Chapter 2

Importance of City Buildings in National Energy Use: Will Energy Efficiency Make a Difference?

Contents

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Residential and commercial buildings together account for about one-third of U.S. energy consumption. The buildings that are the primary subject of this report—multifamily buildi rigs, office buildings, retail buildings, hotels, educational buildings, public buildings, and single-family homes inside central cities–together used about half of all U.S. building energy in 1980. Most of the rest of the building energy in the United States is used by single-family homes outside central cities. A previous OTA report, Residential Energy Conservation, described at length the prospects for improved efficiency of single-family homes. This report also discusses single-family houses but only in the context of those building and owner types characteristic of central cities. Table 7 shows what share of U.S. building energy use is used by different building types.

Table 7.—Primary Energy Consumption in Different Types of Buildings (1975)

Building type	Quads	Percent of building energy
Single-family residential	15.3	57.5%
Multifamily low density	0.7	2.6
Multifamily high density	1.6	6.0
Mobile homes	0.3	1.1
office	1.4	5.2
Retail/wholesale	2.2	8.3
Garage	0.1	0.3
Warehouse	0.3	1.1
Educational	1.7	8.4
Public	0.4	1.5
Hospital	0.7	2.6
Religious	0.3	1.1
Hotel/moral	0.5	1.6
Miscellaneous	1.1	4.1
Total	26.6	100

NOTE: Percentages may not add to 100% due 10 rounding

SOURCE Alton J Penz, *"Building Energy Efficiency The Motivation for Change,"* Institute for Building Sciences Research Report No 16, Carnegie.Mellon University, April 1981, table 2, p 10 These numbers were estimated from estimates of numbers of buildings, building square footage and energy use per square foot, for different building categories (Details available from Mr Penz) They are generally consistent with but not precisely the same as estimates of commercial energy use in Jerry Jackson, *The Commercial Demand for Energy A Disaggregated Approach,* Oak Ridge, ORNL/CON-15, p 11, and estimates of residential energy use in Eric Hirst, et al *The ORNL Engineering-Economic Model of Residential Energy Use,* Oak Ridge, ORN L/CON-24, appendix

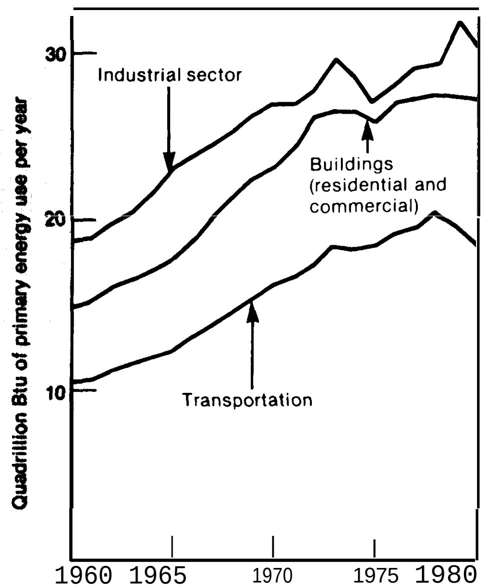
TRENDS IN BUILDING ENERGY USE

Primary energy use in buildings essentially remained constant from 1976 to 1980 despite continued expansion of total square feet. The long-term trends are shown in figure 2. I Since 1965, building energy use has increased at about the same rate as energy for either transportation or industry. The most important source of increase in energy use in both commercial and residential buildings has come from their increasing dependence on electricity. As can be seen in figure 3, the share of final demand for electricity increased from about 9 to 20 percent in the residential sector and from about 13 to about 21 percent in the commercial sector. I n terms of primary energy (see footnote 1), electricity use by all buildings (1965-80) increased from 36 to 49 percent in commercial buildings and from 31 to 48 percent in residential buildings.

These trends–overall slow growth in the energy use of buildings but a rapid increase in the share of electricity—can be understood in light of the trends in the prices of those fuels used by buildings. While the prices of all fuels increased rapidly in current dollars over the decade from 1970 to 1980 **(see** figs. **4, 5,** and **6)** the real price of electricity (in 1972 dollars) increased quite slowly, by only 11 percent over the decade, while the real price of natural gas (in 1972 dollars) increased by 66 Percent and the real price of fuel oil (in 1972 dollars) increased by 153 percent. The contrast between the slow increases in real electricity prices and the more rapid increases in real natural gas and fuel oil prices can be seen clearly in figure 7. To be sure the price of electricity varies more from

[1]This is based on tables of energy end-use by fuel and sector in the Energy Information Administration, *1980 Annual Report to Congress*, April 1981. Electricity end-use was multiplied by 3.3705 to get primary energy. This assumes 3,412 Btu/kWh electricity end-use and 11,500 Btu/kWh primary energy.

Figure 2.—Trends in Primary Energy Use by Sector, 1960-80



NOTE Primary energy Includes energy used to generate electricity. Energy consumption by electric utilities is allocated to the major end-use sectors in proportion to electricity sales by privately owned Class A and B electric utilities. These electric utilites accounted for 78 percent of total electricity sales in 1979,

SOURCE Energy Information Administration, *1980 Annual Report to Congress*, April 1981

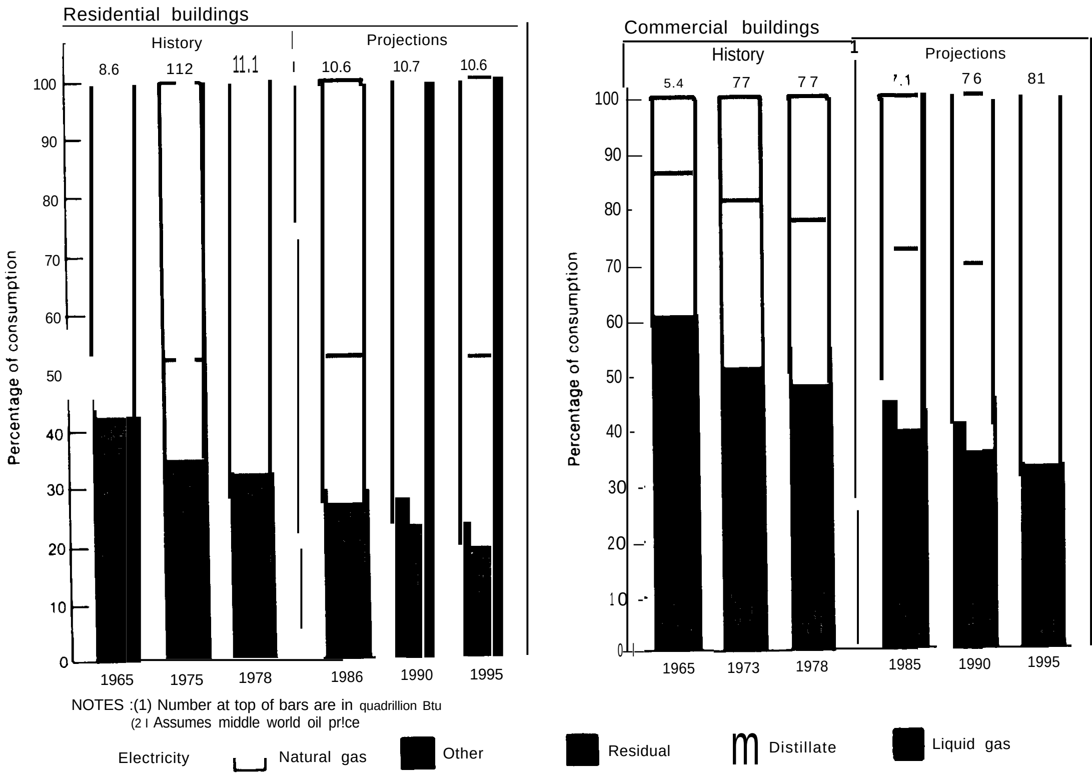
region to region than the price of natural gas or fuel oil. A few utilities such as Long Island Lighting (1 5.5 percent growth per year from 1973 to 1979) and Arizona Public Service (1 3.9 percent per year) experienced rapid growth in prices.[2] The price increases by these utilities, however, were offset by slow growth in prices of electricity by other utilities such as Cincinnati Gas & Electric (6.9 percent per year) and Puget Sound Gas & Electric (7.0 percent per year). Electricity prices in the latter two utilities actually increased slightly more slowly than the general increase in prices over the same period. J

For both residential and commercial buildings, the biggest share of energy goes for space heat (see figs. 8 and 9). Space cooling and lighting are the next most important uses of energy for commercial buildings while hot water and cooling are for residential buildings.

'Increases in Residential Electricity Rates. Source: Electrical world, *Directory of Electric Utilities*, 1974-75, 83d cd., 1974: and 1980-81, 89th cd., 1980. (See table 1 in ch. 9 of this report.)

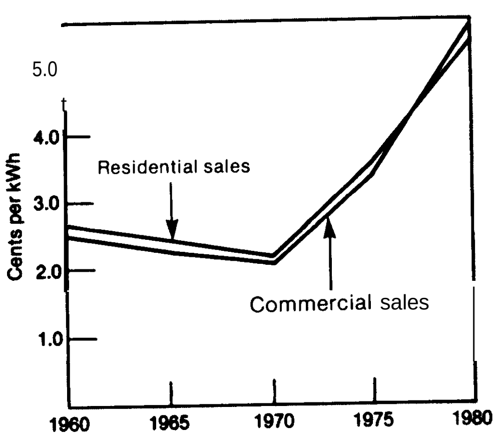
'Electrical World, op. cit.; G N P deflator increased at 7,4 percent per year from 1973-79 (vol. 2: EIA, *1980 Annual Report to Congress*, April 1981).

Figure 3.— History and Projections of End-Use Energy by Fuel Type: Residential and Commercial Buildings



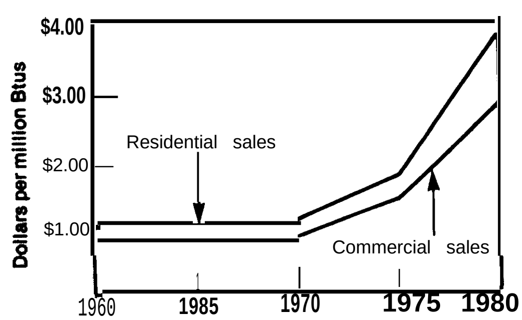
SOURCE Energy Information Administration, *1980 Annual Report to Congress*, April 1981, pp 60-61

Figure 4.—Trends in the Price of Delivered Electricity, 1960-80



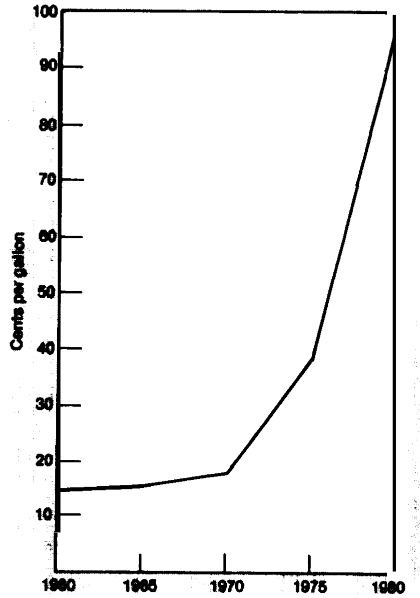
SOURCE *1980 Annual Report to Congress, Volume 2*, DOE/EIA-0173 (80)/2, Energy Information Administration, U.S. Department of Energy, Washington, D.C., April 1981.

Figure 5.—Trends in the Price of Delivered Natural Gas, 1960-80



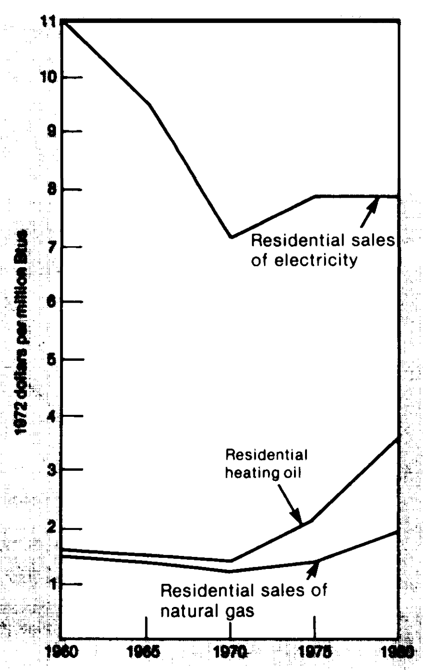
SOURCE 1980 *Annual Report to Congress, Volume 2*, DOE/EIA 0173 (80)/2, Energy Information Administration, U S Department o'Energy, Washington, D C , April 1981

Figure 6.—Trends in the Price of Delivered Home Heating Oil, 1960-80



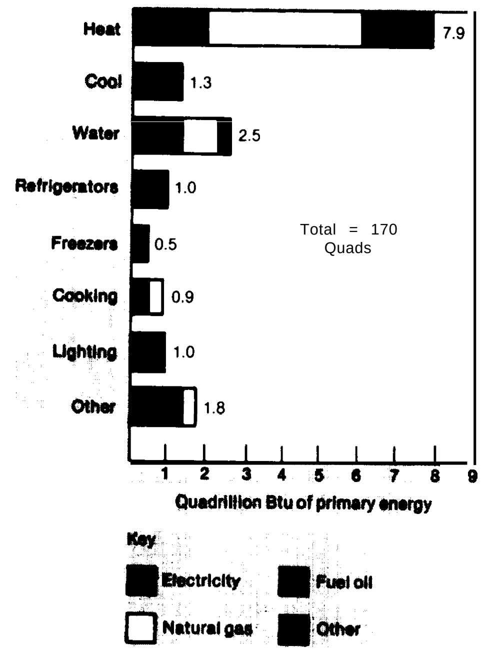
SOURCE *1980 Annual Report to Congress, Volume* 2, DOE/EIA-.0173 (80)/2, Energy Information Administration, U S. Department of Energy, Washington, D C., April 1981.

Figure 7.—Trends in Real Energy Prices (1972 dollars), 1960-80



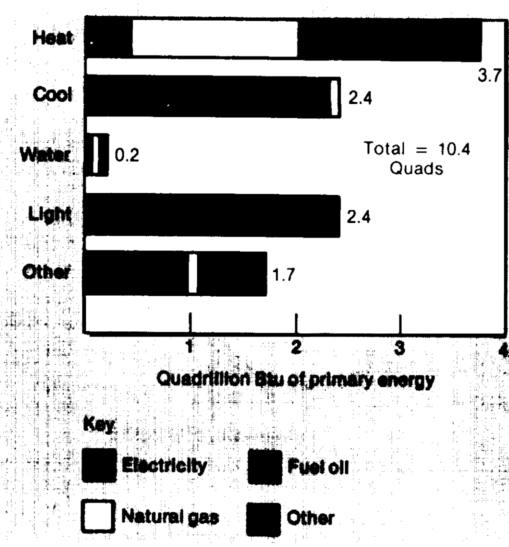
SOURCE: 1980 Annual Report to *Congress, Volume 2,* DOE/EIA-.0173 *(80)/2,* Energy Information Administration, Washington, D.C., April 1981,

Figure 8.—Primary Energy Use by Fuel and End-Use for Residential Buildings, 1980



SOURCES: *1980 Annual Report to Congress, Volume 2,* DOE/EIA- 0173 (80)/2, Energy Information Administration, U.S Department of Energy, Washington, D C , April 1981; Off Ice of Technology Assessment

Figure 9.— Primary Energy Use by Fuel and End-Use for Commercial Buildings, 1980



SOURCES: 1980 ***Annual*** Report to Congress, ***Volume*** 2, DOE/EIA-0713 (80)/2, Energy Information Administration, U.S. Department of Energy, Washington, D. C., April 1981; *The* ***Commercial*** *Demand* ***for*** *Energy; A* ***Disaggregated*** *Approach,* ORNL/CON-15, Oak Ridge National Lab, April 1978; Office of Technology Assessment.

CENTRAL CITY BUILDING STOCK

More than half of all the denser forms of housing are located in central cities: 48 percent of all attached housing, 50 percent of all multifamily housing buildings with two to four units, and 56 percent of all multifamily housing in buildings of five units or more.[4] Only 21 percent of all single-family houses are located in central cities, but single-family houses, nonetheless, are a large fraction (43 percent) of all the housing units in central cities.

OTA was not able to assemble national data on the urban, suburban, or rural location of the 4 million commercial buildings. The first survey of the commercial building stock was published in March 1981 by the Energy Information Administration (E IA) of the Department of Energy, but it did not include data on the location of buildings (central city, metropolitan area outside central city, or rural). Rough estimates of commercial location could in theory be constructed from fire insurance maps for individual cities but this is time-consuming and difficult to make representative of the whole building population. Estimates can also be constructed from employment data. This method is also subject to considerable inaccuracy.[5]

[4] *Annual Housing Survey 1978:* Part *A General Housing Characteristics*, U.S. Department of Commerce, Bureau of the Census, and U.S. Department of Housing and Urban Development.

[5] *Nonresidential Buildings* Energy *Consumption Survey: Building Characteristics*, March 1981, DOE/EIA-0246, Energy Information Administration. Estimating the location of the commercial building stock from employment data reported in Commerce Department reports on *County Business* Patterns suffers from two problems: employment data by county is not complete and there is no accurate information on square footage per employee. Furthermore, there is no way to estimate the size distribution of commercial buildings from employment data.

FORECAST ENERGY PRICES

There is considerable uncertainty about future energy prices for different fuels. While most published forecasts agree that the price of oil will continue to increase rapidly (and they may also be equally wrong), there is no consensus about the likely impact of price increases in either electricity or natural gas. On the one hand, forecasts of relative stability in electricity prices (at least by the late 1980's) in many parts of the country are based on assumptions of the continued regulation of electricity prices (which averages in high-priced electricity with low priced). Other assumptions are a gradual shift in electricity generation away from high-priced oil and natural gas and a slowdown in the addition of new generating plant with its expensive debt service. On the other hand, continued dependence on oil and gas and further rapid additions of new generating plant could lead to continued substantial increases in the price of electricity. As in the past the price of electricity will vary sharply from utility to utility. Some utilities will experience price increases considerably faster than inflation; others will have electricity prices falling relative to the general price level.

There is equal uncertainty about the price path of natural gas that is still regulated but which is scheduled to be gradually increased in price until 1985. Full deregulation would increase the pace of price increases but it is not clear where the price of natural gas would settle relative to oil and electricity prices. Since natural gas competes with efficient use of electricity in buildings and industry there is some speculation that the price of gas may eventually stabilize if the price of electricity stabilizes. On the other hand, it may increase to full parity with oil prices.

PROJECTIONS OF BUILDING ENERGY USE

In the most recent forecast of energy use prepared by EIA, and shown in table 8, primary *energy use* by buildings (including the fuel used to generate electricity), is projected to increase by about 35 percent between now and the year 2000. Commercial floorspace is projected to increase by 2.4 percent per year and residential dwelling units are projected to increase by 2 million units per year, or about 2.5 percent per year. For both residential and commercial buildings, increased primary energy use is largely due to a projected increase in the share of end-use electricity (see fig. 3).

The accuracy of such projections is limited by the fact that there are far better data available on which to base a projection of residential energy use than for a projection of commercial building energy use. The U.S. Census collects regular data on numbers of dwelling units by type and location and on new construction and demolition of dwelling units. Until this year (when EIA completed a survey of commercial buildings), there were no such comprehensive data on the U.S. commercial building stock. Based on data obtained in the survey, EIA estimated the current stock of commercial and industrial buildings at 52 billion ft^2, a much higher figure than the 32 billion ft^2 of at least one previous estimate.[6] There are very incomplete data on annual demolitions or annual new construction of commercial buildings, so there are as yet no data on which to base an estimate of how fast the commercial building stock is likely to increase.

Table 8.—EIA's Projection of Primary Energy Use in Buildings in the Year 2000

	Primary energy use (quadrillion Btu)		
	1980	2000	Percent change
Residential.	17.0	20.9	+ 230/o
Commercial	10.4	16.0	+ 54
Total combined	27,4	36.9	+35

SOURCE 1980 *Annual Report to Congress,* Energy Information Administration, April 1981, p 142, Mid. Level 011 Price Project Ion

[6] *Nonresidentia l Buildings Energy Consumption Survey* F u e l *Characteristics* and *Conservation Practices*, fig. 1, p. 4. Energy Information Administration, June 1981. One prior estimate was made by Oak Ridge as reported in A *User's Guide to the ORNL Commercial Energy* Use Mode/, R. W. Barnes, C. J. Emerson, Kenton R. Corum, ORNL/CON-44, Oak Ridge National Laboratory, May 1980, p. 40.

PROJECTIONS OF THE IMPACT OF ENERGY CONSERVATION ON BUILDING ENERGY USE

There are two different approaches to estimating the impact of energy conservation on building energy use and both of these are illustrated in table 9. Both assume that strenuous efforts are made to induce energy conservation beyond what is likely to be induced by an increase in energy prices. The impact of energy prices alone is incorporated in a base case or trend energy projection.

One approach is to assume that high conservation policies increase the relative energy efficiencies of different appliances and heating and cooling systems but that the increased efficiencies are offset by increased use of these more efficient appliances and systems. As calculated by EIA, this results in a modest reduction from trend energy use of 6 percent in residential buildings and 10 percent in commercial buildings by 1990. Applying these same percentages to 2000, as has been done in table 9, gives a modest reduction of 3 Quads from trend energy use. Even if the percentage impact in 2000 were double what was estimated for 1990 by EIA the reduction would only be about 6 Quads.

Another approach, also illustrated in table 9, is to calculate the technical feasibility of different improvements in energy efficiency and assume that all of them which fall within some defined limit of cost effectiveness will be carried out. This approach was used by the Solar Energy

Table 9.—Two Projections of Reduced Building Energy Use in the Year 2000

Definition of projection	Projected building energy use in the year 2000 (quadrillion Btu of primary energy)	
	Energy Information Administration	SERI
Trend or base case	36.9	35.3
Assuming all technically feasible improvements in energy efficiency. . . .	—	18.3
Projection assuming "high conservation" Federal policies	33.6a	—
Reduction in energy use	3.3	17.0

[a]Applies percentage ~@ uctions in residenti al and commercial use i n "high con servation use" in 1990 to the projection of trend energy use in 2000

SOURCE 1980 *Annual Report* to Congress, Energy Information Agency, p 65 and *A New Prosperity Bu//dlng a Sustainable Energy Future* The SE RI/SOLAR Conservation Study (Andover, Mass Brick House Publishing, 1981), p 13

Research Institute (SERI) for its report Building a Sustainable Energy future. SERI calculated the cost of retrofits to several prototypical buildings assuming the retrofits would be paid for in annual payments on a loan of 3-percent real interest rates over the lifetime of the measure (generally 20 years). Any retrofit costing less per Btu saved (on this basis) than the current (1980) cost of fuel oil or electricity would be considered cost effective. The technical potential for reductions in energy use calculated in this way is much greater than the reductions projected by EIA, 17 Quads instead of 3. The difference between these two projections is a measure of the range of controversy about how much of the technically feasible reductions in building energy use are likely to come about within the framework of the decisions made by those responsible for buildings.

THE CONTRIBUTION OF THE BUILDINGS IN THIS STUDY TO FUTURE BUILDING ENERGY USE

This study looks more closely at some residential and commercial building types to examine how much cost-effective retrofit might actually occur given the motivation of different owners to invest in retrofit. The analysis that follows draws on the detailed analysis in the rest of the report but relies on some simplifying assumptions consistent with that analysis. It also ignores some subtleties important for designing retrofit strategies for particular cities but not important when analyzing national energy use two decades from now. The overall analysis presented here is designed for simplicity and clarity. Readers should be aware that the main objective of the whole report was not to perform a national energy forecast but to clarify the complexity of the building sector that is one of the most inherently local of all economic sectors in the way in which decisions are made about growth and investment.

From table 7 energy use for the primary building types covered in this report are obtained. They are as follows:

Multifamily	2.3 Quads
Off Ice buildings.	1.4 Quads
Retail/wholesale	2.2 Quads
Hotel/motel	0.5 Quad

In addition to these building types, owner motivation and public policies are analyzed for three other building types:

Educational buildings	1.7 Quads
Public buildings.	0.4 Quad
Single-family homes owned by low-income people'. ., ...	1.6 Quads

[7]See appendix to this chapter for assumptions used in calculating energy use by low-income people.

The technical potential and owner motivation for all these categories of building types is assessed regardless of where they are located, on the grounds that such building types make up a large fraction of buildings in central cities but that city/suburban boundaries do not make an important difference in the retrofit potential of such buildings.

The study, however, devotes some brief attention to another group of buildings only to the extent they are located in central cities. These are single-family houses owned by families of all income classes, but located in central cities. Although the technical potential for retrofit and owner motivation for retrofit of such buildings was thoroughly analyzed in OTA's previous report on Residential Energy Conservation, this new report sheds some additional light on public and private programs to stimulate retrofit in these buildings. Single-family houses in cities use a large fraction of city building energy use:

Single-family houses in cities. . . . ., 3.5 Quads

All of these building types taken together used half the building energy use in 1975.

ENERGY SAVINGS POTENTIAL AND LIKELIHOOD OF RETROFIT

The analysis of the likely energy savings compared to the possible energy savings for the building types covered in the report uses a set of simple assumptions consistent with the results of the detailed analysis described in the rest of the chapters of the report.

The detailed assumptions used in the analysis are described in the appendix to this chapter and include assumptions about:

- The rate of demolition of the current building stock.
- The rate of addition of new energy inefficient buildings (since these will require retrofit to become energy efficient).
- The technical potential for retrofits of different types of buildings.
- The likelihood that different types of owners will actually retrofit their buildings.
- The share of commercial buildings that are owner occupied.
- The share of residential dwelling units that are occupied by low-income people.

Using these assumptions, OTA calculated for each building and owner type:

- Projected trend energy use in 2000 (same as 1975 because of cumulative effect of changes due to demolition or additions of energy inefficient buildings).
- Savings if all technically feasible, cost-effective measures were installed.
- Likely savings (either fast payback retrofits only or maintenance and use savings only).
- The gap between technically possible savings and likely savings.
- What share of the gap is represented by fast payback savings that are not likely to be achieved.

Since the projection is meant to illustrate the implications of the findings in the study if they were carried forward, the calculations assume current energy prices in estimating the technically feasible retrofits (as did the SERI projection described above) and current costs and accessibility of capital in estimating the likely response of building owners. No attempt to forecast changes in real energy prices or changes in the cost of capital was made. If real energy prices on average were to increase significantly the amount of technically feasible ret refit would increase slightly, and if the cost of capital were to fall significantly, the motivation of building owners to retrofit should increase. Readers of this report may take these two possibilities into account in judging the implications of OTA'S projections.

Potential and likely savings are shown for each building type i n table 10. The results for all buildings needing retrofit between now and 2000 and covered in this report can be summarized as follows:

- For the building types covered i n this report, the total trend energy use i n 2000 of

Table 10.—The Likely Primary Energy Savings Compared to the Technically Possible Savings for Building Types Covered in This Report

Building types	Trend energy use[a]	Year 2000: Technical savings potential	Likely savings	Gap: technical potential saving not realized	Gap: fast-payback savings not realized[b]
		(quads of Btus)			
Residential					
Single-family buildings					
• **Low income**	**1.6**	**0.8**	0.2	0.6	(0.2)
• Moderate and upper income in cities	3.5	1.8	0.9	0.9	o
• Moderate and upper income outside cities (not dealt within report)	(10.2)	(5.1)	(2.5)	(2.5)	0
Ž Mobile Homes	(0,3)	unknown	unknown	unknown	unknown
Multifamily buildings					
• Low-income	0.6	0.2	0.1	0.1	(0.1)
• Moderate and upper income master-metered	0.9	0.4	0,1	0.3	(0.1)
• Moderate and upper income tenant-metered	0.8	0.4	0.1	0.3	(0.1)
Total residential energy dealt with in this report	7.4	3.6	1.4	2.2	(0.5)
Not dealt with in this report	(10.5)				
Total residential primary energy	17.9				
Commercial buildings					
Office buildings					
• **Owner-occupied**	0,7	0.4	0.2	0.2	0
. Investor-owned	0.7	0.4	0.1	0.3	(0.1)
Retail buildings					
• Owner-occupied	1.1	0.6	0.3	0.3	0
• Investor-owned	1.1	0.6	0.1	0.5	(0.2)
Hotel/motel					
• Owner-occupied	0.3	0.2	0.1	0.1	0
• Investor-owned	0.3	0.2	0	0.2	(0.1)
Educational buildings	1.7	0.9	0.4	0.5	0
Public buildings	0.4	0.2	0.1	0.1	0
Commercial energy dealt with in this report	6.3	3.5	**1.3**	2.2	(0.4)
Not covered in this report:					
Hospitals	(0.7)				
Warehouses	(0.3)				
Religion	(0.3)				
Miscellaneous	(1,1)				
Total	(2.4)				
Total commercial primary energy	8.7				
Total energy covered in this report.	**13,7**	**7.1**	**2.7**	**4.4**	(0.9)
Total building energy	26.6				

[a]Assumes 2000 energy use by inefficient building 1975 use (see text)
[b]Fast-payback savings not realized are included in figures on total savings not realized in column at left

SOURCE Office of Technology Assessment

buildings in existence in 1980 plus the fraction of buildings built between now and 2000 that are energy inefficient (about 33 percent) is projected to be 13.7 Quads (out of a total building energy use for existing buildings and new energy-inefficient buildings of **26,6** Quads).

- Of this energy use, technically feasible and cost-effective (see p. 4 for definition) retrofits could produce 7.1 Quads of savings.
- Only 2.7 Quads of savings of this amount are actually likely to be saved because of stringent criteria applied to energy retrofits placed by building owners of different kinds and described in chapter 4 of this report.
- Of the estimated 4.4-Quad gap between the technical potential for savings from retrofit and likely savings from retrofit, about 0.9 Quad are very cost-effective retrofits

(fast payback retrofits) that will not be installed because some owners totally lack financial means (low-income owners) or motivation (owners of tenant-metered multifamily buildings) or both, The rest of the gap, 3.5 Quads, represents the retrofits that cost more compared to the savings they bring about but would still be considered cost-effective investments by an investor with a long perspective. Of these about 2.5 Quads are from retrofits of moderate payback.

CHAPTER 2 APPENDIX–ASSUMPTIONS USED IN CALCULATING PROJECTED ENERGY SAVINGS FROM RETROFIT OF BUILDINGS

The assumptions used in constructing table 10 were as follows:

Trend Energy Use in the Year 2000 of Building Types Covered in This Report That Are Also Candidates for Retrofit.–For simplicity this is assumed to be the same as the breakdown shown in table 7 for 1975. This result comes about because a set of far more complicated assumptions have the overall effect of canceling each other out. The more detailed assumptions are as follows:

- **1980** building energy use is **3** percent higher than 1975 energy use.
- Residential buildings in existence in 1980 will be demolished at 1 percent per year until 2000 leaving 82 percent of the 1980 buildings standing. Commercial buildings will be demolished at 1.25 percent per year leaving 74 percent of the 1974 buildings still standing.
- New residential buildings will be constructed between 1980 and 2000 equivalent to 50 percent of the 1980 building stock. One third of these, or about 17 percent of the 1980 building stock will be energy inefficient and will need retrofit.
- New commercial buildings will be constructed between 1980 and 2000 equivalent to 60 percent of the 1980 building stock. One third of these (or 20 percent of the 1980 building stock) will be energy inefficient and will need retrofit.
- Compared to the 1975 stock the result of these assumptions is that trend building energy use for those buildings needing retrofit in **2000** will be 102 percent of 1975 energy use for residential buildings and 97 percent for commercial buildings. This is too close to 1975 energy use to make any difference in OTA's crude calculations of savings potential and so the 1975 energy was used as a starting point.

Low-Income Share of Single-Family and Multifamily Housing.–OTA assumed that 10 percent of all single-family energy use is low income and 25 percent of all multifamily energy use. This is based on the further assumption that 13 percent of single-family owners are low income (125 percent of poverty) and they use 80 percent of the energy used by moderate and upper income. For multifamily renters, 30 percent are assumed to be low income, also using 80 percent of the energy used by moderate and upper income people.

Master and Tenant Metering of Multifamily Buildings.–OTA assumed that half of all multifamily buildings are master metered and that this proportion will not change between now and 2000.

Technical Potential of Retrofit of Commercial Buildings.–Based on the analyses of retrofit potential described in chapter 5, it is assumed that if all cost-effective measures were installed in commercial buildings, the average energy savings would be 50 percent of trend energy use.

Technical Potential for Retrofit of Residential Buildings.– From the analysis in chapter 5 *multifamily buildings*, on average, have less retrofit potential. OTA assumed a potential savings of 40 percent of trend energy use. For *single-family buildings* OTA assumed a technical retrofit potential of 50-percent savings.

Owner Occupancy of Office, Retail, and Hotel Buildings.–OTA assumed that 50 percent of these buildings are **owner occupied. This is consistent** with the data in the March 1981 survey of nonresidential buildings (see footnote 5 for reference). EIA data shows that the proportion of owner occupancy averages 48 percent and does not vary greatly by type of commercial building or size of building.

Savings Achieved by Fast-Payback Retrofits.– Based roughly on the technical analysis described in chapter 5, OTA assumed that 20-percent savings can be achieved by fast payback retrofits in multifamily buildings and that 30-percent savings can be achieved by fast payback retrofits in commercial buildings and single-family buildings.

Savings Achievable by Changes in Maintenance and Behavioral Practices.—OTA assumed that 10-percent savings is achievable in all building types without capital investment but with changes in use and maintenance practices.

Willingness of Owner Types To Do Retrofits.– Based on the analysis of building owner motivation in chapter 6, OTA made the following assumptions about average owner willingness to retrofit their build buildings:

- Willing *to invest* **in** a full set of technically feasi*ble* retrofits. None as a group although small categories within some groups.
- Willing to invest in *fast* payback retrofits *only.*
  - — Owner-occupants of office buildings, retail buildings and hotels. The willingness of the better financed owners of these buildings to do more is offset by the reluctance of the poorly financed owner-occupants to do *any* retrofits.
  - — Owners of educational and public buildings.
  - — Moderate and upper income owners of single family buildings in cities.
  - — Master-metered multifamily buildings.
- Unwilling to retrofit *but* achieving *savings due to* changes in *use or behavior.*
  - — investor-owners of office buildings, retail buildings, and hotels.
  - — Owners of tenant-metered multifamily buildings.
  - – Low-income owners of single-family homes.