Chapter 1

Introduction and Summary of Findings

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INTRODUCTION

The future of buildings in this Nation's cities arouses both interest and concern. Great department stores and hotels, museums and cultural centers are by and large to be found in cities. The office buildings of the financial districts of New York, Chicago, Houston, and San Francisco shelter major economic decisions affecting our Nation. Some of the most exciting modern real estate development has occurred within cities—Baltimore's Harbor Place, Boston's Quincy Market and San Francisco's Ghiradelli Square. The Nation's rediscovery of its own past has found expression in loving restoration of Victorian homes in such cities as Savannah, Cincinnati, Pittsburgh, and Hartford. Elsewhere, however, empty factories and boarded up tenements in cities are reminders of economic stagnation and population shifts. Some magnificent old buildings in cities stand crumbling amid pitted streets and recalcitrant ancient sewers, testimony to the failure to maintain the architectural and engineering legacies of the past.

One contributor to the economic difficulties of buildings i n cities has been the rise in the cost of energy. This study of the energy efficiency of buildings in cities has a double focus, arising both from concern about the Nation's cities and the viability of their building stock and from concern about the Nation's energy future and the prospects for increased energy efficiency in the building sector.

Looked at from the point of view of urban policy this report deals with the energy efficiency of commercial and multifamily buildings because such buildings are important in the building stock of U.S. central cities. Over half of the denser forms of housing–attached houses, small multifamily buildings with up to four apartments and larger multifamily buildings —are located in central cities.

From an energy policy perspective, the buildings that are the primary subject of this report–all commercial buildings, all multifamily buildings, all housing occupied by low-income people, and single-family homes located in central cities—are also important. These categories of buildings together used about 14 Quads of primary energy in 1980, half of all U.S. building energy i n that year. Most of the rest of energy in buildings was used by middle and upper income single-family homes located outside central cities (about 10 Quads of primary energy). The technical and economic prospects for improved energy efficiency of single-family homes were dealt with in an earlier OTA report Residential Energy Conservation. *

This report attempts to bridge the gap between urban and housing specialists, on the one hand, who understand such subjects as primary and secondary mortgages, building codes, and the ins-and-outs of municipal bonds, and, on the other hand, energy specialists who are expected to understand building envelope efficiencies, heating system efficiencies, utility load forecasting, and load management potential. Both sets of specialists must understand some of the others' expertise if sensible building energy policy (including deliberate nonintervention) is to be made. The analysis is from the perspective of various different actors i n the field with potential impact on building retrofit—including the energy auditor or retrofit contractor, the real estate financial analyst, and the city energy program director. The analysis attempts to assess energy conservation opportunities in the context of real estate decision making.

Many aspects of the energy efficiency of buildings are not affected by the building location—urban, suburban, or rural. This report treats buildings regardless of location in several chapters: chapter 2, projections of building energy use; chapter 3, technical prospects for

*Office of Technology Assessment, U.S. Congress, Residential Energy Conservation,, OTA-E-92 (Washington, D. C.: Government Printing Office, July 1 979).

improved energy efficiency of buildings; chapter 7, private sector marketing of energy conservation; chapter 8, utility conservation programs; and chapter 9, State and Federal energy conservation programs.

On the other hand, an urban location does influence some aspects of real estate decision-making and local government policy. The discussion of building owner motivation (ch. 4) is based on interviews with owners of buildings in central cities. The description of local government programs (in ch. 9) deals only with city government and may not apply to suburban, small town, or county government. The report includes a set of case studies (ch. 10) drawn exclusively from central cities: Buffalo, N.Y.; Jersey City, N. J.; Des Moines, Iowa; Tampa, F1., and San Antonio, Tex. Finally, the chapter on district heating (ch. 6) describes a technology which is primarily suitable for cities, although it may be feasible elsewhere under the right circumstances.

In order to avoid covering ground that has been amply covered elsewhere, this report does not address, except in passing, several topics which also have a bearing on the development of national energy policy for the building sector. The report mentions but does not discuss extensively the many factors which have influenced the development of a national energy policy in recent years, such as national security considerations, balance of payments or conservation of capital resources. Nor does the report examine the basis for alternative projections of energy use in the building sector, although it does present a simple projection of building energy use for purposes of placing the more detailed examination of the building sector in context. The report assesses the practical potential for building retrofit but does not itself set out to define the technically optimum degree of conservation investment. Rather it seeks to compare what seems practical and feasible for some actual buildings with what is likely to occur in the majority of buildings.

Finally, the reader is cautioned against overgeneralization. In buildings, as in many other aspects of everyday life, there are many special situations. Just as buildings differ widely in their energy use and retrofit characteristics, many individuals, companies and building owners will vary in their choices of investment. The diversity that characterizes the opportunities for conservation makes it difficult to make universally applicable statements. The report seeks rather to explain and examine the many factors that underly that diversity, so that Federal policies may take advantage of, rather than be thwarted by, these individual choices.

SUMMARY OF FINDINGS

Overview

Overall, OTA estimates that about 7 Quads* per year of energy savings is technically possible by 2000, through feasible** investments in the improved energy efficiency of building types covered in this report (see table 1). Nearly 3 Quads of these potential energy savings are likely to come about because of investments in energy efficiency made by building owners who have personal or business reasons to invest money in improved energy efficiency of their buildings.

The other 4 Quads of potential energy savings, on the other hand, may not occur because building owners fail to make investments in the energy efficiency of their buildings. Part of the failure to retrofit is due to the difficulty and costliness of improvements in energy efficiency to some building types. Part of the failure is due to building owners' stringent

*A Quad equals a quadrillion Btu of energy, a very large unit of energy. It is equivalent to about 500,000 barrels of oil per day for a year, or about 50 million tons of coal, or the output of 18 1,000-MW powerplants at average utilization. Seven Quads is equivalent to the energy of more than two-thirds of the oil the United States imported in 1981.

**Feasible investments are defined as those which in 1981 are technically feasible and which would be cost effective over a 20-year lifetime, assuming no real increases in energy prices and a 3-percent real return on investment.

requirements for return on investments in energy efficiency. The diversity of buildings and owners and their implications for national energy use is described below.

Table 1.—The Gap Between Likely Energy Savings Through Retrofit and Technically Feasible Savings by the Year 2000: Building Types Covered in This Report (quadrillion Btus of primary energy)

	Projected energy use [a]	Technical savings potential [b]	Likely savings [c]	Gap: technical savings potential not realized
Multifamily buildings (all)	2.4	1.0	0.3	0.7
Commercial buildings (all)	6.3	3.5	1.3	2.2
Low income single family (all)	1.6	0.8	0.2	0.6
Moderate and upper income single family homes in cities	3.5	1.8	0.9	0.9
Total buildings covered in this report	13.8	7.1	2.7	4.4

[a]Projected energy use in 2000 assumes no reduction from current energy use by these buildings and is based on a set Of assumptions, that are described in the appendix to ch. 2, about demolition of existing buildings and construction of new buildings needing retrofit A quadrillion Btu equals approximately 500,000 barrels of oil per day for a year.
[b]The technical savings potential is defined as that resulting from all retrofits to these building types which as of 1981, are technically feasible and which would be cost effect we over a 20-year lifetime, assuming no real Increases in energy prices and a 3-percent real return on investment
[c]Likely savings are those which are likely to come about from investments by building owners under Current conditions Of availability of capital, retrofit Information, and public programs.

SOURCE. Off Ice of Technology Assessment

BUILDING BY BUILDING RETROFIT POTENTIAL

Technical Description

The national potential (estimated in table 1) for increased energy efficiency of the building stock is the result of physical changes to improve the energy efficiency of millions of buildings. For convenience, these physical changes are referred to as energy retrofits i n this report. While recognizing that each building is to some extent a unique problem, OTA did identify the major characteristics of buildings which influence the types of energy retrofits that are likely to be most effective. These are:

- Size.—Energy retrofits which improve the energy efficiency of the building envelope (walls, windows, and roof) are more important for small buildings than for large buildings. On the other hand, certain kinds of retrofits which bring about similar savings in small buildings and large buildings will cost relatively less per unit of energy saved in large buildings because of economies of scale.
- **Wall and roof** type.–Masonry or curtain walls and flat roofs without attics or with very small crawl spaces are much more difficult to insulate than are wood frame walls and roofs with attics and ample crawl spaces.
- **Mechanical system (HVAC)** type.– Physical changes to the way space heating or cooling is produced and circulated can provide significant increases in building efficiency but vary with the type of heating ventilation and air conditioning (HVAC) system used by the building.
- **Building** use.–Most commercial buildings are used from 9 to 5 on weekdays (offices) or 9 to 9 daily (shopping centers) and are unoccupied outside these hours. This provides opportunities for improved energy efficiency by careful control of temperature and lighting between operating and nonoperating hours. Opportunities also exist for more efficient and task-specific lighting in commercial buildings. Finally, retrofits to

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the hot water system of multifamily buildings can usually save considerable energy.

Capital Costs

OTA reduced 43 potential combinations of the four building characteristics described above to 13 building types for which the lists of appropriate retrofit options are distinct (although there may be considerable overlap among them). The 13 building types are shown in table **2, OTA identified no major category of building typically found in cities for which substantial savings were not available from retrofits of low or moderate capital cost compared to savings.**

For some of the building types, a major part of the potential savings are likely to come from retrofits of low capital cost compared to savings (see table 3) in the sense that they will pay for themselves in energy savings in 2 years or less and will earn real rates of return over the life of the retrofit (20 years on average) of more than so **percent per year assuming no increase in the real cost of energy.** These building types include all small frame houses, moderate or large multifamily buildings with central air or water mechanical systems, and all commercial buildings except the usually older commercial buildings with water or steam heating systems and window air-conditioners. Clearly the problem of financing retrofits for these buildings should be minimized by the fast payback (and high return) of their retrofit options. Some of these fast payback retrofit options include wall insulation in frame buildings, economizer cycles which make greater use of outside air for air-conditioning in commercial buildings and hot water flow restrictors in multifamily buildings.

For all of the remaining building types, on the other hand, substantial savings are more likely to come from retrofit options of moderate capital cost compared to savings, which will payback in 2 to 7 **years and whose real rate of return can range from as high as 50 percent to as low as** 13 percent **per year over a 20-year retrofit life** (also see table 3), These building types include all small masonry rowhouses, moderate or large multifamily buildings with decentralized heating and cooling systems, and older commercial buildings with water or steam systems and window air-conditioners. For owners of such buildings there may be significant

Table 2.—Thirteen Types of Buildings With Significantly Different Retrofit Options

Building type and wall type	Mechanical system type	Retrofit options predominantly: Low capital Cost[a]	Retrofit options predominantly: Moderate capital cost[a]
Small house with frame walls (single family or 2-4 units)	Central air system	X	
Same	Central water system[b]	X	
Same	Decentralized system	X	
Small rowhouse with masonry walls (single family or 2-4 units)	Central air system		X
Same	Central water system		X
Same	Decentralized system		X
Moderate or large multifamily building (masonry or clad walls)	Central air system	X	
Same	Central water system	X	
Same	Decentralized system		X
Moderate or large commercial building (masonry or clad walls)	Central air system	X	
Same	Central water system		x
Same	Complex reheat system	x	
Same	Decentralized system	x	

[a]See table 3 for a definition.
[b]OTA's assumption is that this building type has a central water system and window air-conditioners.

SOURCE Off Ice of Technology Assessment.

Table 3.—Three Ways to Express the Relative Cost Effectiveness of Energy Retrofits

Relative capital cost[a]	Simple pay back[b] (in years)	Annual real return on investment (percent)
Low capital cost[d]	Less than 2 years	More than 50°/0 per year
Moderate capital Cost[d]	2 to 7 years	13 to 500/0 per year
High capital cost[d]	7 to 15 years	3 to 130/0 per year
Cost of retrofit exceeds savings[e]	More than 15 years	Less than 3°/0 per year

[a]See ch. 3 for a full definition. Low capital cost is defined as less than $14.00 per annual million Btu saved. Moderate capital cost is defined as $14.00 to $49.00 per annual million Btu saved. High capital cost is defined as $49.00 to $105.00 per million Btu saved. In all OTA's calculations in ch. 3, all electricity savings are multiplied by 2.46 to reflect the higher cost of electricity.
[b]Number of years for value of first year's energy savings to equal retrofit costs. Assumes value of energy savings is $7.00 per million Btu (approximately equal to the average price of distillate fuel oil in 1960).
[c]Annual real discount rate that equates costs and savings over a 20-year measure lifetime. This assumes that fuel savings escalate at the same rate as inflation.
'Compared to savings.
'Not cost effective.

SOURCE: Office of Technology Assessment,

Photo credit, Department of Housing and Urban Development

Single-family detached framehouses supply more than half of all housing in U.S. Central cities

problems of financing substantial energy retrofits. Some examples of effective retrofits with moderate capital cost include: roof insulation and storm windows for masonry rowhouses, hot water heat pumps for multifamily buildings with decentralized systems, and replacing low efficiency window air-conditioners with more efficient models.

For most of the building types there are also retrofit options of high capital cost compared to savings with paybacks of longer than 7 years and annual real rates of return of less than 13 percent per year (over 20 years). If lifecycle costing is used, such retrofits may in fact be less expensive over the full life of the measure of the cost of the energy they would save. However, their very slow payback and low annual rate of return create serious financing obstacles. **For most of the building types OTA examined, such high cost retrofits would save no more than 20 percent of the full technical savings potential.** The three exceptions and the estimated percentage of total savings from high cost retrofits are:

- Masonry rowhouse with a heating system using air (40 percent).
- Masonry rowhouse with a water or steam system (25 percent).
- Large multifamily building with an air system (30 percent).

Examples of some high cost retrofits which produce substantial savings in certain building types include: wall insulation in masonry rowhouses and multifamily buildings and night-time window quilts in multifamily buildings.

Importance of Solar Retrofits

Passive and active solar system retrofits can reduce the energy requirements for space heating and hot water just as nonsolar energy retrofits can. OTA compared costs and energy savings of seven different kinds of solar retrofits to

Photo credit: Department ot Housing and Urban Development

Adding wall insulation to masonry rowhouses saves substantial energy but is of high capital cost compared to savings small and large residential building types. Many solar retrofits are of high capital cost (slow payback and low return on investment); a few are of moderate capital cost and none are of low capital cost. For all building types and retrofits examined there are nonsolar energy retrofits which save as much and cost the same or less, If chosen strictly on the basis of capital cost and effectiveness, the nonsolar retrofits would probably be chosen first, although there are many reasons including aesthetic ones for choosing solar retrofits. Some cost-effective solar retrofits on some building types are identified in chapter **3.**

DIFFICULTY OF PREDICTING THE OUTCOME OF A RETROFIT TO A PARTICULAR BUILDING

While the general prospects for cost-effective retrofit are good they may be very unpredictable for particular buildings. Extensive research and applied work on the retrofit of buildings to improve energy efficiency has only been underway for the past few years and most of this work has focused on single-family housing. **There are little data on the actual effects of building retrofits, and for some types of buildings there are almost no data.** Few energy auditors or building owners have maintained and made available careful records of preaudit fuel consumption, cost and type of retrofit, and postretrofit performance. A recent compilation of data on actual retrofits of commercial and larger multifamily buildings (see ch. 3) included data on **222** buildings. Among these, there was only one multifamily building, one shopping center, and four hotels. Most of the rest were schools and office buildings. **These data on actual retrofits confirm that, on average, considerable savings are possible from low and moderate cost retrofits.** For almost 90 percent of the buildings surveyed with good cost data available, the cost of the retrofit package installed paid back in energy savings in 3 years or less.

However, actual savings may be considerably higher or considerably lower than predicted for individual buildings. For the 60 buildings with data on savings predicted by an audit as well as actual savings achieved by the retrofit, actual savings varied in both directions (more than predicted and less than predicted) by a wide margin. For a group of 18 similar community centers, for example, actual energy savings averaged 85 percent of the predicted amount but varied (within one standard deviation) from 50 percent more than predicted to **80** percent less than predicted. Such results are only suggestive. Carefully designed data collection would be necessary to estimate more accurately the predictability of energy savings from different combinations of retrofit measures. The available data, however, are consistent with OTA's finding that there are inherent characteristics of building retrofit which are responsible for the substantial variation of likely savings from a particular retrofit from the predicted value. The variability can be reduced from its present level but it will probably remain substantially above zero.

Each structure is a unique combination of design, siting, construction, and previous retrofits. The behavior of the building occupants and the climate will also affect energy savings in unpredictable ways. These factors make it difficult to gather consistent data to determine the actual (compared to the theoretical) results of retrofit. Buildings with the same generic design will use energy differently due to the location of the structure in relation to the Sun. Further, buildings tend to vary in construction, even given the same design. Substantial amounts of energy can be lost through openings in interior walls, through leaky duct systems, and in other ways not obvious to the observer.

While there are methods commonly used to calculate heating loads, cooling loads, and other factors, these formulas best apply to a controlled situation rather than a real structure. As each energy retrofit is added to a structure, the system is changed, and very little is known

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about how to predict the interaction of several retrofits on a given building. Differences from building to building in the number of occupants and their living and working patterns (e.g., open windows v. air-conditioning) complicate the issue. In addition to behavior, microclimates and yearly weather changes will affect the actual amount of energy used. Thus, a researcher trying to figure out the real building energy use in a multifamily structure needs to know vacancy rate and local weather conditions that year as well as fuel use. Not all data are corrected for climate, and not all climate correction techniques are the same. It is even less common for data to be corrected for occupancy. The variation in data adds to uncertainty.

In many buildings increased energy efficiency depends heavily on building operation and maintenance. Some of the buildings described in the survey above failed to save as much energy as predicted because of poor performance by the equipment operator. For larger buildings, systematic improvements in operation and maintenance are likely to save as much or more energy as capital investment. An energy auditor can recommend these changes in practice but they are not permanent improvements and will affect the degree to which actual savings match predicted savings.

WILL OWNERS OF CITY BUILDINGS INVEST IN THE ENERGY EFFICIENCY OF THEIR BUILDINGS?

Given an investment with a probable high return but a possibility of partial or complete failure (as well as a possibility of greater-than-expected success), how are the owners of buildings in cities likely to respond to the opportunities to increase the energy efficiency of their buildings?

Energy is now important. After many years of energy price increases the cost of energy is now sufficiently important for building owners in the balance of income and expense of their buildings that steps have to be taken to control it. This is a change from general building owner opinion of several years ago.

Several categories of building owners with good access to equity capital, reliable professional advice on retrofits and a long holding strategy for their buildings are retrofitting their buildings and installing retrofits of low and moderate capital cost compared to savings. Institutional owners of buildings, such as insurance companies and pension plans, have set energy efficiency goals for their property managers and routinely make capital investments in energy efficiency if they will pay back in less than 5 to 7 years (see table 4). Large corporations which generally occupy any buildings they own also install retrofits with moderately long expected paybacks (3 to 5 years). Nationally syndicated partnerships also have generous payback criteria.

Several other categories of building owners with access only to debt financing and tight constraints on the building's cash flow are only installing the most cost-effective retrofits in their buildings. Small business owner-occupants and owner-occupants of multifamily buildings expect to hold their buildings for a long time and would benefit from retrofit, but they are severely constrained by lack of access to capital and generally cannot tolerate losses in cash flow. Individual and small partnership investor-owners of buildings require that energy retrofits pay back in 1 to 2 years. They have poor access to equity capital and poor access to professional advice.

The prospects for retrofit of commercial and multifamily buildings differ. With the exception of flourishing markets in dynamic neighborhoods in such cities as Washington, D. C., and San Francisco, multifamily buildings have suffered as a group from lagging rents and therefore lagging resale value (except as condominiums) that reduces their likelihood of retrofit

Table 4.—Retrofit Payback Criteria, Holding Periods and Access to Financing, and Advice for Different Types of Owners

Building owner type	Typical payback criteria	Building for own use?	Expected holding period	Access to capital	In house professional advice
Owner-occupants					
Large corporations	3-5 years	Yes	Long	Good	Good
Small businesses	1 year	Yes	Long	Poor	Poor
Multifamily owner-occupants	1-3 years	Yes	Long	Poor	Poor
Condominium	No Data	Yes	Long	Mixed	Fair
Investor-owners					
Institutional owners	5-7 years	No	Long	Good	Good
Development companies	1-3 years	No	Short	Fair	Good
Partnership syndicates	3 years	No	Short	Fair	Good
Local partnerships	1-2 years	No	Short	Poor	Fair
Individuals	1 year	No	Mixed	Poor	Poor

NOTE Long holding period = more than 10 years Short holding period = 8 to 10 years

SOURCE Office of Technology Assessment.

Photo credit. Department of Housing and Urban Development

Net and passthrough leases reduce the incentives of owners of small retail and office buildings to retrofit their buildings below that of commercial buildings owned by the same owner. Where technically possible, owners of multifamily buildings have converted them to tenant utility meters so that owners will no longer be responsible for paying the utility costs. Owners of tenant-metered buildings have little or no current incentive to retrofit their buildings. Most believe that it will be a long time before owners of energy efficient multifamily buildings can charge higher rents than owners of similar but inefficient buildings.

The most likely buildings to be retrofit are office buildings, hotels, and department stores owned by a large corporation or institutional owner. The least likely to be retrofit are tenant-metered multifamily buildings owned by individuals or local partnerships.

Why Do Some Owners Forego the Large Potential Returns on Retrofit?

Most individual owners and many partnership owners will not invest in energy retrofits even if they payback in as short a period as 2 or 3 years. This unwillingness occurs despite the fact that a retrofit package with a 3-year payback will generate a very large return on investment—more than 33 percent real return per year—over a 20-year life of a retrofit installation.

High Cost of Finance

Much of real estate, including major development companies, is financed by debt not equity. In the terms of the industry, equity is "highly leveraged. " A major portion of the financing for purchase of a new or existing building almost always comes from a mortgage. Additional financing for expansion, rehabilitation, repair, or retrofit of a building has traditionally come from refinancing a building with a new bigger mortgage at a similar rate of interest as the original mortgage. The recent increase in interest rates has effectively eliminated that option for most building owners. No one is likely to refinance a **7-, 9-,** or 1 l-percent mortgage at 14- to 17-percent interest in order to get funds for rehabilitation or retrofit. The primary source of funds other than mortgages for building owners is a commercial loan. These are generally 18- or 24-month high-interest loans used for financing construction projects. During much of 1980 such loans were only available at variable interest rates 2 percentage points above the prime rate.

A building owner, unable to tolerate much reduction in the cash flow from a building, cannot manage anything but a retrofit with a very fast payback if his only financing option is a short-term high-interest loan. Figure 1 illustrates this clearly. A 2-year payback retrofit will generate more energy savings than it will cost in debt service, even at 22-percent interest, if it is financed with a 3-year loan or longer. A 5-year payback retrofit, on the other hand, will cost more the first year in debt service than it will generate in energy savings unless it is financed for at least 10 years at interest rates of 10 or 13 percent, or for 20 years at an interest rate of 16 percent. *

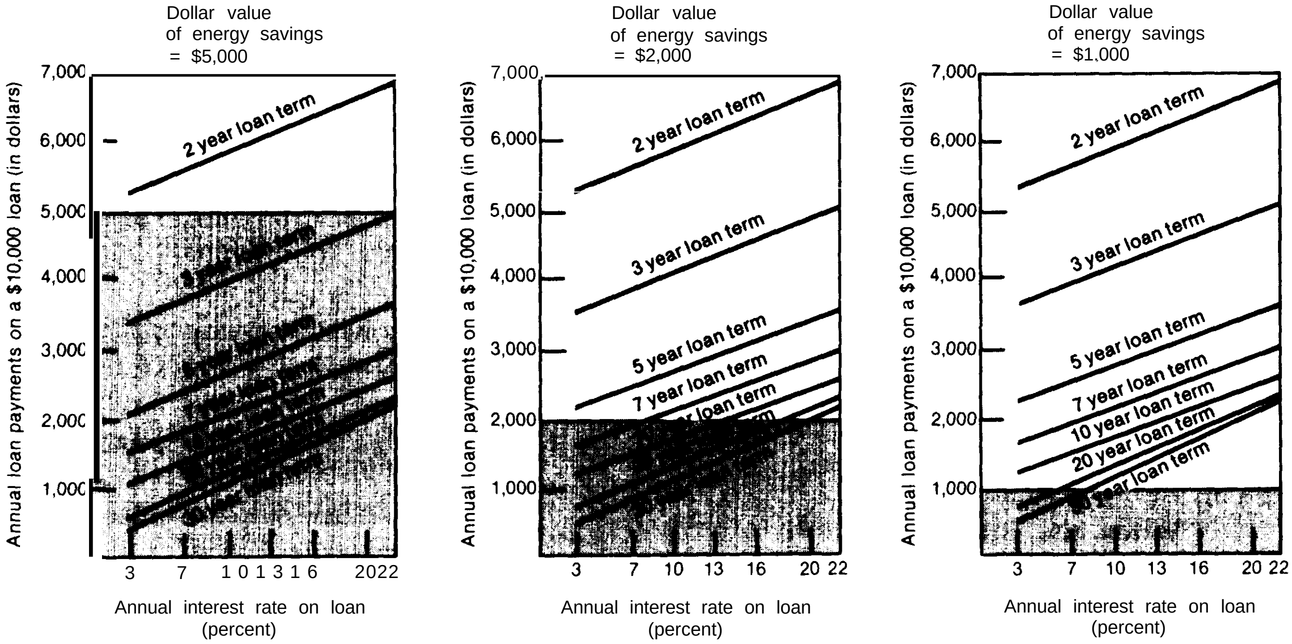
Impact of Risk

The problems faced by a building owner forced to finance a retrofit with short-term, high-cost debt are made much more serious by the uncertainty of the return on retrofit for his particular building, even though, on the average, the general prospects for retrofit are good. Based on the limited information cited earlier on the accuracy of audits, it is possible that savings from a retrofit could be 50 and even 70 percent below those predicted by an audit. (There is an equal likelihood that actual savings will be above predicted.) A predicted 3-year payback retrofit will turn into a 6-year payback retrofit if actual savings are 50 percent below the prediction, and it will turn into a 10-year payback retrofit if savings are 70 percent below what is predicted.

Extent of savings	First-year savings *from a $10,000* loan	*Payback* (in years)
Predicted by an a audit................	$3,300	3
50 percent below prediction.............	$1,650	6
70 percent below prediction..................	990	10

*In years after the first year, Inflation in energy costs (even if no faster than general inflation) will increase the value of energy savings relative to debt service. If energy costs increase at the rate of inflation, they will increase in current dollars and will be constant in real 1972 dollars, while fixed annual debt service payments are constant in current dollars and decrease in real 1972 dollars over time. Thus, any debt service payment in excess of fuel savings will diminish over time.

Figure 1.—Combinations of Loan Terms and Interest Rates Which Allow the Value of Energy Savings to Exceed the Cost of Borrowed Money the First Year



Case 1: Energy savings from a 2 year payback retrofit (maximum payback considered by an individual or local partnership owner)

Case 2: Energy savings from a 5 year payback retrofit (criteria used by corporations, insurance company owners)

Case 3: Energy savings from a 10 year payback retrofit (maximum payback criteria of any owner interviewed)

Key:

Cash flow loss the first year

Cash flow *increase* the first year

SOURCE. Office of Technology Assessment

it would be devastating, especially to many small business owners, or investor-owners of multifamily buildings, to carry the debt service for a major retrofit and fail to achieve the energy savings necessary to keep their cash flow up. Yet this is a realistic possibility given both the newness of the retrofit business and the individual nature of building energy performance.

The Impact of Two Forms of Subsidies: Lower Financing Costs and Tax Credits

Until interest rates drop, various subsidies from public sources or private sources such as utilities may be helpful. OTA analyzed some hypothetical multifamily buildings to determine whether a tax credit* or a financing subsidy might increase the ease of doing a retrofit and concluded from this analysis that a financing subsidy is more helpful in making retrofits possible and less expensive than a tax credit. The beneficial impact of a financing subsidy is greatest for a hypothetical low-rent high energy cost building typical of the low-rent end of the multifamily market. An unsubsidized retrofit

*It should be remembered that a tax credit for energy retrofit is only one of several tax provisions that affect energy use and energy retrofit. Energy expenses are fully deductible as a business expense, while Investments In energy retrotit can be partly deductible through deductions of interest rates and depredation.

loan (16 percent interest for 5 years) for a 6-year payback retrofit virtually wipes out the cash flow of this building.

A subsidy of approximately 15 percent to lower the interest rate and extend the loan term (13 percent interest for 10 years) restores the cash flow of the building immediately and increases it noticeably by the fifth year following the retrofit. (This analysis of hypothetical multifamily buildings is described in ch. 4.) Of the building owners interviewed, two-thirds preferred a financing subsidy to a tax credit. The one-third that preferred a tax credit included some partnerships that welcomed increased tax shelters, and also included some corporations that had adequate internal sources of finance but would benefit from a tax shelter.

When the Building Owner Is the Government

Energy use in buildings owned by local, State, or Federal government is significant. About 0.5 Quad of energy was used by public buildings in 1980 and about 1.5 Quads in educational buildings, most of which are publicly owned. Much like the corporate or large institutional owner, governments and school districts have annual formal budgeting procedures which identify the importance of energy cost increases and compare them from year to year. Governments and school districts have professional general property management department and often at least part-time energy advisors.

Unlike the corporate or large institutional owner, on the other hand, government owners of buildings have severe constraints on access to capital due to constraints on annual budgets and many kinds of limits on bonding authority. The result (see ch. 9) is that government owners of buildings often implement effective operating programs of improved maintenance and energy conservation practices by building occupants but restrict their capital investment in buildings to retrofits with 1 to 2 years payback. Only if the retrofit can be linked to other major repairs (such as roof insulation with new roofs) or if paid for by a Federal grant, are longer payback periods allowed.

General Prospects for Retrofit of Buildings in Cities

Public programs and private campaigns to market increased energy retrofits of buildings must take into account the variety of motivations of building owners. Owners not likely to retrofit their buildings either lack financial reason to do so, lack feasible means to do so, or both. The implications for public policy and private marketing are different for each category.

The category of owners willing and able to retrofit (labeled category A in table 5) do not need

Table 5.—Owners Likely and Not Likely to Retrofit Their Buildings

Owners' access to finance and tolerance of risk	Importance of reducing energy costs to owner's goals: Important	Importance of reducing energy costs to owner's goals: Not Important
Owner can both finance and absorb risk	**A. Willing and** *able to retrofit* • Corporate owner-occupants of commercial buildings • Institutional investor-owners of commercial and multifamily buildings	*B. Able but unwilling* • Large partnership owners of tenant-metered multi-family buildings • Well.financed owners of office buildings and retail buildings in tight, energy-insensitive markets (large partnerships and development companies)
Owner can't risk and/or lacks financing	*C. Willing but* **not able** • Owner-occupants of small multi-family buildings • Small business owner-occupants • Individual and small partnership owners of master-metered multi-family buildings . Individual and small partnership owners of office buildings in energy. sensitive markets Ž Government owners of buildings	*D. Unwilling and* **unable** • Individual and small partnership owners of tenant-metered multi-family buildings • Individual and small partnership owners of office or retail buildings with net or pass-through leases in energy insensitive markets • Owners of buildings in marginal areas

SOURCE: Office of Technology Assessment, any additional public incentives to retrofit. Many are prime targets for private marketing efforts by companies that specify and/or install retrofit products. Category B is able but unwilling to retrofit. This category of owners would be expected to respond to increased requirement for energy efficiency in existing buildings. If required, they would have the means to carry out the retrofit.

Those owners that are willing and even anxious to retrofit but lack access to low-cost finance and good technical advice and cannot to/crate risk are labeled category C in table 5. These owners would be prime targets for marketing by successful private companies organized to put up capital and absorb the risk of retrofit. These owners are also likely to respond to public programs that reduce financing costs and lower the risk of retrofit.

The most difficult to motivate are the owners i n category D for they are both *unwilling and* unable to retrofit. If local governments choose to require them to invest in the energy efficiency of their buildings (through an energy efficiency code for existing multifamily buildings, for example) local government must also see to it that financing of at least moderately long terms is available, or these owners will not be able to comply with the requirement. Owners of buildings in marginal areas are unwilling to invest in their buildings unless they believe the neighborhood is viable enough to recoup their investment in the resale value of the building. For such owners, an energy retrofit program is best folded into a general neighborhood rehabilitation program which combines concentrated private investment in one neighborhood with such public investment as improved sidewalks, storm sewers, and tree planting.

There are insufficient data on either the physical nature of the building stock or patterns of ownership to allow anything but very rough estimates of the amount of energy that might be saved by each of these categories of owners. OTA estimates that about 1 Quad of the 4-Quad gap in foregone energy efficiency retrofits is attributable to multifamily and commercial building owners that are willing but unable to retrofit because they lack financing and/or access to reliable information. Another 1.5 Quads of the foregone retrofits would be due to building owners that were unwilling to retrofit their buildings because they could see insufficient advantage in doing so. About two-thirds of these owners also lack access to financing or professional advice.

The rest of the estimated 4 Quads of foregone retrofits would result from moderate and upper income homeowners in cities unable or unwilling to finance retrofits of moderate and high capital cost compared to savings (about 1 Quad) and low-income homeowners (regardless of location) unable to finance any retrofits (about 0.5 Quad).

PROSPECTS FOR DISTRICT HEATING

District heating is a system for piping heat in the form of hot water (or steam) from a central source of heat to individual buildings. Under the right conditions a well-managed district heating system may be an energy efficient way of supplying heat to city buildings.

From a national energy perspective, district heating offers an opportunity to save fuel oil or natural gas by making use of the waste heat from electricity generation for space and water heating. Hot water district heating has been widely and successfully introduced in Northern Europe over the past three decades. District heat also offers an opportunity to shift from premium fuels such as natural gas and distillates to coal or renewable resources (including municipal solid waste) for supplying heat to buildings. To building owners who are district heating customers, it promises slower increases i n energy prices. For local governments, district heating can be a tool in the overall task of economic development since it uses local workers for construction and operation, helps attract new development to central city locations, and helps to stabilize energy prices for existing buildings.

For all the possible advantages of district heating, however, the design, approval, construction, and successful operation of a district heating system is a formidable undertaking whose complexity and difficulty should not be underestimated. To be successful, a district heating system must offer heat at prices that are low enough to persuade owners of existing buildings to abandon their buildings' natural gas or fuel oil boilers or furnaces, retrofit their buildings to accept the hot water (or steam) from the district heating system and continue to purchase the district heat through the life of the system. Or the system must persuade owners of new buildings of the long-term advantages of foregoing the cost of their own heating system and equipping their buildings to take district heat rather than burn fuel directly.

If general interest rates lower substantially or a substantial financing subsidy is made available, hot water district heating could become a sensible long-term investment that stabilizes fuel prices costs over the long run in one or two dozen U.S. cities. **At current high interest rates and without special subsidies, large-scale district heating may be feasible for those few U.S. cities with dense areas of customers using expensive fuel oil, and a long enough heating season to make possible a reasonably high use of district heating capacity.** This number is less than five and may even be zero. However, small district heating systems for a small number of large buildings located close together may be feasible even at current high interest rates.

PROSPECTS FOR PRIVATE SECTOR MARKETING OF ENERGY RETROFITS

In theory, there should be ample opportunity for private businesses to fill the gap between the large potential return on investment in energy efficiency and the slow pace of retrofit among some types of buildings. Businesses willing to provide the capital over a long term and willing to absorb all or part of the risks of retrofits to individual buildings ought to be able to realize part of that return.

Investors could lease energy efficient equipment to building owners and claim the tax benefits for themselves. They could install energy efficiency measures and provide energy savings guarantees to building owners. Or they could take over responsibility for the energy costs of a building as energy management companies. In the latter case the investors, in return for a monthly energy management fee, would install energy efficient equipment and assume all responsibility for paying utilities.

In practice OTA was able to identify only a handful of enterprises providing retrofit capital or absorbing the risk of retrofit. In part this is the result of the general difficulties encountered by all new businesses in a time of high interest rates. Energy retrofit enterprises, however, also face several special problems. It is difficult to predict accurately energy savings from specific energy efficiency investments partly because much retrofit technology has not yet been installed in many buildings. It can be difficult to come to a legally viable agreement on what constitutes energy savings given variations in energy use caused by changes in weather, occupancy of a building, and occupant behavior. It can be difficult to agree on a definition of the equipment to secure the investment since much energy efficient equipment becomes part of the building it is installed in.

OTA was also able to identify only a few co-ops and nonprofit corporations involved in the retrofit of buildings. Co-ops and nonprofit corporations are hampered by lack of capital and the difficulties of managing a large-scale retrofit program.

WILL GAS AND ELECTRIC UTILITIES STIMULATE INVESTMENT IN ENERGY RETROFITS?

Rapid deterioration in the financial health and future prospects for many electric and gas utilities have created more than token interest in developing energy retrofit programs. Customers are increasingly vocal against utility rate increases at rate hearings. In response to increased prices, customer demand for electricity and gas has grown more slowly than forecast a decade ago and in some utility areas has actually declined. In an era of growth in interest costs and inflation in construction and fuel costs, lags in utility ratemaking have led to utilities earning less than the designated rate of return. in response to many of these problems, some utilities have developed energy efficiency improvement programs either to improve relations with customers, earn a greater return, or both.

Some utilities have energy retrofit programs in response to directives by their State regulatory commissions (e.g., Florida, New York, and California) and others developed energy audit programs on their own. In all, about 65 utilities offered residential energy audits as of the winter of 1977-78 before the Federal Residential Conservation Service (RCS) program was announced. Even if such audit programs are no longer mandated by the Federal Government under the RCS, many utilities are likely to continue them. Customer demand for utility audits, however, is likely to remain limited unless the utility markets audits vigorously with an eye to achieving measurable energy conservation goals.

A few electric utilities have built energy retrofit programs into their projections for future generating capacity and have deliberately exchanged planned new capacity for planned curtailment of demand. The New England Electric System (NEES) for example has announced a program to assist in the retrofit of commercial buildings for load management, thus reducing the need for new peak generating capacity. As now structured, the NEES program would not affect residential buildings much at all.

Theoretically, both slow-growing utilities, like NEES, which have time to plan and assess conservation, and fast-growing utilities, such as those in Florida who have to try everything to avoid falling short of meeting demand, could build energy retrofit programs into their strategic planning. In practice, utilities who do this must have the innovative leadership to develop new products, new marketing techniques, new customer relations, and new forecasting and monitoring techniques. **In a period when utilities are struggling against very difficult financial problems, OTA concluded that few may develop the leadership to undertake ambitious large-scale energy retrofit programs on their own.** A larger number of utilities may be willing to cooperate with State governments that are promoting energy retrofit programs as in Florida and California. As electric utilities become increasingly interconnected across State boundaries, there could be a role for the Federal Government in encouraging cooperation among State utility regulatory commissions as they integrate conservation goals and planned new electric generating capacity. Utilities, however, will continue to look to the State ratemaking process for encouragement or discouragement of conservation programs since State level ratemaking determines utility return.

PUBLIC SECTOR PROGRAMS TO STIMULATE ENERGY RETROFITS

Potential Role of City Governments in Urban Building Retrofit

A few visionary leaders in a few cities have created a link between the energy retrofit of local buildings and such broad goals as the long-term viability of the housing stock, and the long-term stability of regional income and economic productivity. They have promoted this view in speeches and reports and encouraged citizens to be aware of energy and its role in the city or region.

In most cities, however, citizens' worry about rising energy costs has been more directed at the local utilities, and mayors and city councils feel little pressure in city hall to do anything directly about energy. Most cities do not have active energy programs. Only 5 percent have full-time energy coordinators; most of the part-time energy coordinators spend less than 1 day a week on energy. The primary energy concern of most mayors and formally designated city energy coordinators is to reduce the growing share of energy cost in the cities budgets.

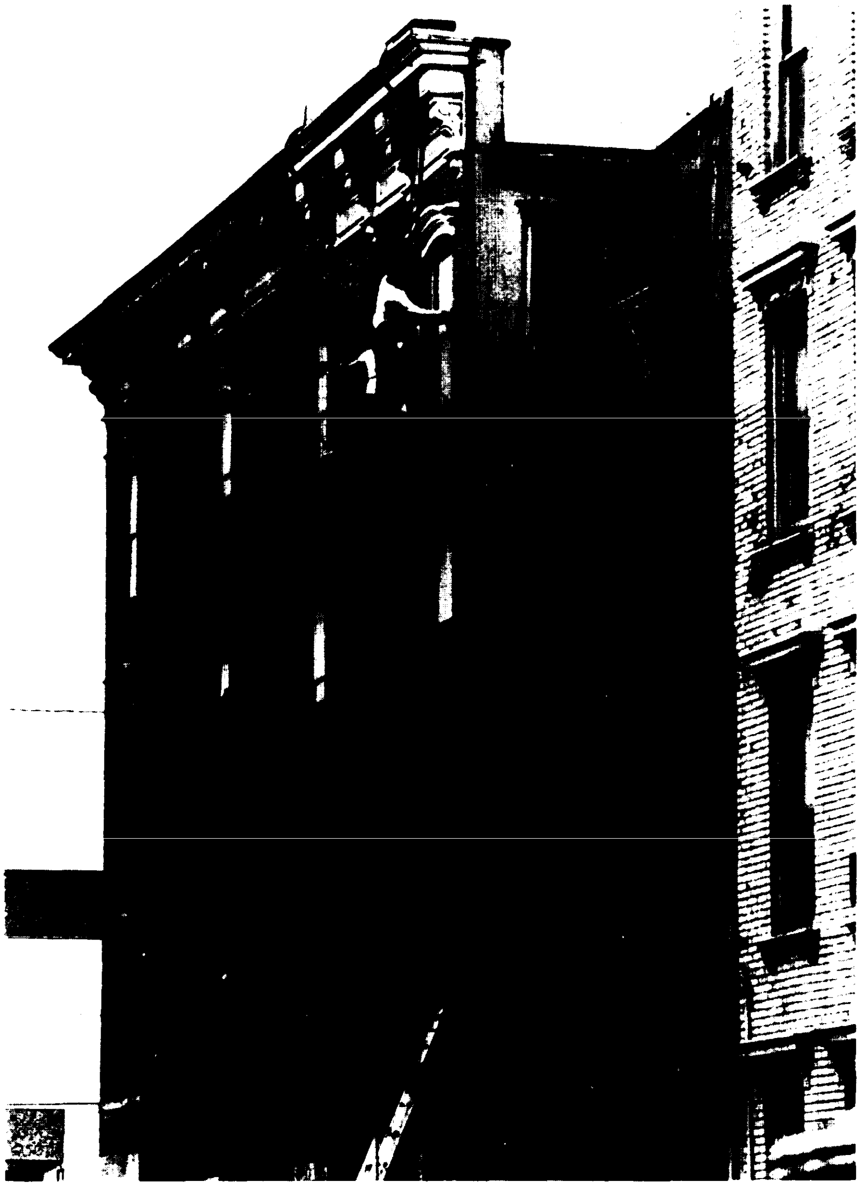


Photo credit: *OTA staff*

For many cities, energy retrofit programs fit best in the context of programs to promote general housing rehabilitation

For some cities energy problems do reach city hall in the form of complaints about landlords' failure to provide adequate heat. In New York City, for example, the number of such complaints increased from **225,000** in 1978-79 to **320,000** in 1980-81, In cities where a metropolitan oversuppply of housing softens the market for rental housing in the center city, the rapid increase i n energy costs is sometimes perceived as a trigger for landlord abandonment of buildings. Such abandonment has been reported as severe in such smaller cities as Rochester, N.Y., and Springfield, Mass.

Many cities have incorporated energy retrofit into their housing rehabilitation programs. These are usually financed by Federal community development block grants (CDBG) or other housing rehabilitation funds. Linking retrofit to general housing rehabilitation has two advantages. It makes possible general repairs in roof or windows that are needed to make the energy efficiency measures work. It also addresses the concern of property owners confronting a retrofit investment that the building as a whole hate resale value and that the neighborhood it is located in be economically stable. Housing rehabilitation programs in cities generally proceed neighborhood by neighborhood, often combining support for private rehabilitation with expenditures on such public works as sidewalks. **A program that promotes energy retrofit in the context of general property upgrading fits well with city government concern for the general health of the housing stock and the property tax base.**

Cities have other ways to promote building retrofit besides their housing rehabilitation programs. They may promulgate energy efficiency building standards at time of sale (Portland), issue municipal bonds to subsidize private retrofit expenditures (Minneapolis and Baltimore), or manage Federal weatherization directly and vigorously (Des Moines) rather than allow it to be administered by local nonprofit antipoverty agencies.

Potential Role of State Governments in Urban Building Retrofit

Some States have active energy audit or retrofit programs with potentially far-reaching results. Florida and California typify one source of motivation for States. Both States have rapidly growing populations and projected requirements for continued expansion of electrical generating capacity. Both States have difficultly finding large number of sites for new powerplants. Although their climates are mild and yearly energy bills lower than States with colder climates, both States face certain increases i n natural gas prices and possible sharp increases in electricity prices it powerplant capacity must be added very fast. Florida and California have both required that utilities develop extensive energy audit programs, linked to slowdowns in construction of new generating capacity.

New York, Minnesota, and Massachusetts on the other hand have slowly growing or stable populations, State officials are not concerned about utility construction plans since utilities in these States are likely to face economic problems caused by excess generating capacity rather than the need to construct new generating capacity. Rather, State officials are motivated by concern about the health of the housing stock and hardship caused by the combination of high energy prices and severe winters.

States seeking to bring about large-scale retrofit have several possible tools to use. They may require high-powered utility audit programs (generally using the framework of the Federal RCS audit program), bring effective management to bear on the Federal weatherization program (Pennsylvania), require energy efficiency building code standards for new or existing buildings (Minnesota), or occasionally provide their own subsidized financing for energy retrofit (New Jersey).

For every State, however, which has developed programs to stimulate building retrofit, there are many States with similar concerns

which have not developed active retrofit programs. Like cities, States have many other demands on their economic and managerial resources. Thus, State stimulus of building retrofit is likely to remain uneven, strong in some States and weak or nonexistent in others.

THE FUTURE: FEDERAL POLICY OPTIONS FOR STIMULATING THE RETROFIT OF BUILDINGS IN CITIES

Many programs developed or implemented by States and local government actually originated with the Federal Government. After 7 years of steadily increasing Federal involvement in energy conservation since the 1973 oil embargo, a basic shift in emphasis is now underway, All but a few of the Federal energy conservation programs have been substantially reduced in the 1982 budget.

The current debates about the proper role of the Federal Government in energy conservation, housing and community development programs and assistance to the poor will affect the nature of the Federal role in stimulating the retrofit of buildings in cities. The following discussion of the Federal options for stimulating building retrofit reflects the broad range of Federal roles advocated by different parties to the debate.

Option A: No Intervention

The rationale for this option for the Federal role is that energy retrofit is best left to the private sector. If managerial and legal problems can be solved, a wide variety of innovative technical and financial approaches will be developed by the private sector over the next decade to take advantage of the investment opportunities presented by retrofit. Efforts to reduce the high risk of retrofit by more accurate documentation of energy savings will eventually be better undertaken by trade associations and other private organizations with a stake in the results than they would be by the Federal or other levels of government.

Under this option, State governments and city governments would be free to develop energy retrofit programs of their own: States, as part of their regulation of public utilities; cities, as part of community development programs. Federal efforts to stabilize the economy, to allow accurate energy price signals and to lower interest rates are viewed as the only legitimate Federal role in accelerating retrofit opportunities.

Option B: Small Federal Market Assistance Role

Under this view, the private market must be assisted by the Federal Government because there is a strong national interest in higher energy efficiency, and because it is possible that the private market, by itself, is insufficient to satisfy national need and to maximize economic efficiency. On the other hand, according to this view, constraints on the Federal budget are severe enough to prohibit all but a small Federal role.

Even with a fairly low budget, however, the Federal Government could develop a clearly focused research, development, and information program to reduce the risks of retrofit. Such a program is probably best modeled on private sector efforts in order to ensure maximum information exchange. Several restaurant chains have set up proprietary programs to test retrofits in different building types. Sears & Roebuck explicitly tested several kinds of retrofits in its stores before launching a multi million dollar retrofit program. An ongoing Department of Energy program to test retrofits to hotels and motels and disseminate the results through the American Hotel & Motel Association could be expanded to other trade associations and other building types. The most urgent need is to document retrofits within the multifamily building sector and publicize them through the several multifamily trade associations, Small-scale Federal retrofit subsidy programs, such as the schools and hospitals program and the Solar and Conservation Bank (described in ch. 9) would have the most impact if used primarily to increase knowledge and reduce the risk of retrofit. Public housing modernization funds used for energy retrofit of public housing could also be used to document energy savings from energy retrofits. Under this approach, private building owners or public housing authorities receiving subsidies, would be asked to participate in a program to describe and document the results of the retrofit and disseminate it, through trade associations and chambers of commerce, to other building owners.

Option C: Large Active Federal Role

This Federal role would be consistent with both an activist philosophy of government and the view that reducing U.S. energy use over the long run is an important national goal for reasons of national security, minimizing disruption to the environment and maximum economic growth and competitiveness. Under the rationale for a high budget Federal role, if energy retrofit is the path of least total cost and if it is not likely to come about because of the nature of the energy problem and private markets, then the Federal Government should encourage and subsidize energy retrofit to the point where the major part of the cost-effective retrofit actually occurs.

This Federal approach should first and foremost include the risk-reducing activities described in the low budget approach above. A reduction in the perceived risk of a retrofit is essential if all building owners are to take advantage of a financing subsidy and make the investment. Vigorous promotion of State and utility development of audit programs for all building types and development of audit training programs would also, under this approach, help reduce the perceived risk of retrofit.

The Federal Government already provides a major financing subsidy to single-family homeowners in the form of a residential energy tax credit. About 4.8 million taxpayers used the credit in 1979 to make about $3.5 billion worth of energy efficiency investments. The credit cost the Treasury about $440 million. Multifamily building owners currently have no effective access to energy tax credits (although there is a narrowly defined business energy tax credit for improving the energy efficiency of industrial processes).

A new Federal effort to subsidize energy retrofit could either extend the energy tax credit to multifamily and commercial building owners or it could take the form of a program to subsidize interest rates and extend energy retrofit loan terms to such owners. OTA estimated the approximate size of a large-scale effort designed to produce 2 Quads of annual savings through retrofit at the end of 10 years. A subsidy used to lower annual interest rates by 2 to 3 percentage points and extend loan terms could subsidize about $4 billion worth of retrofits per year at an annual cost of about $600 million, a little more than the current cost to the Treasury of the residential energy tax credit (see table **6).** (The assumptions behind this estimate are described in ch. 11 .)

Table 6.—Two Forms of Federal Subsidy

Subsidy type	Cost per year	Energy impact	Estimated value of savings (in dollars)
Subsidized $40 billion in conventional loans over 10 years for energy retrofit	$600 million	2 Quads saved annually after 10 years	$14 billion to $30 billion per year
Ten district heating systems allowed to use tax-exempt financing ($1.5 billion each), constructed 10 years	$600 million	0.3 Quad displaced annually from fuel oil or gas to coal, solid waste or waste heat (after 10 years)	$1.2 billion per year

SOURCE Off Ice of Technology Assessment

An active Federal approach might also include a financing subsidy for district heating, most conveniently by permitting tax-exempt bonds in magnitudes greater than the currently allowed $10 million. A subsidy to pemit 10 systems of $1.5 billion each in 10 cities is likely to cost annually about 4 to 5 percent of the system (in foregone taxes on tax-free bonds). The 10 systems could be expected to displace about one-third of a Quad of fuel oil or natural gas and substitute coal, heat from solid waste or waste heat from electricity generation.

Two Quads of energy savings per year is a substantial amount of energy. It is the equivalent of 1 million barrels of oil per day, or about 20 percent of all U.S. oil imports in 1981. It is also equivalent to about 36 electric generating plants of 1,000 **MW** each, at average utilization rates. There are two ways of estimating the value of 2 Quads of energy savings in 1981 dollars; they would be worth $14 billion at the 1981 average price for home heating oil of about $1 per gallon, or $20 billion to $30 billion at the current estimated price of synthetic oil from coal in 1981 dollars. (See the forthcoming OTA report on synfuels for further discussion.)

The value of savings from an equivalent subsidy to district heating is much less. If district heating primarily serves to shift demand from premium fuels, such as oil and gas to coal, the savings comes from the price difference between the two kinds of fuel, At $4 per million Btus, (about the current price differential between oil and coal for utilities), substituting 0.3 Quad of heat from coal for heat from oil would be worth $1.2 billion.

It also may be possible, although OTA has not analyzed this option, to achieve the same impact on energy retrofit not by subsidizing retrofit but by reducing or eliminating the tax deduction of energy costs as a business expense, since this tax deduction has the effect of subsidizing the inefficient use of fuel.

Energy Conversion Factors

To convert	Into	Multiply by approximately	Exactly
Energy **units used in national energy projections**			
1. Quads/year.	Millions of barrels of oil per day	0.5	0.4760
2. Quads	Trillion cubic feet of natural gas	1.0	0.9872
3. Quads	Million tons of coal	44.0	Depends on type of coal
4. Quads	Billions of kWh	**300.0**	*294.0000*
5. Quads/year of primary fuel[a].	Number of 1,000-MW powerplants	18.0	Depends on specific assumptions
Energy units used **in** *building energy analysis*			
1. Million Btu/year	Thousand kWh/year	**300.0**	**294.0000**
2. Million Btu/year	Gallons of fuel oil	7.0	7.1400
3. Million Btu/year.	Thousand cubic feet of natural gas	1.0	0.9870
4. Million Btu/year	Therms of natural gas	10.0	10.0000
Energy units used in district heating analysis			
1. Trillion Btu of annual thermal output.	Million kWh of annual output (thermal kWh)	300.0	Depends on specific assumptions about capacity, etc.
2. Megawatts (thousand kilowatts) of thermal capacity[b]	Million Btu of annual thermal output	8,800.0	
3. Billion Btu of annual output[c].	Kilowatts of peak thermal capacity	114.0	
4. Million Btu/hour of peak thermal output.	Kilowatts of peak thermal capcity	300.0	
Energy units **used in powerplant analysis**			
1. 1,000 megawatts of electric generating capacity[d].	Trillion Btu of annual end-use output of electricity	17.5	Depends on specific assumptions about capacity utilization and fuel conversion efficiency
2. 1,000 megawatts of electric generating capacity[e].	Million Btu of primary fuel used to generate electricity	58.0	
3. Billion Btu of annual end-use electricity	Kilowatts of electric generating capacity	57.0	
4. Billion Btu of annual primary fuel used to generate electricity	Kilowatts of electric generating capacity	18.0	

NOTES: Assumptions used in conversions between annual energy output and peak capacity for district heating and electric powerplants

[a] If one 1,000-MW plant requires 56,555 billion Btu/year primary fuel consumption (see explanation e below) then 1 Quad/0.0565 Quad per plant = 17.7 1,000-MW plants per Quad.

[b] 1 MW x 8,766 *hours* x 0.3 capacity factor = 2,632,000 kWh/300 kWh per million Btu = 8,773 million Btu

[c] 1,000 million Btu (1 billion Btu) x 300 kWh per million Btu = 300000 kWh/ (8,766 hours per year x 0.3 capacity factor) = 114 kW generating capacity

[d] 1,000 MW x 8,766 hours x 0.6 capacity factor = 5,260,000 kWh *per year/300 kWh* per million Btu = 17,532 billion Btu/year end-use electricity per year from one 1,000-MW plant.

[e] To produce 17,532 billion Btu/year end-use electricity from a 1,000-MW powerplant – by 0.31 (efficiency of conversion from fuels to electricity) = *56,555* billion Btu/year primary fuel consumption for one 1,000-MW powerplant

[f] One billion Btu of annual end-use electricity x 300 = 300,000 kWh annual output – (8,766 hours per year x 0.6 capacity factor) = 57 kW of electric generating capacity

[g] One billion Btu of primary fuel used to generate electricity x 0,31 efficiency of conversion from fuels to electricity = 31(l million Btu of end-use electricity x 300 kWh per million Btu = 93,000 kWh end-use output - (8,766 hours per year x 0 *6* capacity factor) = 177 kW of capacity