energy use and prices in the building sector. Following is a section on contributing factors underlying these trends such as: efficiency changes, fuel and building mix, income and wealth effects, and demographics. Since the main drivers of energy use are also the main drivers of carbon emissions, our next discussion shows how building energy use trends are related to changes in carbon emissions.

[1] The opinions and conclusions expressed herein are solely that of the authors and should not be construed as representing the opinions or policy of any agency of the United States Government.

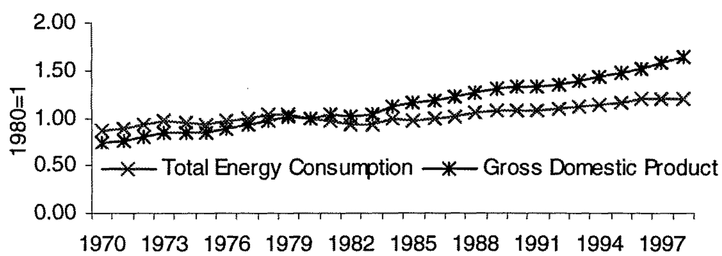
Finally, two types of scenarios are presented. The first scenarios show the trends in energy and carbon emissions holding the fuel mix constant. The second set of scenarios deal with the energy and carbon savings that could be realized if existing household appliances were replaced by new energy-efficient appliances, or if older commercial buildings had the energy intensities of the newer commercial building stock.

Data Used

Initially, overall energy and carbon trends in the building sector are presented using data from Energy Information Administration's (EIA) *Annual Energy Review 1998* and the *State Energy Data Report 1997.* More in-depth analysis of the contributing factors underlying these trends relies on data obtained from the actual users of energy. The detailed energy-use statistics used in this analysis are from two of EIA's energy-use surveys, the Residential Energy Consumption Survey (RECS) and the Commercial Building Energy Survey (CBECS).

Trends in Building Energy Use and Carbon Emissions in the United States

Figure 2. Primary Energy and Gross Domestic Product, 1970-1998



Source: Energy Information Administration, Annual Energy Review 1998, Table 1.5.

Until 1980, the growth of primary energy[2] use outpaced the growth of economic activity as measured by Gross Domestic Product (GDP) (EIA 1999a). The pattern changed after 1980, as GDP growth quickly outpaced growth in primary energy (Figure 2). For the most part, the main factor responsible for this turnaround was the oil shock of 1973, the Arab OPEC embargo. Petroleum prices shot up by 400 percent. However, when petroleum prices collapsed in 1986, long-term changes prevented a return to the energy-GDP relationship that had been present before the price spikes.

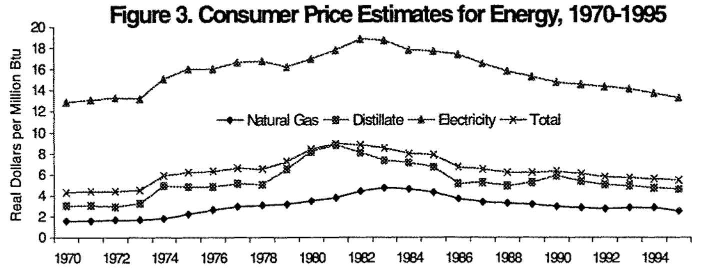
The building sector experienced long-term changes, such as the installation of energy-efficient appliances, lighting, and HVAC systems, that prevented a return to the previous energy/GDP relationship. During the 1980's, energy intensities (Btu per sq. ft.) were falling while total primary energy increased (EIA 1995).

In the building sector, primary energy use was 34 percent higher in 1998 than in 1980—26.5 quadrillion Btu in 1980 versus 33.7 quadrillion Btu in 1998. Change in energy use reflected only partially the law of supply and demand. From 1973 into the early 1980's, energy prices did climb—especially for those fuels that were petroleum based—leading to many short-term adjustments in primary energy use (Figure 3). The use of petroleum in buildings declined and continued to decline. Although real prices for distillate fuel oil fell 31

[2] Primary energy is the amount of site or delivered energy plus losses that occur in the generation, transmission, and distribution of the energy.

percent between 1984 and 1988, the rapid decline in price did little to reverse the decline of use. With the exception of a rise in petroleum prices in 1990, petroleum prices continued ~~to~~ decline while petroleum use in the building sector continued to fall and then level off (Figure 4). Switching to natural gas may explain some of this behavior. Natural gas is a cleaner energy source, less subject to supply uncertainty than petroleum.

Figure 3. Consumer Price Estimates for Energy, 1970-1995



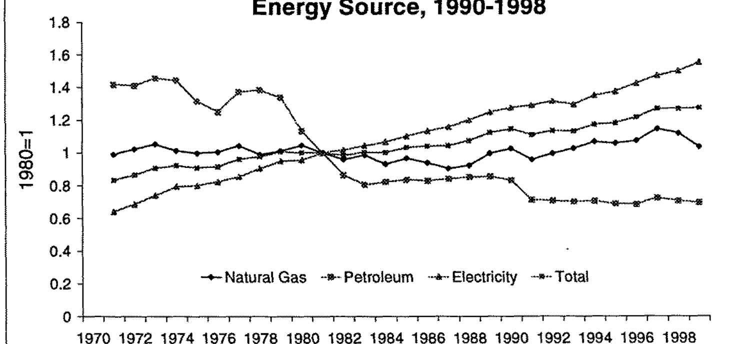
Notes: Real price estimates were obtained using the Consumer Price Index.
Source: Energy Information Administration, Annual Energy Review 1998, Table 3.3

From 1973 to 1986, the building sector experienced only an 11 percent decline in natural gas use while real prices more than doubled—from $1.64 per million Btu in 1973 to $3.71 per million Btu in 1986. However, the peak in natural gas prices occurred in 1984, at $4.57 per million Btu, after which prices fell to $2.77 per million Btu in 1992. Although prices were falling during this period, natural gas use in the building sector was also declining. When prices started to rise slowly, natural gas use in the building sector showed small increases.

With little exception, primary electricity use has historically shown a continuous growth in the building sector, growing by 79 percent from 11.88 quadrillion Btu in 1973 to 21.24 in 1995. During this period, end-use prices for electricity remained relatively flat—$13.20 per million Btu in 1973 to $13.32 in 1995.

Clearly, factors other than trends in prices are contributing to the trends in energy use.

Figure 4. Energy Consumption in the Buildings Sector by Energy Source, 1990-1998



Source: Energy Information Administration, Annual Energy Review 1998, Table 2.1.

Factors Behind the Growth of Energy Use in the Building Sector

Energy use in the building sector are affected by a multitude of factors, such as location, physical characteristics, age, efficiency of the equipment, occupants' energy-related behavior, income, and fuel mix, to name just a few. Since 1980, two main trends have been apparent in building energy use. The first is an increasing energy efficiency of building and equipment for traditional end uses such as HVAC, water heating, refrigeration, and lighting. Secondly, there has been a fuel-mix shift, especially in the electrification of energy use.

This section discusses the contributing factors underlying these two main trends along with discussions of two other major contributing factors—an income and wealth effect, and demographic effects. Much of the discussion focuses on the household sector. The structure and behavior of the household sector drive demand for goods and services.

Energy efficiency. Several factors contributed to reductions in the use of energy. One main factor was the passage of state and federal legislation that led to appliance and building efficiency standards (EIA 1995). The National Appliance Energy Conservation Act of 1987 mandated minimum energy efficiency standards for several types of household appliances and equipment such as refrigerators, freezers, room air conditioners, television sets, furnaces, water heaters, and heat pumps. This followed the earlier voluntary appliance efficiency targets of the Energy Policy and Conservation Act of 1975 and various State appliance-efficiency standards. Manufacturers responded by improving the energy efficiency of household appliances and equipment over the past 20 years. Estimates from the Department of Energy's Office of Codes and Standards indicate that "current appliance standards have already saved consumers $1.9 billion".

The Energy Policy Act of 1992 expanded coverage to include commercial building heating and air conditioning equipment, certain incandescent and fluorescent lamps, distribution transformers, and electric motors. In 1993, the RECS survey asked about a number of purchase considerations such as price, availability, and energy efficiency. Most households did consider energy efficiency an important consideration in making their selection. However, not all households did, especially for refrigerators—a large user of electricity.[3] Households thought that price and size were more important than energy efficiency (EIA 1999c).

Another factor was the rise in demand-side-management programs. From the early 1990's until recently, electric utilities have been offering demand-side management (DSM) programs. From 1989 through 1993, utility DSM programs exhibited steady or accelerating growth in energy savings and utility expenditures. The largest share of utility expenditures and energy savings was associated with energy-efficiency programs (EIA 1997).

Fuel and building mix. Over the last 30 or more years, electricity use in both the commercial building and household sector has grown continuously. In the mid-1980's, site electricity overtook natural gas to become the largest source of site energy in commercial buildings. The share of site electricity in the commercial building sector rose from 38 percent in 1979 to 49 percent in 1995.

Site electricity also increased its share of household energy, from about a quarter in 1980 to over a third in 1997. Two major structural changes have fostered the growing electrification in the United States—the rise of the service sector and population shifts from the Northeast and Midwest to the South and West increasing the use of air conditioning.

In 1997, the service sector, as a percent of real GDP[4], was 47 percent higher than in 1984 (USDOC 2000). With the growth of the service sector, the commercial building stock increased. The number of commercial buildings increased by around 25 percent between 1979 and 1995, with the number of office and mercantile and service buildings increasing by almost 72 percent. Office and mercantile and service buildings used 45 percent of all the electricity used in the commercial building sector in 1995.

As the commercial building sector was adding more offices and mercantile and service buildings, the housing stock was also undergoing changes. In 1997, there were almost 25 million more homes than in 1978—a 33 percent increase in the stock from 20 years earlier.[5] Although some of the housing growth was in townhouses and large apartment

[3] In 1994, average electricity use for refrigerators was 1,323 kWh--13 percent of household electricity.

[4] Real GDP was calculated in 1992 dollars.

[5] During this period, new homes were added while old homes were being demolished. Vacant and seasonal homes were not included.

houses, which use relatively less energy per household, the overall use of electricity was climbing. Residential sector total energy use fell by 3 percent between 1978 and 1997 and so did energy use per housing unit (138 million Btu per housing unit in 1978 to 101 million Btu in 1997). However, electricity use demonstrated a 43 percent increase during this period. The average size of homes increased and the number of homes increased as household size decreased—fueling demand for electrical appliances. The appliance and lighting share increased from 17 percent of total energy in 1978 to 27 percent in 1997.

Income and wealth effects. Since 1980, for the most part, the United States has experienced economic growth. During that time, only three official recessions took place: (1) January 1980 to July 1980, (2) July 1981 to November 1982, and (3) July 1990 to March 1991. Real GDP was 75 percent higher in 1998 than it was in 1980—4.6 trillion real dollars in 1980 versus 8.1 trillion real dollars in 1997 (USDOC 2000, 459). Personal consumption expenditures, a component of GDP, was growing by 82 percent, from 3.0 trillion real dollars in 1980 compared to 5.5 trillion real dollars in 1997. Two economic factors fueled this growth in expenditures: (1) the increase in disposable personal income (DPI) and (2) the decline in the annual savings rate as a percentage of DPI—from 10.2 percent in 1980 to 3.7 percent in 1998.

Additionally, since 1970, the generation of new wealth has increased—more than $700 billion per year on average.[6] As this wealth was being created, more of the middle class was becoming involved. Business writer Nocera describes, in his book, *A Piece of the Action: How the Middle Class Joined the Money Class,* the shift from savers to investors (U.S. News). Together with additional factors, such as the increase in two-wage earning households and the time constraints on these households, income and wealth effects have been strong generators of demand for durable and nondurable goods and services. In turn, the demand for inputs, including energy, to produce these goods and services has also risen strongly.

Demographics. Demographics have been used to identify movements in consumer markets. The energy market is no exception. Changes in the population size, the number of housing units, the size of households, labor-force participation rates, and the age structure of the population are just a few of the important demographics. These demographics affect the amount and type of energy that is used, not only in the home, but also by the providers of services and goods for the households.

Historically, household formation has grown faster than population growth. This trend continues today. A smaller household uses less energy per household but more energy on a per capita basis, because each small household uses many of the same appliances (refrigerator, stove, television, etc.) that a large household would use. Therefore, as population growth continues, the number of smaller households demanding more goods and services also increases.

From 1980 to present, more married women entered the labor force, thereby raising household income. Increased household income is a contributing factor leading to increases in energy use (and decreases in energy use when not at home). The labor force participation rate for married women rose from 49.9 percent in 1980 to 61.2 percent in 1996 (USDOC 2000, 416). The accompanying time constraints now placed on the household increased the

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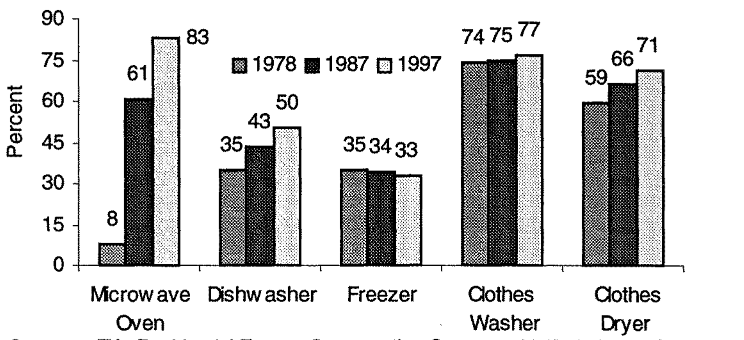
[6] The Dow Jones Industrial Average stood at 832.92 in 1970—rising to 9181.42 in 1998 (USDOC 2000, 883).

demand for more energy-using, but timesaving, appliances such as dishwashers and clothes dryers (Figure 5). The time constraints also increased the demand for food prepared outside of the home. In food-service buildings, between 1986 and 1995, energy use climbed by 28 percent. Inside the home, microwave ovens penetrated quickly—reducing the use of conventional methods. Almost 25 percent of food cooked inside the home is prepared in microwaves (EIA 1999c). Much of the energy that was previously used within the household for specific purposes is now displaced into the other sectors, in restaurants, prepared food providers, and beauty shops, to name just a few, increasing their energy use.

Figure 5. Appliances Used in Housing Units, 1978, 1987, 1997



Sources: EIA, Residential Energy Consumption Surveys, 1978, 1987, and 1997.

Between 1980 and 1996, the U.S. experienced a 23 percent growth in the number of senior citizens[7]—most still living in the household. Although there does not seem to be an appreciable difference in the amount of energy senior citizens use, there are differences in the way they use energy. In 1997, senior citizens used 99 million Btu per household compared to 101 million Btu per household for the U.S—a very small difference. However, per household, senior citizens used less energy for air conditioning, water heating, and appliances, but more energy for space heat, than the U.S. average. In 1997, this group accounted for 28 percent of all households and used 28 percent of the total energy while using 32 percent of space heating energy. Additionally, many senior citizens tend to live in older, less insulated homes—increasing energy use (EIA 1999c).

Also, during these years, construction of medical facilities more than doubled. Some of this demand was driven by an increasing number of our older population (USDOC 2000, 15). Although energy use in commercial buildings was flat when comparing 1983 to 1995, energy use in health care buildings grew by 21 percent. The number of health care buildings grew by 72 percent, while floorspace grew by only 2 percent, indicating an increase in the number of smaller outpatient health-care buildings.

Trends in Carbon Emissions: The Buildings Sector

By 1998, the residential and commercial sectors accounted for 35 percent of all U.S. energy-related carbon emissions, more than either the industrial or the transportation sectors. Most of these carbon emissions were due to energy use in buildings.

From 1979 to the late 1990's, a similar pattern held for both residential and commercial buildings. Demand for energy services, as measured in terms of the number of households or the amount of commercial floorspace, increased at a faster pace than either energy consumption or energy-related carbon emissions (Table 1).

Carbon emissions closely tracked energy consumption in both residential and commercial buildings. Carbon emissions are a product of service demand, energy intensity,

[7] Senior citizen, as used in this paper, includes those 60 years or older.

and carbon intensity.[8] In the 1980's and 1990's, service demand increased while energy intensity declined, although not enough to offset the increasing demand. Carbon intensity

Table 1. Number, Energy Consumption, and Energy-Related Carbon Emissions of Households, 1980-1997

	1980	1997	Percent Change
Number of Households (million)	81.6	101.5	24.4
Energy Consumption (trillion Btu)	9,320	10,250	10.0
Energy-Related Emissions (million metric tons of carbon)	251.9	279.3	10.9
Electricity Consumption (trillion Btu -- site energy)	2,460	3,540	43.9
Electricity-Related Emissions (million metric tons of carbon)	144.0	175.9	22.2

Sources: Energy Information Administration, 1980 and 1997 Residential Energy Consumption Surveys.

remained relatively flat, up 5 percent for household energy use and 2 percent for commercial buildings' energy use.

The 1980's and 1990's have seen an increasing fuel share for electricity, a relatively carbon-intensive energy source when off-site emissions from generation are considered. The increasing electricity share might have been expected to increase energy-related carbon emissions at a rate exceeding that of energy consumption. Instead, electricity's share of household carbon emissions only increased from 57 percent in 1980 to 63 percent in 1997. Electricity's share of commercial carbon emissions barely budged, from 68 percent in 1979 to 70 percent in 1995.

To understand how electricity's fuel share could increase without a larger increase in carbon emissions, we need to examine more closely electricity consumption in buildings and the associated electricity-related carbon emissions that occur at the point of electricity generation. Both households and commercial buildings showed an increasing gap between electricity consumption and the associated carbon emissions (Table 2).

Table 2. Floorspace, Energy Consumption, and Energy-Related Carbon Emissions of Commercial Buildings, 1979-1995

	1979	1995	Percent Change
Floorspace (million square feet)	43.546	58,772	35.0
Energy Consumption (trillion Btu)	4,965	5,321	7.2
Energy-Related Emissions (million metric tons of carbon)	164.2	178.7	8.8
Electricity Consumption (trillion Btu -- site energy)	1,908	2,608	36.6
Electricity-Related Emissions (million metric tons of carbon)	111.7	125.6	12.4

Sources: Energy Information Administration, 1979 and 1995 Commercial Buildings Energy Consumption Surveys.

[8] EIA (1999b) defines carbon intensity as carbon emissions per unit of energy use. This definition corresponds to the Schipper et al. (1997) carbon emissions coefficient.

From 1980 to 1997, residential and commercial electricity consumption increased by over 60 percent, increasing electricity's share of site energy use to 35 percent in households and 49 percent in commercial buildings. At the same time, the carbon intensity of electricity decreased by 15 percent. The decrease in the carbon intensity of the fuel mix used in electricity generation was almost enough to counteract the shift towards a greater fuel share for electricity within buildings. The decline in the carbon intensity of electricity was due in large part to nuclear plants coming into service during the 1980's. As older nuclear plants are starting to be decommissioned, there has been a slight rise in the carbon intensity of electricity since 1995.

In the future, service demand is likely to continue to increase in residential and commercial buildings, and electricity seems likely to maintain or increase its fuel share. Energy-related carbon emissions will also increase, unless either the energy intensity in buildings declines more rapidly, or a less carbon-intensive fuel mix is used in electricity generation.

Scenarios: Constant and Change

Change in energy use and carbon emissions over time is driven by a combination of effects, and may differ among energy services. Deciding which effects, such as weather, behavioral, and structural changes, should be considered as inherent in any energy efficiency (or carbon emissions) measurements is a daunting task. However, even if it is difficult to remove these effects, it is important to recognize that they exist. This section of the paper uses two scenarios to investigate the components of change in energy use and carbon emissions. In these scenarios, the use of an energy source, *f*, at time, *t*, is treated as

energy use(*f*, *t*) = service demand(*t*) * fuel share(*f*, *t*) * energy intensity(*f*, *t*), and
carbon emissions(*f*, *t*) = energy use(*f*, *t*) * carbon intensity(*f*, *t*).

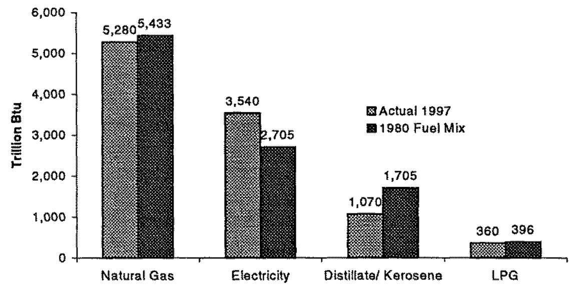
The first set of scenarios investigate the fuel share component of energy use and carbon emissions by applying their 1979 (commercial) or 1980 (residential) values to the most recent survey year, as if the changes had not happened. The second set of scenarios attempts to investigate the energy intensity component. For households, the actual 1997 appliance intensities are replaced with those of the most efficient appliances on the market. For commercial buildings, the intensities of buildings constructed during the 1990's—representing current (not necessarily best) practice—are applied to the entire building stock.

Structural Effects—As If Change Did Not Happen

Fuel mix. During the 1980's and 1990's electricity use in the building sector experienced a rapid growth. However, the related carbon emissions experienced a decline, due in large part to nuclear plants coming into service during the 1980's. Holding the fuel mix to an earlier year demonstrates what would happen if there had not been an electrification, but more importantly, if there had not been a change in the energy used to generate the electricity. For both the household and commercial building sector, the share of natural gas would have been higher. Also, the share of petroleum-based energy would have been higher while electricity's share fell (Figures 6 and 7).

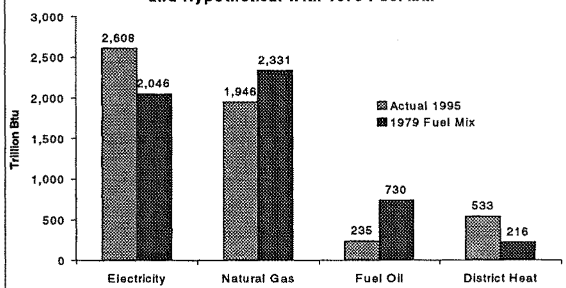
What is interesting in both the household and the commercial building sector is that the lower percent of the electricity used—holding the fuel mix constant—does not relate ~~to~~ the same percentage fall in carbon emissions (Figures 8 and 9). In the residential sector,

Figure 6. Actual 1997 Residential Energy Consumption and Consumption With 1980 Fuel Mix



Sources: Energy Information Administration, Residential Energy Consumption Surveys, 1980 and 1997.

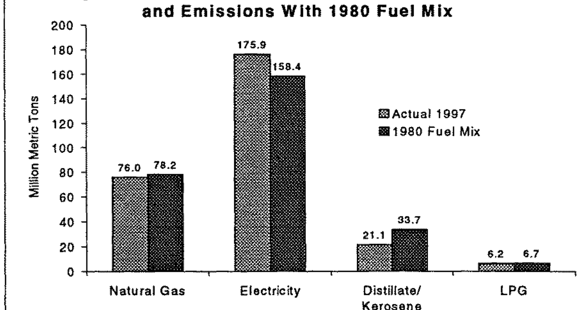
Figure 7. Actual 1995 Commercial Energy Consumption and Hypothetical With 1979 Fuel Mix



Sources: EIA, Commercial Buildings Energy Consumption Surveys, 1979 and 1995.

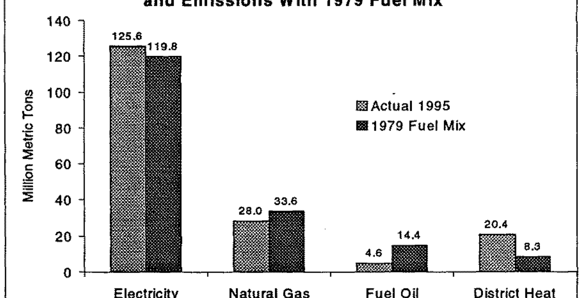
holding the 1997 fuel mix to 1980 levels lowers electricity use by 24 percent. However, it only lowers carbon emissions by 10 percent, reflecting the higher carbon content of the energy used to generate the electricity in 1980. In commercial buildings, holding the 1995 fuel mix to 1979 levels lowers electricity use by 22 percent, but the carbon emissions only 5 percent, again reflecting the higher carbon content of the energy used to generate the electricity in 1979.

Figure 8. Actual 1997 Residential Carbon Emissions and Emissions With 1980 Fuel Mix



Sources: EIA, Residential Energy Consumption Surveys, 1980 and 1997.

Figure 9. Actual 1995 Commercial Building Carbon Emissions and Emissions With 1979 Fuel Mix



Sources: EIA, Commercial Building Energy Consumption Surveys, 1979 and 1995.

Residential Efficiency Improvements—As If Change Happened

Appliances. Although the energy efficiency of new appliances has improved since the enactment of various state and federal appliance efficiency standards, it is not readily apparent in the data since the stock includes a large number of older appliances. In this paper, two hypothetical possibilities are considered: (1) replacing all the 1997 stock with new appliances—the upper limit, and (2) more realistically, replacing only the appliances that were 10 years or older. [9]

If the entire 1997 residential appliance stock were replaced by new appliances listed in Table 3, 923 trillion Btu per year would be saved, along with 23 MMTC in carbon emissions. Refrigerators and freezers demonstrated the highest efficiency gains and along with natural gas space-heating systems, showed the most gain in energy savings.

[9] The methodology (EIA 1993) assumes that that age characteristics were the same, average size of appliance did not change, older appliances work as well as the new appliance, and all replaced units were not used again. Estimates were not used where the householders did not know the age of the appliances.

If all of the 96.3 million most-used refrigerators were replaced by the most efficient, the energy savings is 159 trillion Btu—116 trillion Btu if only the 31 million older refrigerators are replaced. The energy savings from replacing older refrigerators is only 27 percent less than the savings from replacing all—showing the effects of energy standards on newer refrigerators.

The 1997 freezer stock (33 million) was 14 percent more efficient than a freezer purchased in 1992. However, if all the freezers were replaced in 1997 with new freezers, the stock then would be 76 percent more efficient than in 1992—an energy savings of 68 trillion Btu. If only the 19 million older freezers were replaced with new freezers, than the 1997 stock efficiency would be 67 percent more efficient than 1992—an energy savings of 58 trillion Btu. The more plausible scenario—replacing the older freezers—is only 15 percent less in energy savings than if all freezers were replaced in 1997, again showing the effects of energy standards on appliance energy use.

Table 3. Potential Efficiency Gains, and Energy and Carbon Emission Savings, of Replacing Existing 1997

	Refriger-ator	Freezer	Room AC	Central AC	Natural Gas Space Heat	Natural Gas Water Heat
1997 Stock Efficiencies (1992 = 100)	1.32	1.14	1.16	1.11	1.04	1.09
1997 Consumption (Tbtu)	437	125	68	320	3347	1061
1997 Carbon Emissions (MMTC)	21.7	6.2	3.4	15.9	48.2	15.3
1997 Stock Replaced All						
Efficiency (1992 = 100)	1.8	1.76	1.27	1.29	1.22	1.15
Efficiency Gain	36%	54%	9%	16%	17%	6%
Energy Savings (TBtu)	159	68	6	52	579	58
Carbon Savings (MMTC)	7.9	3.4	0.3	2.6	8.3	0.8
1997 Stock Replaced 10 Yrs.+						
Efficiency (1992 = 100)	1.67	1.67	1.26	1.25	1.18	1.14
Efficiency Gain	27%	46%	9%	13%	13%	5%
Energy Savings (TBtu)	116	58	6	40	451	49
Carbon Savings (MMTC)	5.8	2.9	0.3	2.0	6.5	0.7
Potential Savings from These Appliances						
1997 Stock Replaced All			**1997 Stock Replaced 10 Yrs.+**			
Energy Savings (TBtu)	923		Energy Savings (TBtu)			720
Carbon Savings (MMTC)	23.4		Carbon Savings (MMTC)			18.1

Sources: Energy Information Administration, 1997 Residential Energy Consumption Survey; Jim McMahon, Lawrence Berkeley National Laboratory, unpublished data.

The 1997 stock of natural gas space-heating systems (50 million systems), although experiencing lower efficiency gains, realized the most energy savings, just by the sheer number of units in the stock and total amount of energy used—35 percent of all the energy used in the residential sector in 1997. Natural gas space-heating systems demonstrated energy saving of 579 trillion Btu when the entire stock was replaced and 451 trillion Btu energy savings when 29 million older natural gas heating systems were replaced.

In terms of carbon emissions, replacing older appliances with new ones does produce carbon savings (Table 3). However, when the energy saved is natural gas, a higher amount of energy savings is needed to produce a MMTC of carbon savings, reflecting the carbon content of natural gas versus the carbon content of the energy sources used to produce electricity. As an example, it takes 70 trillion Btu of energy savings to produce a MMTC of carbon savings for natural gas space-heating systems, whereas it takes only 20 trillion Btu savings to produce a MMTC of carbon savings for refrigerators.

Commercial building energy intensity. Energy intensity is often used as a measurement indicator of energy efficiency; and in fact, the concepts of intensity and efficiency are sometimes used interchangeably. However, trends in energy intensity can be influenced by factors other than energy efficiency. Nevertheless, trends in energy-intensity indicators are

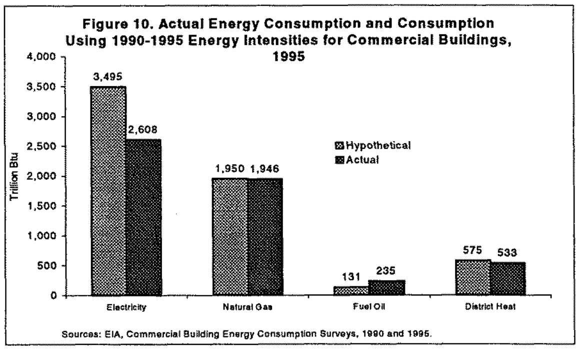


Figure 10. Actual Energy Consumption and Consumption Using 1990-1995 Energy Intensities for Commercial Buildings, 1995

Sources: EIA, Commercial Building Energy Consumption Surveys, 1990 and 1995.

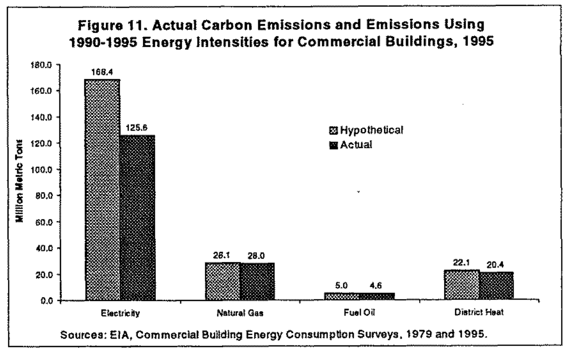


Figure 11. Actual Carbon Emissions and Emissions Using 1990-1995 Energy Intensities for Commercial Buildings, 1995

Sources: EIA, Commercial Building Energy Consumption Surveys, 1979 and 1995.

generally suggestive of trends in energy efficiency. In this section, energy consumption and the related carbon emissions are measured using new building (1990-1995) energy intensities for the major energy sources.

The main result is that if all buildings used energy like newer commercial buildings, electricity consumption and the related carbon emissions would have been 34 percent higher in 1995 (Figures 10 and 11). New building growth has primarily been in the South and these buildings use more electricity with a higher intensity—especially electricity for cooling. In 1995, new commercial buildings in the Northeast had an intensity of 16.6 kWh per sq. ft., versus 21.5 kWh per sq. ft. for the South and 20 kWh per sq. ft. for the West. If this building trend continues, the share of electricity in total consumption may rise leading to a rise in carbon emissions.

Summary

In the U.S., 82 percent of all greenhouse gas emissions due to human activity is energy-related carbon dioxide. The buildings sector (residential and commercial) emits 35 percent of energy-related carbon, more than either the industrial or the transportation sectors. Since an understanding of energy use is so crucial to an understanding of carbon emissions, this paper examines trends and underlying factors in building energy use and associated carbon emissions since 1980.

After the oil shocks of the 1970's, growth in economic activity (as measured by GDP) began to outpace growth in primary energy use. Even after the 1986 petroleum price collapse, economic growth continued to exceed growth in energy use. Efficiency standards, reinforced by demand-side management programs, continued the trend towards greater efficiency in building energy use. At the same time, important changes in building fuel mix were taking place, most notably a decline in the use of fuel oil, and an increase in electricity use. Despite the increasing electrification, especially in commercial buildings, the growth in carbon emissions was less than the growth in energy use. The gap between carbon emissions and energy use is due to changes in the mix of fuels used to generate electricity, outside the buildings sector. In particular, the 1980's saw an increase in the proportion of electricity generated from nuclear energy, and a decline in the carbon-emitting fossil fuel component of generation.

Several scenarios are explored in an attempt to further understand building energy consumption and carbon emissions. One scenario examined how consumption and emission in the late 1990's would have differed had fuel mixes, in buildings and generation, not changed since 1980. Another scenario shows what commercial energy consumption would be like if all buildings had the same consumption patterns as buildings constructed during the 1990's. A third scenario examines the energy and carbon savings which would be realized if more efficient appliances were used in households.

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