Building Energy Efficiency

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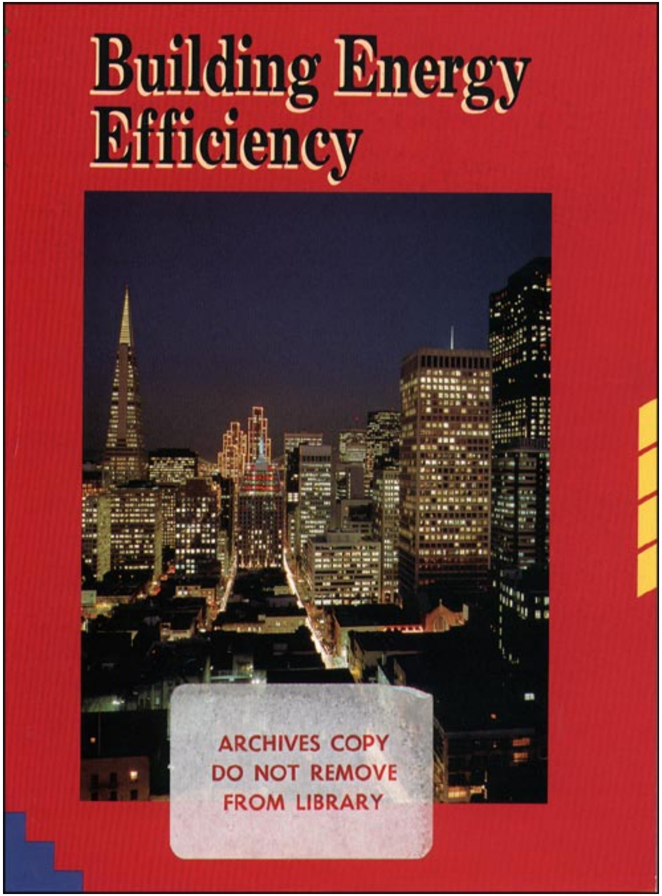

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Foreword

This report was prepared as part of the ongoing OTA assessment, ‘ ‘U.S. Energy Efficiency: Past Trends and Future Opportunities,” carried out in response to requests from the Senate Committees on Governmental Affairs and Energy and Natural Resources; the House Committee on Energy and Commerce; and an endorsement from the Chairman of the Subcommittee on Environment of the House Committee on Science, Space, and Technology. Other reports in this assessment examine energy use in the Federal Government, industry, transportation, and the role of utilities in energy efficiency.

This report focuses on energy use in buildings, which account for over one-third of all energy used in the United States. Significant energy savings in buildings are possible through the use of commercially available, cost-effective, energy efficient technologies; yet adoption rates for these technologies are often low. Interviews with industry, property managers, homeowners, and others were used to explore why technology adoption rates are so low. Past Federal efforts to encourage energy efficiency are reviewed, and policy options for encouraging the adoption of energy efficient technologies are discussed.

OTA benefited greatly from the substantial assistance received from many organizations and individuals in the course of this study. Members of the advisory panel provided helpful guidance and advice, interviewees helped to ensure that all perspectives were accurately portrayed, and reviewers of the draft report contributed greatly to its accuracy and completeness. OTA and the project staff sincerely appreciate their time and effort.

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NOTE: OTA appreciates and is grateful for the valuable assistance and thoughtful critiques provided by the advisory panel members. The panel does not, however, necessarily approve, disapprove, or endorse this report. OTA assumes full responsibility for the report and the accuracy of its contents.

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Report Contents

Summary

Summary

INTRODUCTION

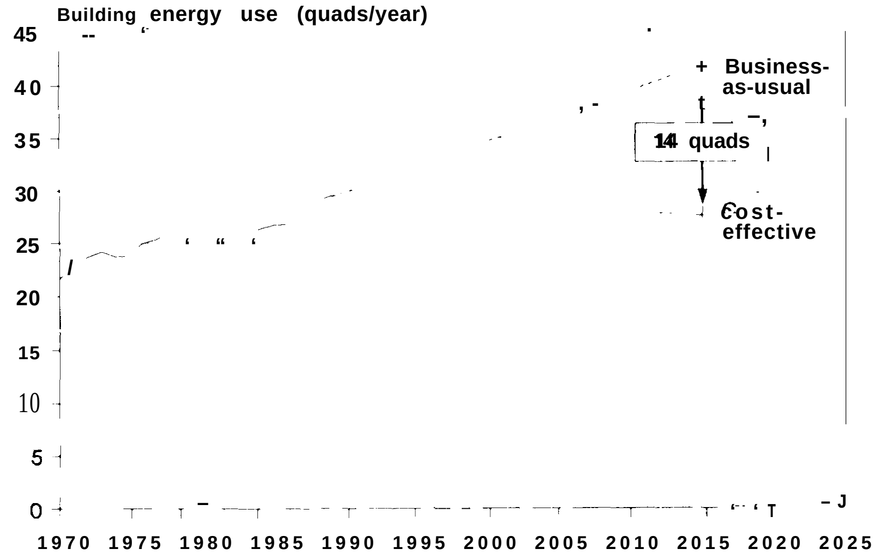
Residential and commercial buildings account for about one-third of U.S. energy consumption, at an annual cost of $170 billion. Using commercially available, cost-effective technologies, building energy consumption could be reduced up to one-third by 2015, compared to a business-as-usual projection (figure 1).[1] Many other estimates of this savings potential exist and, although the results vary, there is general agreement that the untapped potential for improved energy efficiency in buildings is significant. Along with saving both energy and money, wider use of efficient technologies would address multiple environmental concerns, offset the need for additional electricity generating capacity, and reduce national dependence on imported oil. This report assesses technologies for enhanced energy efficiency in buildings, discusses why they are not widely used, and offers Federal policy options for encouraging their use.

BACKGROUND

Energy use in buildings has grown in the last 20 years (figure 1). Sheer increases in numbers underlie much of this growth-more people, more households, and more offices. Increased service demand —more air conditioning, more computers, larger houses—has contributed as well. However, the application of improved technology has moderated this growth. Energy efficient building shells, appliances, and building designs have lowered energy intensity in residences (energy use per household per year) and stabilized energy intensity in the commercial sector (energy use per square foot per year).

Building energy use in the future will be driven by technological change but will also be influenced by

Figure I—Building Energy Use: Two Future Scenarios



NOTE: "Business-as-usual" is OTA's estimate of future consumption without policy change. "Cost-effective" is OTA's estimate of future consumption if all energy efficient technologies with a positive net present value are implemented. There is considerable uncertainty in both estimates. See text for details.

SOURCE: Office of Technology Assessment, 1992 (see ch. 1).

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[1] Cost-effective is defined here as positive net present value to the consumer at a 7 percent real discount rate. See ch. 1 for a detailed discussion of energy savings estimates.

Table I--Cost-Effectiveness of Selected Energy Efficient Technologies

Technology	Typical payback (years)
Additional insulation	6 to 7
Compact fluorescent lamps	Less than 2
Condensing gas furnace-95% + efficient	4 to 7
Electronic ballasts for commercial lighting	3 to 4
Improved burner head for oil furnaces	2 to 5
Residential duct repair	Less than 2
Highly efficient room air conditioner	6 to 7
Water heater tank insulation.	Less than 1

NOTE: Payback is the amount of time for the energy savings to exceed the additional first costs. Paybacks shown here are based on the incremental first cost and undiscounted savings of the highly efficient unit relative to a standard efficiency unit. Actual, measured savings rather than predicted savings are used where available. Paybacks will vary depending on climate, use patterns, and other factors.

SOURCE: Office of Technology Assessment, 1992 (see ch. 2).

other factors, including population and economic growth, changes in household size, changes in lifestyle, and migration patterns. Although the complexity and interactions of these factors make it difficult to predict accurately future levels of building energy use, OTA estimates that, in a ‘‘business-as-usual’ scenario (i.e., assuming no policy change), building energy use will continue to grow at a moderate pace, reaching roughly 42 quads by 2015. An alternative perspective, assuming all energy efficient technologies with a positive net present value to the consumer are implemented, suggests building energy use could actually decrease to about 28 quads by 2015. This corresponds to an annual energy savings of 14 quads by 2015 (figure 1), worth $80 billion at today’s energy prices.

ENERGY EFFICIENT TECHNOLOGIES

As suggested by the modeling results described above, there is considerable potential to further improve energy efficiency in U.S. buildings. For most major energy uses, there is a large efficiency gap between the average new units and the most efficient new units available. For example, residential gas furnaces are available with an efficiency of 97 percent, compared to the 78 percent typical of new units sold today. The most efficient room air conditioner on the market today uses 28 percent less energy than the average new unit. Many houses in the United States still lack basic efficiency features, such as storm windows and ceiling insulation. In many cases new technologies have other benefits as well, such as longer life, quieter operation, and greater ease of use. For example, many new commercial lighting technologies can provide a higher quality of light and use far less energy.

While many efficient technologies cost more to purchase, energy savings often more than repay the extra capital cost (table 1). The financial returns offered by these technologies are typically far better than those offered by other personal financia1 investments.

IF IT’S SUCH A GOOD IDEA, WHY HAVEN’T WE DONE MORE OF IT?

If cost-effective technologies are available, why aren’t they in greater use? OTA interviews suggest commercially available, energy efficient technologies are not used for ‘good’ reasons-reasons quite understandable from the perspective of the individual decisionmaker. These reasons include the following:

- There is often a separation between those who purchase energy-using equipment and those who pay to operate the equipment, which undermines existing incentives for efficiency. For example, one-third of housing, and one-quarter of commercial building floor space, is leased or rented rather than owned.
- Decisions on purchasing energy-using equipment require comparisons across many attributes, such as frost cost, performance, appearance, features, and convenience. These other attributes often overshadow energy efficiency considerations.
- Individuals pursue several goals when making energy-related investment decisions—for example, minimizing the time to make a decision, spending the least amount upfront, or minimizing risk by obtaining the same item that worked before. Very few pursue the goal of minimizing life-cycle costs (the sum of capital and operating costs over the life of the equipment), which energy efficient technologies achieve.
- When trading off frost cost and energy savings, consumers will not invest in efficiency unless it offers very short payback periods-less than 2 years for home appliances, for example. In contrast, personal financial investments generally offer much lower returns.
- Energy costs are relatively low (about 1 percent of salary costs in a typical office, for example),

so those concerned with cost reduction often focus elsewhere.

- Energy efficiency is often (mis)perceived as requiring discomfort or sacrifice, limiting its appeal.

These reasons have slowed the acquisition and use of many proven energy efficient technologies. For example, despite their attractive 3- to 4-year payback, less than 4 percent of all fluorescent light ballasts shipped in the United States in 1990 were of the efficient electronic design. These reasons suggest that policy changes may be needed to encourage cost-effective efficiency.

REVIEW OF PAST FEDERAL EFFORTS

The Federal Government has in the past supported efforts to increase energy efficiency, with mixed results. The multiple Federal programs aimed at saving energy in buildings are often narrow in scope, overlooking critical barriers that prevent cost-effective investments in efficiency. Many programs stress only two strategies: providing information or funding retrofits for low-income households and small firms.

Cost-effectiveness criteria are generally not used in program planning or evaluation, particularly in those programs offering grant monies. Federal programs aimed at saving energy in buildings often achieve measurable energy savings, but the cost-effectiveness of those savings remains unclear. Program evaluation is infrequent. For example, the Federal Trade Commission (FTC) appliance labeling program was evaluated only once in its 12-year history, and the Department of Energy's Weatherization Assistance program (WAP) was evaluated only once in its first 15 years. To understand the successes and failures of program goals and implementation, all programs should undergo regular evaluations. Such evaluations require relatively few resources compared to other program activities, and they have the potential to improve greatly program benefits by fine-tuning (or revamping) efforts to save energy in buildings.

POLICY OPTIONS

There are numerous policy options available to the U.S. Congress that could be used to encourage greater use of cost-effective energy efficient technologies. Increasing energy efficiency is in the Nation's interest, yet there are arguments both for and against changes in Federal policy. Arguments for Federal policy change include the market imperfections noted above (e.g., short payback requirements and a separation between those making investment decisions and those paying operating costs), the large untapped potential for energy and financial savings from increased efficiency, and the existence of environmental and other externalities. Arguments against changes in Federal policy include: attempts to increase energy efficiency through regulation or other similar methods may have unanticipated administrative or other costs; past Federal efforts to implement energy efficiency have had mixed success; current levels of energy efficiency reflect consumer preferences given existing economic incentives and levels of information; and there is often little consensus on the best methods to promote efficiency.

Federal policies for improving building energy efficiency must be considered in the context of the diverse State and utility efforts already underway. In almost all areas of energy efficiency policy—incentives, information, research & development, regulation-States and utilities are often more active than the Federal Government. Increased Federal efforts would be most effective if they complemented these existing efforts. In most cases, States and utilities would welcome Federal support and assistance, however in a few areas-notably building codes and utility regulation—an enhanced Federal role would be controversial.

OTA identifies a number of policy options to promote greater use of cost-effective energy efficient technologies. These options make use of several strategies, including:

Changing the incentives for efficiency. Individuals often have few or mixed financial incentives for energy efficiency. Federal policies can address this issue by enhancing these incentives, for example, through pricing changes and tax policy.

Federal leadership through procurement, public recognition, and demonstration. The Federal Government has considerable purchasing power due to its size, and this power can be used to increase the sales and distribution of energy efficient technologies.

Research, development, and demonstration (RD&D) for efficiency. The Federal Government conducts RD&D on buildings technologies, and changes in RD&D planning and execution could help ensure the applicability and usefulness of the results.

Encouraging utilities to invest in efficiency. Utilities are well-equipped to implement efficiency, and Federal actions such as technical support for least-cost planning can aid their efforts.

Mandating efficiency through codes and standards. In some cases regulation may be needed to set minimum efficiency levels, and such regulation may be most appropriate at the Federal level.

Improving information and awareness of efficiency opportunities. The Federal Government can provide information to enhance and support other efficiency programs such as rebates and incentives.

OTA offers a number of specific options of each type. These specific options are grouped into three distinct levels, in order of increasing Federal involvement and energy savings. The *basic* level includes relatively low-cost, simple policy measures that require little or no new legislation or change from present practice (box A). If Congress determines that changes are needed to effect improvements in energy efficiency, then the basic level could be considered as a first step. The *moderate* level includes several options that are more ambitious, and in some cases require changes to existing legislation and increased Federal spending (box B). The *aggressive* level includes options that require new legislation, an increased Federal role in energy regulation, and increased Federal spending (box C). Many such packages could be constructed; the three described here are intended only to illustrate the range of options Congress could consider.

In summary, energy efficient technologies that save energy and money are commercially available, yet often underutilized. The indirect benefits of these technologies-reduced environmental damage, enhanced economic competitiveness, and increased national security-would be considerable. OTA offers three levels of policy options to promote greater use of these technologies.

It is useful to compare the options in this report to those contained in the National Energy Strategy (NES), a comprehensive strategy proposed by the Administration in 1991. OTA finds that the NES options do not represent the range of options Congress could consider to implement energy efficiency in buildings. This report expands the menu of options for the U.S. Congress to consider to implement energy efficiency in buildings.

Box A—The Basic Package

Incentives

- Direct the Departments of Energy (DOE) and Health and Human Services to set aside an adequate amount of program spending for program evaluation; particularly to determine the cost-effectiveness of low-income weatherization.
- Direct and fund DOE to expand research on the measurement and pricing of externalities associated with energy production, distribution, and consumption.

Federal leadership

- Encourage energy efficiency in Federal buildings by upgrading procurement guidelines for energy-using equipment so as to incorporate energy efficiency.
- Extend the Environmental Protection Agency (EPA) Green Lights concept to other end users.

Research, development, and demonstration

- Require all DOE Office of Building Technologies applied research projects reaching the demonstration stage to conduct some minimum level of technology transfer and market assessment.
- Encourage or require DOE to define specific technological goals that relate to program objectives in the DOE Conservation multiyear planning process.
- Conduct regular RD&D program evaluations for Congress to identify the successes, failures, and future direction of projects in the DOE Office of Building Technologies.

Utilities

- Instruct DOE to expand its research and development related to the design, operation, and evaluation of utility efficiency programs.
- Instruct DOE to increase its activities as an information clearinghouse for efficiency program design, operation, and evaluation.
- Instruct DOE to evaluate whether the Northwest Power Planning Council represents a useful model for energy planning that could be applied to other regions of the country.

Mandates

- Assess compliance with and enforcement of existing State building codes as they pertain to energy efficiency.
- Ensure that section 109 of the Cranston-Gonzalez Affordable Housing Act of 1990 (Public Law 101-625) requiring the use of the Council of American Building Officials Model Energy Code, 1989 Edition (CABO MEC '89) in Department of Housing and Urban Development assisted housing is implemented.
- In conjunction with organizations such as the Council of American Building Officials and the American Society of Heating, Refrigerating, and Air-Conditioning Engineers, instruct DOE to continue to improve Federal building standards and guidelines and provide implementation materials and support services to promote their use on the State level.
- Instruct DOE to examine the feasibility and likely impacts of extending the coverage of the National Appliance Energy Conservation Act of 1987 to include appliances and equipment not covered by the program.

Information

- Instruct the Federal Trade Commission (FTC) to revisit its 1979 exemption rulings for appliance energy labeling.
- Instruct the FTC and/or DOE to assess the feasibility of extending labeling requirements to commercial sector equipment.
- Extend labeling requirements to windows and lamps.
- Instruct the FTC and/or DOE to investigate alternative label designs that might inform consumers better.

Box B—The Moderate Package

Incentives

- Pass legislation making utility rebates nontaxable.
- Enact or increase taxes on the production and use of fuels consumed in the buildings sector.
- Direct and fund DOE to provide technical and financial assistance to States interested in measuring and pricing energy externalities.
- Direct the Federal housing and national mortgage agencies to simplify and expand their energy efficient mortgage programs.

Federal leadership

- Allocate (or increase access to) funds for efficiency improvements in Federal buildings.
- Encourage manufacturers, utilities, and other interested parties to extend the Golden Carrot concept to other technologies for demonstration and marketing.

Research, development, and demonstration

- Make greater use of market surveys to assess manufacturer and consumer response to potential new technologies prior to initiating Office of Building Technologies (OBT) RD&D projects.
- Increase industry involvement in RD&D project planning, funding, and execution.
- Examine the feasibility of both least-cost and net-benefit planning for DOE applied conservation RD&D programs.
- Establish an ambitious level of technology transfer and marketing efforts for RD&D projects of OBT beyond that currently pursued.
- Increase OBT funding for RD&D work.

Utilities

- Direct the Tennessee Valley Authority and the power marketing administrations to integrate better least-cost planning techniques and principles into their operations and management.
- Instruct the Federal Energy Regulatory Commission to examine its rate setting and other regulatory actions to determine their consistency with State-approved utility least-cost plans.
- Instruct DOE to support through grants, technical support, or other means State and utility efforts related to the design and implementation of least-cost planning.
- Encourage or require States not already doing so to consider adopting least-cost plans.

Mandates

- Direct and fired DOE to provide technical and financial support to those 34 States with residential building codes less stringent than CABO MEC ’89 to evaluate the cost-effectiveness of upgrading their codes to the CABO benchmark.
- Direct and fired DOE to provide technical and financial support to States considering the adoption of more stringent commercial building codes.
- Direct and fund DOE to provide technical and financial assistance to communities and States instituting retrofit-on-resale rules.
- Direct and fund DOE to enlarge their efforts at code official training and education.
- Extend National Appliance Energy Conservation Act of 1987 coverage to include residential and commercial equipment not currently covered by the program.

Information

- Direct DOE to explore methods for producing an accurate, verifiable whole- building rating, and to provide technical support for State and utility programs that rate whole buildings.
- Encourage DOE to work with manufacturers, designers, and builders to demonstrate energy efficient equipment that works.
- Encourage DOE to set Up a building energy audit program involving architecture and engineering schools.

Box C—The Aggressive Package

Incentives

- Mandate the measurement and pricing of energy externalities.

Federal leadership

- Instruct DOE to promote actively the demonstration of efficient technologies in Federal buildings to strengthen markets for energy efficient goods and services.

Research, development, and demonstration

- Require DOE to market buildings conservation RD&D results to utilities, State agencies, and its own regulatory programs, including the Office of Codes and Standards (within the Office of Building Technologies).
- Require DOE to perform least-cost or net-benefit conservation RD&D planning.

Utilities

- Direct federally owned utilities to provide incentives to, or require, its customer utilities to adopt least-cost plans.

Mandates

- Require States to meet or exceed federally set minimum building efficiency standards, such as the Building Energy Performance Standards (BEPS).
- Adopt more stringent cost-effective National Appliance Energy Conservation Act standards by identifying equipment efficiency levels that represent longer paybacks than most current standards allow.
- Encourage or require secondary mortgage market institutions (e.g., the Federal Home Loan Mortgage Corporation) to require residences to meet the Council of American Officials Model Energy Code 1989 Edition (or some other major code).

Information

- Require point-of-sale disclosure of whole-building energy ratings.

Chapter 1

Energy Use in Buildings: Past, Present, and Future

Box I-A--Chapter Summary

Energy issues are of continuing policy concern, due to the crucial role played by energy in environmental quality, economic vitality, and national security. In recent reports OTA has suggested that energy efficiency is a critical component of a comprehensive policy framework to further these issues. This report addresses energy use and efficiency in U.S. buildings, which account for over one-third of U.S. energy consumption.

Energy use in buildings has grown in the last 20 years. Sheer increases in numbers underlie much of this growth-more people, more households, and more oftices. Increased service demand—-more air conditioning, more computers, larger houses----has contributed as well. However the application of improved technology has moderated this growth. Energy efficient building shells, appliances, and building designs have lowered energy intensity in residences (energy use per household per year) and stabilized energy intensity in the commercial sector (energy use per square foot per year).

Building energy use in the future will be driven by technological change but will be influenced by other factors as well, including population and economic growth, changes in household six, changes in lifestyle, and migration patterns. The complexity and interactions of these factors make it difficult to predict accurately future levels of building energy use, however OTA estimates that, in a "business-as-usual" scenario (that is, assuming no policy change), building energy use will continue to grow at a moderate pace, reaching roughly 42 quads by 2015. An alternative perspective, assuming all energy efficient technologies with a positive net present value to the consumer are implemented, suggests that building energy use could actually decrease to 28 quads by 2015. Although predicted savings estimates are extremely uncertain, there is general agreement that the technical and economic potential for savings is considerable.

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Chapter 1

Energy Use in Buildings: Past, Present, and Future

INTRODUCTION: THE POLICY CONTEXT

Recent events have once again brought energy issues to the forefront of national policy debate. In 1991 the Persian Gulf War and its effects on world oil markets seized world attention. The same year, the administration released a National Energy Strategy,[1] and numerous legislative options are being considered by Congress in its wake. This renewed interest in energy, however, is different from the prevailing concerns of the 1970s when fears about oil price and availability were triggered by the major oil supply disruptions of 1973 and 1979.

In the 1990s, concerns about U.S. energy production and use are broader, longer term, and more complex.[2] In 1990, prior to the Persian Gulf War, pressing energy concerns related to environmental quality-including regional issues of urban air quality, acid rain, and nuclear waste, as well as global issues such as the role of fossil fuels in climate change. Indeed, the Clean Air Act Amendments of 1990 are among the most significant energy-related national legislation in recent years.

The Persian Gulf War returned energy security to the national policy agenda after a decade of absence, but even the nature of energy security concerns has changed.[3] Concerns about U.S. reliance on imported oil, which has risen steadily from 22 percent of total oil use in 1970 to 42 percent in 1990 and is expected to rise to 62 percent by2010,4 has as much to do with the role of oil imports in the U.S. trade deficit as with the concerns over supply reliability or price volatility.

The role of energy in economic production is also changing as the structure of the U.S. economy changes. For many years, the conventional wisdom held that energy use and gross domestic product (GDP) were immutably linked, moving in lock step. We learned from the energy shocks of the 1970s, however, that ingenuity and innovation can substitute for energy supply when the price is right. When energy prices rise, people respond over time by shifting their market basket of purchases and by developing more efficient ways to provide energy services. The energy consumed per unit of GDP fell 2,4 percent per year between 1972 and 1985, mostly due to improved energy efficiency (figure 1-1).[5] This steady drop in energy intensity also reflects changing patterns of consumer demand, a shifting balance of imports and exports for both energy and non-energy goods, and a changing market basket of goods produced and consumed in the United States.

Understanding these trends is essential to grasp the complex interdependence of energy with broader national issues of economic vitality, national security, and environmental quality.[6] Indeed, a critical lesson of the 1970s and 1980s is that energy policy must integrate with these three *issues*, and in recent reports OTA has suggested several policy goals that address these issues, including limiting oil import dependence, improving international competitiveness of U.S. goods and services, and addressing both

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[1] U.S. Department of Energy, *National Energy Strategy: Powerful Ideas for America*, 1st ed. (Washington, DC: February 1991).

[2] The changing nature of U.S. energy policy concerns is addressed in U.S. Congress, Office of Technology Assessment, *Energy Technology Choices: Shaping Our Future*, OTA-E-493 (Washington DC: U.S. Government Printing Office, July 1991).

[3] Energy security and oil import issues are addressed in U.S. Congress, Office of Technology Assessment, *U.S. Oil Import Vulnerability:* The *Technical* Replacement *Potential*, OTA-E-503 (Washington, DC: U.S. Government Printing Office, October 1991).

[4] Data arc total net imports of petroleum as a percent of total U.S. consumption. Historical data from U.S. Department of Energy, Energy Information Administration *Annual Energy Review 1990, DOE/EIA-0384(90)* (Washington, DC: May 1991), p. 129. Forecast from U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 1992, DOE/EIA-0383(92)* (Washington, DC: January 1992), p. 3, reference case.

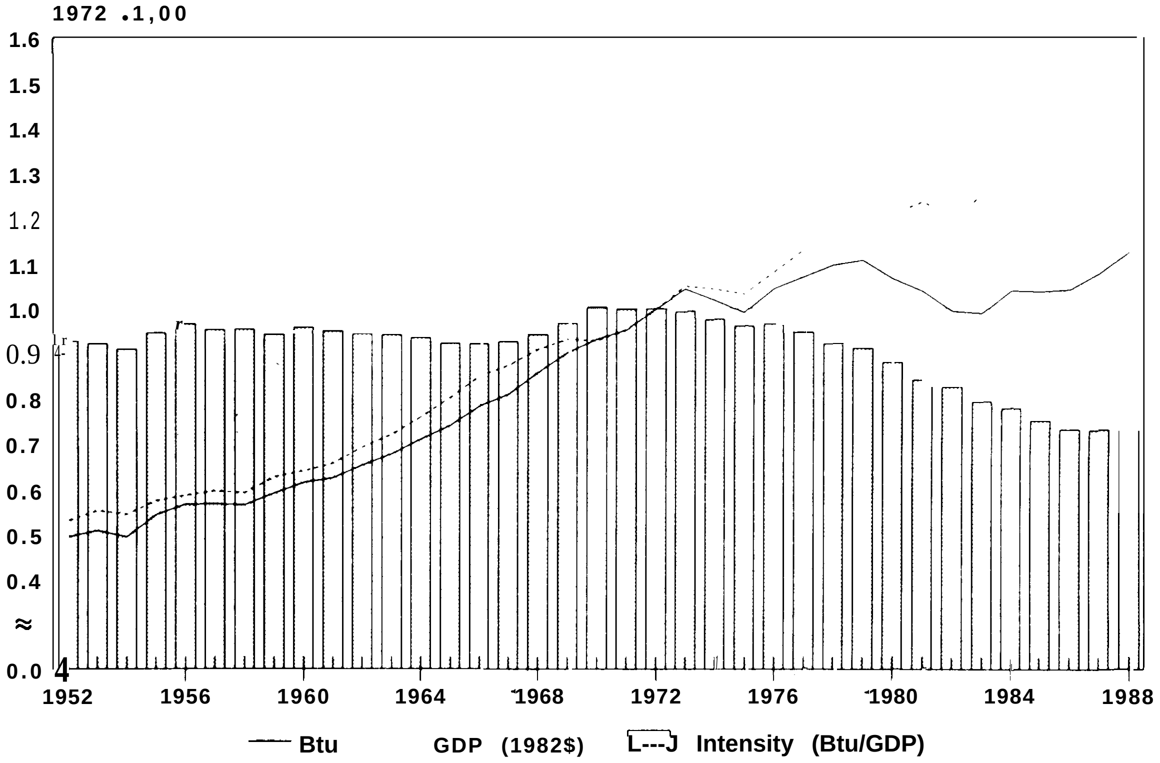
[5] About two-thirds of the reduction in energy use per unit of GDP was due to energy efficiency improvements, and the remaining one-third was due to structural changes in the economy. U.S. Congress, Office of Technology Assessment, Energy *Use and the U.S. Economy*, OTA-BP-E-57 (Washington, DC: U.S. Government Printing Office, June 1990).

[6] These relationships arc discussed in more depth in John H. Gibbons, Director, U.S. Congress, Office Of Technology Assessment, "Energy Policy Context for the 1990s: Considerations for a National Energy Strategy, ' testimony before the House Committee on Energy and Commerce, Subcommittee on Energy and Power, Feb. 20, 1991; and Peter D. Blair, Program Manager, Energy and Materials Program, Office of Technology Assessment, "Considerations for National Energy Policy, " testimony before the House Committee on Banking, Finance, and Urban Affairs, Subcommittee on Economic Stabilization, Oct. 17, 1991.

local and global environmental concerns.[7] In virtually all of this work, energy efficiency is shown to be a critical component of a comprehensive policy to further these goals and is a focus of this report.[8]

This report addresses energy use and efficiency in U.S. buildings. Energy use in buildings accounts for an increasing share of total U.S. energy consumption: 27 percent in 1950, 33 percent in 1970, and 36 percent in 1990.[9] At present, buildings account for over 60 percent of all electricity used in the United States and almost 40 percent of all natural gas.[10] Other OTA reports, recently completed or in preparation, address energy use and efficiency in

Figure I-I—Index of U.S. Energy Use, Gross Domestic Product (GDP), and Energy Intensity



Energy use (Btu) and economic growth (GDP) grew in parallel from 1952 to 1971, causing the energy intensity (Btu/GDP) to be relatively flat. After 1971, GDP continued to grow, but energy use stayed relatively constant, resulting in a decline in the energy intensity until 1986. Due to an increase in energy use after 1985, the energy intensity stayed level from 1986 to 1988.

SOURCE: U.S. Congress, Office of Technology Assessment, Energy *Use and the U.S.* Economy, OTA-BP-E-57 (Washington, DC: U.S. Government Printing Office, June 1990), p. 2.

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[7] These policy goals are addressed in more detail in U.S. Congress, Office of Technology Assessment *U.S. Oil Import Vulnerability: The Technical Replacement Potential,* OTA-E-503 *(Washington* DC: U.S. Government Printing Office, October 1991); and U.S. Congress, Office of Technology Assessment *Energy Technology Choices: Shaping Our Future, OTA-E-493 (Washington DC:* U.S. Government Printing Office, July 1991).

[8] The goal of improving energy efficiency stems in part from a recognition that energy is used not for its own sake but to supply energy ''services'' (e.g., lighting, heating, and transportation). Thinking in terms of energy services, rather than only energy supplies, provides a context for understanding the appropriate role of energy efficiency, as efficiency may be able to supply the needed services at a lower economic and environmental cost.

[9] Industry (37 percent) and transportation (27 percent) account for the rest. Data include energy losses in the conversion and transmission of electricity. U.S. Department of Energy, Energy Information Administration, *Annual Energy Review 1990,* DOE/EIA-0384(90) *(Washington DC: May 1991),* p. 13.

[10] Ibid., pp. 173, 215.

other sectors of the economy, including the Federal Government,[11] industry, transportation, and the role of electric and gas utilities in efficiency .12

A recent OTA study has shown that the use of cost-effective, commercially available technologies could reduce total building energy use by about one-third by 2015, relative to a' 'business-as-usual' baseline .13 The use of these technologies would save money and in addition would reduce the environmental damage associated with energy production. However, the buildings sector presents some distinct policy challenges for capturing these savings. For example, buildings in the United States are technically complex; the building industry is decentralized and fragmented; and buildings are subject to a mix of Federal, State, and local requirements that can frustrate or even discourage improvements in energy efficiency. The nature of buildings, with occupants that are often not owners, creates market imperfections that can be difficult to overcome. Finally, past Federal efforts to improve building energy efficiency have a mixed record, and tools for measurement and evaluation of energy savings are imperfect.

This report assesses technologies for improving energy efficiency in buildings, discusses why these technologies are not widely used, and offers policy options for encouraging their use. Several questions are explored:

- How much energy could be saved through the use of energy efficient technologies? (chapter 1)
- What specific technologies are available, and what are their cost and performance characteristics? (chapter 2)
- What prevents the widespread use of these technologies? (chapter 3)
- What policies have been used in the past to encourage efficiency, and how well have they worked? (chapter 4)
- What policy options are available to the U.S. Congress to encourage greater energy efficiency? (chapter 5)

The remainder of this chapter discusses recent trends in building energy use and the factors affecting this use. The future of energy use in buildings is then discussed from two perspectives: the likely future of building energy use, and what that future could be if energy efficient technologies were used more widely.

ENERGY TRENDS AND CHANGES SINCE 1970

Energy use in U.S. buildings has increased steadily-from about 22 quadrillion British thermal units (quads) in 1970 to about 30 quads in 1989.[14] Several factors have contributed to this growth, while others have acted to constrain it. Understanding these factors illuminates the role of technology in building energy use. (These factors also provide some insight into the efficiency of U.S. buildings relative to other countries-see box l-B.)

The Residential Sector

In 1989, residential buildings used 16.8 quads of energy at a cost of $104 billion dollars[15]-the majority in the form of electricity, followed by natural gas and oil. Space heating is responsible for almost half of total energy use, followed by water heating, refrigerators and freezers, space cooling, and lights (figure 1-2). In the last 20 years, residential energy use increased at an average annual rate of about 1.2 percent (figure 1-3). More recently (1985-89), this growth accelerated to an annual average rate of 2.1 percent. The major factors contributing to this growth include a growing population, shrinking household size (people per household) leading to a greater number of households, and increasing demand for energy-intensive services such as air conditioning (table l-l).

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[11] U.S. Congress, Office of Technology Assessment, *Energy Efficiency in the Federal Government: Government by Good Example?, OTA-E-492* (Washington, DC: U.S. Government Printing Office, February 1991).

[12] Reports covering these other sectors are forthcoming.

[13] U.S. Congress, Office of Technology Assessment, *Changing By Degrees: Steps To Reduce Greenhouse Gases,* OTA-O-482 (Washington, DC: U.S. Government Printing Office, February 1991). This and other estimates of the savings potential are discussed in detail in this chapter.

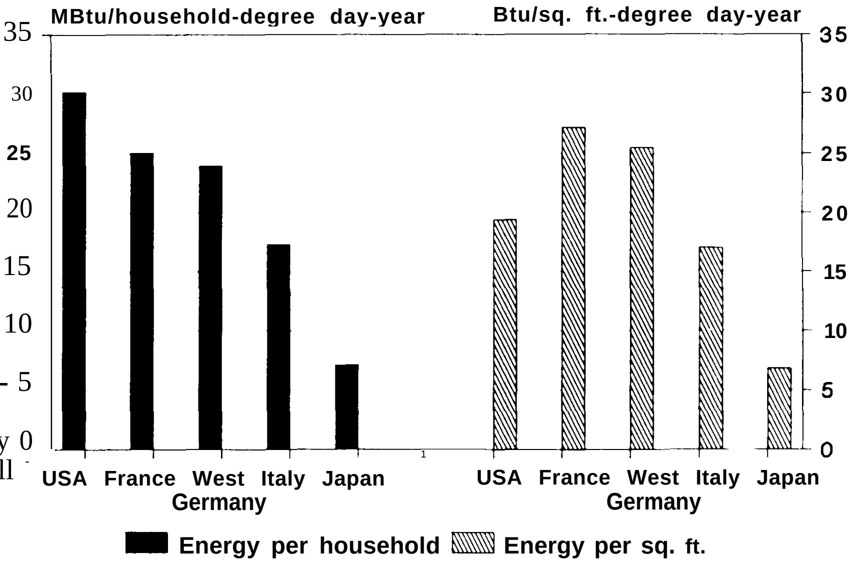
[14] Source is OTA 1992, see app. 1-B. A quad is 10^{15} Btus, worth about $5.7 billion at today's prices for energy used in buildings.

[15] Source is OTA 1992, see app. 1-B. This includes energy used for space heating, space cooling, hot water heating, arid various appliances, but excludes energy used for transportation. Throughout this report, electricity is converted to energy (Btu) units using a primary conversion factor that includes generation losses. See app. 2-C for a discussion of energy conversion issues.

Box 1-B—International Comparisons of Energy Efficiency in Buildings

International comparisons of energy use can be a useful way to *examine* energy use and energy efficiency, however care must be taken to-consider all the factors that might account for differences among countries. In the residential sector, for example, climate, household size, floor space, indoor temperature, and appliance saturation can all be as or more important in determining total household energy use than the thermal properties of homes or the efficiencies of their appliances.[1] As a result, simply calculating the average household energy use among different nations will not always provide a useful measure of relative efficiency.

Figure 1-B-1—Residential Energy Use in Five Countries



The bars on the left show residential energy use per household, while the bars on the right show residential energy use per square foot of living space. The effects of climatic differences have been removed.

NOTE: Includes losses associated with electricity generation.

SOURCE: U.S. Department of Energy, Energy Information Administration, *Indicators of Energy Efficiency: An International Comparison*, SR/EMEU/90-02 (Washington, DC: July 1990), pp. 11-12.

A simple example illustrates this point. After adjusting for climatic differences, consumption data indicate that the United States uses more energy per household than France, Germany, Italy, or Japan (see figure 1-B-1), which-might at first glance suggest that U.S. households are less efficient. However, energy use *per unit of floor space in the* United States is actually lower than in France or Germany (see figure 1-B-1).[2] And although Italy and Japan use less energy per unit of residential floor space than the United States, these countries generally have lower indoor temperatures and use central heating less than the United States,[3] factors that may account for most of the differing consumption levels.

As this example suggests, international comparisons of energy efficiency should be viewed with caution and, where possible, the variables and assumptions underlying such comparisons should be understood. Differences may indeed stem from differing energy efficiencies but may also be related to temperature settings, appliance saturation, and other, nontechnical factors that influence energy use.

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[1] See L. Schipper, A. Ketoff, and A. Kahane, “Explaining Residential Energy Use by International Bottom-Up Comparisons,” *Annual Review of Energy 1985* (Palo Alto, CA: Annual Reviews, Inc., 1985), vol. 10, pp. 341405.

[2] U.S. Department of Energy, Energy Information Administration, *Indicators of Energy Efficiency: An International Comparison* SR/EMEU/90-02 (Washington, DC: July 1990), pp. 11-12.

[3] L. Schipper, A. Ketoff, and A. Kahane, “Explaining Residential Energy Use by International Bottom-Up Comparisons,” *Annual Review of Energy 1985 (Palo* Alto, CA: Annual Reviews, Inc., 1985), vol. 10, pp. 352-353.

The U.S. population increased by 45 million people from 1970 to 1990.[16] At the same time the average number of people per household dropped considerably, from 3.24 in 1970 to 2.68 in 1990 (figure 1-4). The combined effect of these two factors was an almost 50 percent increase in the number of households in just two decades. As each household requires space conditioning, hot water, and other energy services, these changes drove the growth in energy use in the residential sector.

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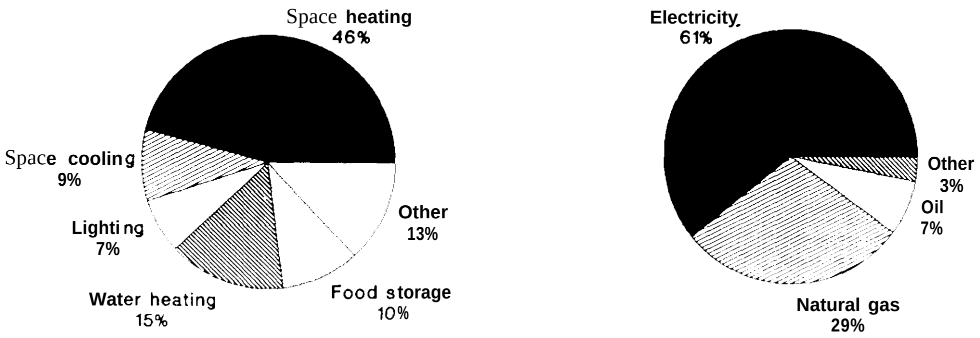
[16] U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States: 1991* (Washington, DC: 1991), p. 7.

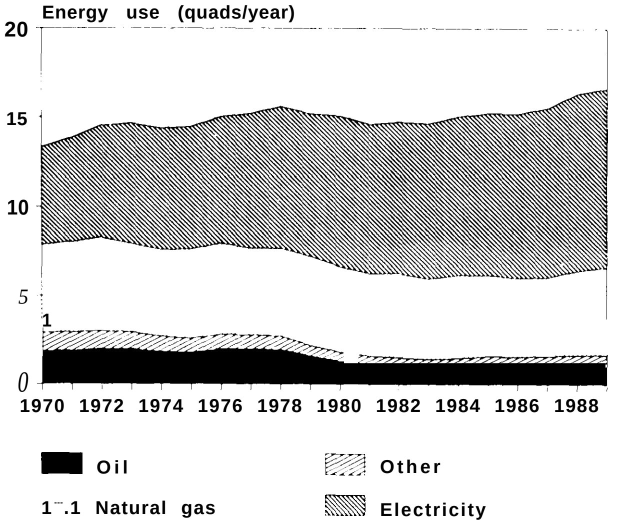
Figure I-2—Residential Sector Energy Use by End Use and Fuel Type, 1988



NOTE: Includes energy losses associated with electricity generation (see app. 2-C).

SOURCE: Office of Technology Assessment, 1992 (see app. I-B).

Figure 1-3—Residential Sector Energy Use by Fuel Type, 1970-89



NOTE: Inciudes energy losses associated with electricity generation (see app, 2-C).

SOURCE: U.S. Department of Energy, Energy Information Administration, *State* Energy Data Report: Consumption Estimates, 1960-1989, DOE/EIA-0214(89) (Washington, DC: May 1991), p. 24.

Table I-l—Major Factors Influencing Residential Energy Use

Factors causing an *increase* in consumption:
- Larger population—more households
- Fewer people per household-more households
- Increased demand for energy-intensive services

Factors causing a *decrease* in consumption:
- New housing more efficient than existing stock
- New appliances more efficient than existing stock
- Retrofits to existing housing
- Migration to the South and West
- More multifamily units

Factors causing fluctuations in consumption:
- Occupant behavior, changes in thermostat settings
- Fuel shifts-more electricity and less oil, changes in wood use
- Price changes

SOURCE: Office of Technology Assessment, 1992.

Increased demand for particular energy-intensive services also contributed to the growth in residential energy use. The popularity of central air conditioning has grown, and it is now routinely installed in over three-fourths of new single-family homes.[17] Increasing market penetration of energy-intensive appliances such as clothes dryers is also contributing to increased energy use.[18] And there is some evidence that residences are becoming larger as well, requiring more energy for space heating and cooling.[19] At present almost all households have space heating of *some* kind, water heating, and at least one refrigerator. Over 90 percent of existing households have color TVs, about three-fourths have clothes washers, about two-thirds have clothes

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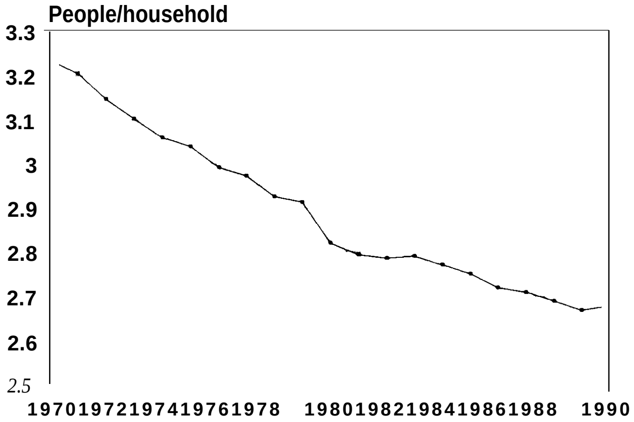
[17] In 1970 about one-third of new single-family homes had central air conditioning; by 1990 this figure reached 76 percent. Pacific Northwest Laboratory, *Residential and Commercial Data Book—Third Edition*, PNL-6454 (Richland, WA: February 1988), p. 3.28; U.S. Department of Commerce, Bureau of the Census, *Characteristics of New Housing: 1990*, C25-9013 (Washington, DC: June 1991), p. 4.

[18] In 198260 percent of households had clothes dryers; by 1987 this had climbed to 66 percent. US. Department of Energy, Energy Information Administration, *Housing Characteristics 1982*, DOE/EIA-0314(82) (Washington, DC: August 1984), p. 69; U.S. Department of Energy, Energy Information Administration, *Housing Characteristics 1987*, DOE/EIA-0314(87) (Washington DC: May 1989), p. 83.

[19] The average new single-family house in 1986 had 1,825 square feet of floor space, by 1990 this *wasup102,080”* square feet. The same trend occurred in new multifamily units as well—from an average of 911 square feet of floor space in 1986 to 1,005 square feet in 1990. U.S. Department of Commerce, Bureau of the Census, *Characteristics of New Housing: 1990*, C25-9013 (Washington, DC: June 1991), pp. 33,40.

Figure 1-4--Changes in Household Size, 1970-90

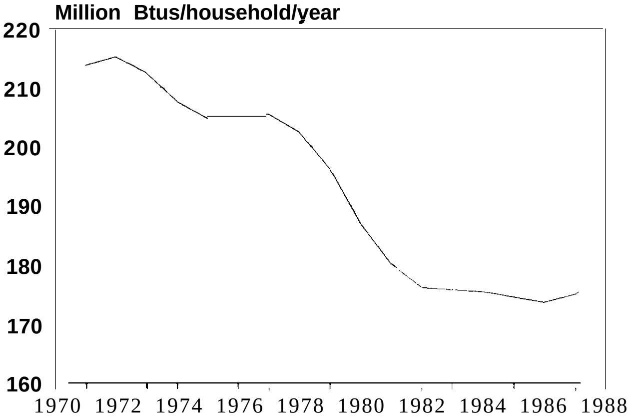


From 1970 to 1990the average household size dropped from 3.24 people to 2.68 people.

NOTE: Y-axis not set to zero.

SOURCE: Office of Technology Assessment, 1992 (see app. I-B).

Figure 1-5-Energy Use Per Household Dropped From 1970 to 1985, But Increased From 1985 to 1988.



NOTE: Three-year moving average shown. Y-axis not set to zero. Includes energy losses associated with electricity generation (see app. 2-C).

SOURCE: Office of Technology Assessment, 1992 (see app. I-B).

Table 1-2-Changes in Construction Practices for New Single-Family Detached Homes

	1973	1985
Average R-value[a] of insulation		
Ceiling	14.4	26.9
Exterior Wall	10.0	12.5
Floor	4.0	10.2
Window type (percent)		
Single-pane	60	19
Double- or triple-pane	40	81

[a] R.value is a measure of resistance to heat flow. A higher R-value means a better insulating value,

SOURCE: Adapted from S. Meyers, "Energy Consumption and Structure of the U.S Residential Sector: Changes Between 1970 and 1985," *Annual Review of Energy* 1987 (Palo Alto, CA: Annual Reviews, Inc., 1987), vol. 12, p. 90.

dryers, and about one-third have central air conditioning.[20]

Although total residential energy use increased from 1970 to 1989, energy intensity-energy consumption per household per year-actually *decreased by 15* percent in the same period (figure 1-5). Several factors contributed to this intensity drop, but improved technology and building practices were key: older houses were retrofit to improve energy efficiency, newer houses make greater use of energy-efficient building practices, and the energy efficiency of equipment in homes has improved dramatically.

Considerable effort has been made to improve the energy efficiency of the existing building stock. National retrofit data are scarce but, by one estimate, from 1983 to 1988 about 26 million owner-occupied U.S. households added storm windows and/or doors, and 17 million added insulation.[21] Careful evaluations of retrofit efforts have shown that energy savings are often substantial.[22] New houses benefited from greater use of energy efficient techniques. For example, new houses built in 1985 were better insulated and had more energy efficient windows than those built in 1973 (table 1-2).

Residential equipment is now more energy efficient as well. The typical new gas furnace sold in 1975 had an efficiency of 63 percent; by 1988, this increased to 75 percent. The efficiency gains in appliances were even greater-the typical new

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[20] u.S. Department of Energy, Energy Information Administration, *Housing Characteristics 1987*, DOE/EIA-0314(87) (Washington, DC: May 1989), pp. 77-79, 83. As noted previously, however, over three-fourths of new single-family homes have central air conditioning.

[21] U.S. Department of Commerce, Bureau of the Census, *American Housing Survey for the United States in 1985*, H-150-85 (Washington, DC: December 1988), p. 98; U.S. Department of Commerce, Bureau of the Census, *American Housing Survey for the United States in 1987, H-150-87* (Washington, DC: December 1989), p. 120; U.S. Department of Commerce, Bureau of the Census, *American Housing Survey for the United States in 1989*, H150/89 (Washington DC: July 1991), p. 122.

[22] See, for example, S. Cohen, C. Goldman, and J. Harris, *Measured Energy Savings and Economics of Retrofitting Existing Single-Family Homes: An Update of the BECA-B Database*, LBL-28147 (Berkeley, CA: Lawrence Berkeley Laboratories, February 1991), vol. 1.

Table 1-3-New and Existing Housing Types

Structure	Percent of existing households, 1987	Percent of new units started, 1988[a]
Single-family detached	62	
Single-family attached	5	(include~~above)
Multifamily: 2 to 4 units	11	3
Multifamily: 5+ units	16	18
Manufactured (mobile) home	6	15

[a] Privately owned only.

NOTE: Mobile home data are "placed for use."

SOURCES: Existing: U.S. Department of Commerce, Bureau of the Census, *American Housing Survey for the United States in 1989,* H-1 50/89 (Washington, DC: July 1991), p, 34. New: U.S. Department of Commerce, Bureau of the Census, Statistical *Abstract of the United States: 1991* (Washington, DC: 1991), pp. 720, 722.

refrigerator sold in 1990 used less than half as much electricity as a comparable unit sold in 1972.[23]

Other factors acted to dampen total energy demand in residences, although their effects were minor. There was a slight shift in the types of homes—the share of single-family homes in the United States shrank slightly from 68.7 percent in 1982 to 66.5 percent in 1987.[24] This means slightly lower heating and cooling requirements, as multifamily units have fewer exterior walls. However, single-family detached homes remain the most common type of housing unit (table 1-3). There has been a slight migration to the South and West in recent years,[25] which has probably decreased space heating needs and increased space cooling needs. The overall effect of this migration is thought to be a small net decrease in energy use.[26]

Several other factors affected residential energy use, although the direction of their effect was either unclear or variable in recent years. Examples include occupant behavior, shifts in fuel types, and energy prices.

The behavior of building occupants can significantly influence energy use. One measure of behavior in residences is the thermostat setting. There is some evidence that heating thermostat settings decreased from 1973 to 1981, increased slightly to 1982, were flat from 1982 to 1984, and then increased again from 1984 to 1987.[27] The impacts of these shifts on energy use are difficult to determine, but higher heating thermostat settings clearly mean more energy for space heating, all else being equal. Broader behavioral factors, such as the fraction of time spent on leisure activities, the trend toward two-career families, and economic shifts from manufacturing to service, may have affected energy use in buildings as well (box 1-C).[28]

The fuel mix of residential energy use has changed as well. Electricity has become increasingly prevalent for both space and water heating, while oil's share of the space heating market has dropped sharply.[29] In 1970, electricity supplied 41 percent of residential energy; by 1988, this had climbed to 61 percent.[30] Yet this trend toward greater electrification maybe changing; electricity's share of the space heating market in new single-family homes dropped sharply in recent years, from 49 percent in 1985 to 33 percent in 1990. Natural gas' share jumped from

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[23] See ch. 2 for sources and definitions.

[24] Includes single-family detached houses and mobile homes. U.S. Department of Energy, Energy Information Administration, *Housing Characteristics 1982,* DOE/EIA-0314(82) (Washington, DC: August 1984), p. 17; U.S. Department of Energy, Energy Information Administration *Housing Characteristics 2987,* DOE/EIA-0314(87) (Washington DC: May 1989), p. 18.

[25] In 1970, 52 Percent of homes were in the Northeast and Midwest; by 1983 this had fallen to 47 percent. S. Meyers, "Energy Consumption and Structure of the U.S Residential Sector: Changes Between 1970 and 1985, " *Annual Review of Energy 1987* (Palo Alto, CA: Annual Reviews, Inc., 1987), vol. 12, p. 87.

[26] L. Schipper, R. Howarth, and H. Geller, "United States Energy Use From 1973 to 1987: The Impacts of Improved Efficiency, " *Annual Review of Energy 1990* (Palo Alto, CA: Annual Reviews, Inc., 1990), vol. 15, p. 482.

[27] S. Meyers,' 'Energy Consumption and Structure of the U.S. Residential Sector: Changes Between 1970 and 1985," *Annual Review of Energy 1987* (Palo Alto, CA: Annual Reviews, Inc., 1987), vol. 12, p. 92; U.S. Department of Energy, Energy Information Administration, *Housing Characteristics 1987,* DOE/EIA-0314(87) (Washington DC: May 1989), p. 3.

[28] These factors are discussed in U.S. Congress, office of Technology Assessment, Technology *and the American Economic Transition,* OTA-TET-283 (Washington, DC: U.S. Government Printing Office, May 1988); also L. Schipper, *Energy Use and Changing Lifestyles,* EPRI CU-7069 (Palo Alto, CA. Electric Power Research Institute, November 1990).

[29] The efficiency implications of this shift depend on the technologies used to convert energy into heat. An electric heat pump, for example, is of comparable efficiency to an oil-fired furnace, if one accounts for electricity generation losses. An electric resistance heater, however, is much less efficient than an oil furnace, if one accounts for electricity generation losses.

[30] Primary equivalent. Source is OTA 1992 (see app. 1-B).

Box I-C-Technology and Behavior: Effects on Building Energy Use

This assessment focuses on technical means to improve the efficiency of energy use in buildings. Technology, however, is not the only determinantt of building energy use. Human behavior-how people operate equipment, how many children they bear, where they reside, and so on-can strongly influence building energy use as well.

In recent years, there has been increased interest in learning how human variables affect energy use in buildings. A major stimulant of this interest was the emerging uncertainty in electrical utility planning. Whereas electricity demand had increased at a fairly steady 7 percent per year from 1950 to 1973, increased prices, appliance saturation, and other factors slowed this increase to 1 to 2 percent per year.[1] An annual rate of 1 to 2 percent represents a doubling time of anywhere from 70 to 35 years, and therefore considerably greater uncertainty than the decadal doubling rate of earlier years. With saturation, patterns of equipment use-rather than the steady growth of new demand introduced by their acquisition-became a primary factor in determining energy demand. And equipment use is a function of human behavior.

Human behavior can be studied on two significantly different levels: the observable behavior of people and the underlying values and attitudes that drive those behaviors. Our understanding of both is imperfect, as is our ability to predict exactly how and when they will change. It is difficult to quantify and compare the contributions of family size, time spent cooking, work habits, and the myriad other behaviors that jointly affect residential energy use. Nor can we predict when, and how strongly, people will be motivated to conserve or stop conserving energy in buildings, beyond the expectation that rather gross changes, such as a steep rise in energy prices, will significantly influence behavior. Despite our limited understanding, it is clear that human behavior and values contribute substantially to variations in building energy consumption. The following paragraphs provide supporting evidence.

Major influences on household energy use are family size, income, average length of daily occupancy, and whether both household heads are employed; all but the last of these influences tend to increase energy use.[2] Although larger families consume more residential energy than smaller ones, this relationship reverses when calculated on a per capita basis.[3] Other relevant factors are the ages of family members and whether or not there are children. Elderly singles, most of whom are not employed, tend to use more residential energy than younger singles, most of whom are employed and spend less time at home.[4]

One estimate of the importance of behavioral differences in residential energy use comes from a careful study that examined variation in winter natural gas consumption of 205 townhouses in Princeton, New Jersey. Physical features-such as the position of the townhouse (end or non-end unit), the number of bedrooms, and the amount of insulated glass-accounted for 54 percent of the variation in energy use. Differences in occupant behavior were associated with much of the remaining 46 percent variation.[5]

In the future, many factors will affect human behavior and its influence on energy demand in residential and commercial buildings. A number of demographic trends are expected to influence future demand but in uncertain ways. For example, the "graying" of the U.S. population will continue; the proportion of those older than 65 is projected to grow from about 12 percent today to about 20 percent by the year 2030.[6] However, the elderly of tomorrow may be different than the elderly of today in terms of health, activity levels, and other characteristics, which could substantially alter their influence on building energy demand.

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[1] L. Schipper, S. Bartlett, D. Hawk, and E. Vine, *Energy Use and Changing Lifestyles*, EPRI CU-7069 (Palo Alto, CA: Electric Power Research Institute, November 1990), p. 1-1.

[2] P. Gladhart, B. Morrison, and B. Long, "HOW@@ Energy, " in P. Gladhart, B. Morrison, and J. Zuiches, *Energy and Families (E. Lansing,* MI: *Michigan State* University Press, 1987), p. 131.

[3] L. Schipper, S. Bartlett, D. Hawk, and E. Vine, "Linking Life-Styles and Energy Use: A Matter of Time?' *Annual Review of Energy 1989, (Palo* Alto, CA: Annual Reviews, Inc., *1989),* vol. *14,* p. *304.*

[4] Ibid., p.305.

[5] R, Socolow (editor), *Saving Energy in the Home: Princeton's Experiments at Twin Rivers* (Cambridge, MA: Ballinger Publishing Company, 1978), pp. 227-228.

[6] Population Reference Bureau, *America* in the *21st Century: Governance and Politics* (W-01+ DC: Population Reference Bureau, rnc., 1990), p. *3.*

The number of households is growing faster than the U.S. population. Household growth is expected to continue to outpace population growth, although by a slower rate than before.[7] Thus, the trend toward smaller households is expected to continue, which in the past has been associated with increased per capita residential energy demand.

As a final example, changes in the ethnic composition of the U.S. population could affect residential and commercial building energy demand but the potential effect is unknown. Due to immigration and differential fertility, the proportion of minorities in the U.S. population has been increasing steadily. In 1980, *about* **20** *percent* of Americans were black Hispanic, or Asian. By 2030, these groups are projected to represent 38 percent of the U.S. population.[8]

The future contribution of behavioral and demographic variables on energy use is unclear. In the absence of better understanding, it maybe prudent for policies to focus on technology, where the links to energy use are better understood. Nevertheless, it is important to recognize that policies affecting behavioral and demographic variables (such as changes in the tax treatment of child care, which could change the incentives for two-career households) could have important effects on future energy use in buildings.

[7] Ibid., pp. 4, 12.

[8] Ibid., p. 5.

44 to 59 percent in the same period.[31] Wood use for space heating has fluctuated; in 1978, 2.5 percent of U.S. households reported that their main heating fuel was wood, and this increased to 7.5 percent in 1984, but then dropped down to 5,6 percent by 1987.[32]

The price of energy underlies many of the changes discussed above. There is little agreement on exactly how energy prices and energy costs influence efficiency. There is general agreement that, all else equal, higher prices are an incentive for more efficiency, but the exact relationships between price, cost, and efficiency are not understood. The expectation of future price increases maybe as important as the actual current price, especially in influencing consumer decisions on capital investments. Price changes may substantially change short-term behavior; for example, the changes in residential thermostat settings discussed above may have been so influenced. However, the longer term impacts on capital equipment selection decisions are unclear. As shown in figure 1-6, energy prices in the residential sector increased during the period 1975 to 1985, in most cases faster than the consumer price index (CPI), but have dropped or held steady since then.

The Commercial Sector

Commercial buildings used 12.9 quads of energy at a cost of $68 billion in 1989.[33] About two-thirds of this energy was in the form of electricity. Space heating, lighting, and space cooling were the principal end uses (figure 1-7). Today, commercial buildings are used for diverse functions, but the predominant ones are retail/service, office, warehouse, assembly, and education. Figure 1-8 details commercial building square footage and energy use by function. Note that the most energy-intensive uses (those with the greatest energy consumption per square foot) are offices, health care, and food.

Energy use in the commercial sector has increased rapidly since 1970--at an average annual rate of 2.3

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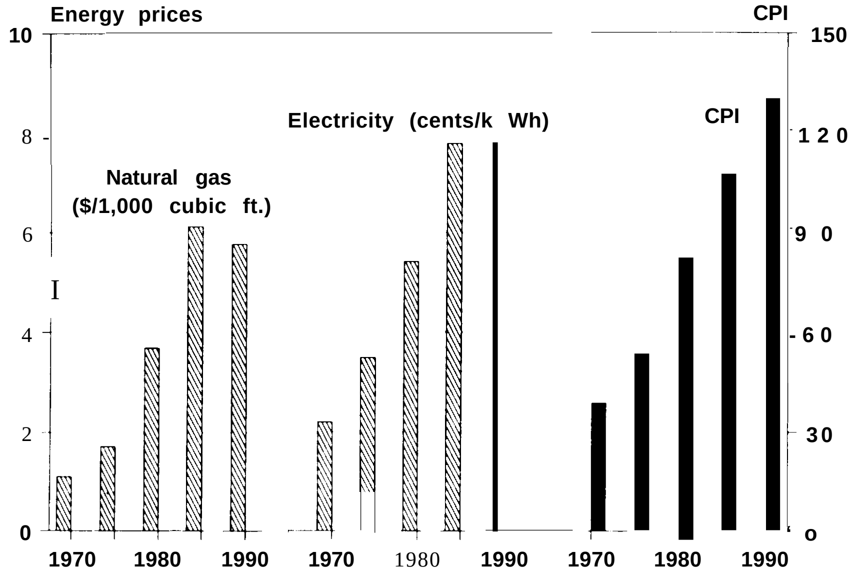
[31] The same trend occurred in multifamily homes—67 percent of new multifamily units had electric space-heating systems in 1985, dropping to 53 percent in 1990. U.S. Department of Commerce, Bureau of the Census, *Characteristics of New Housing: 1989*, C25-8913 (Washington DC: July 1990), pp. 20, 39; U.S. Department of Commerce, Bureau of the Census, *Characteristics of New Housing.'* 2990, C25-901 3 (Washington DC: June 1991), pp. *20,39.*

[32] U.S. Department of Energy, Energy Information Administration, *Housing Characteristics 1987,* DOE/EIA-0314(87) (Washington, DC: May *1989),* p. viii.

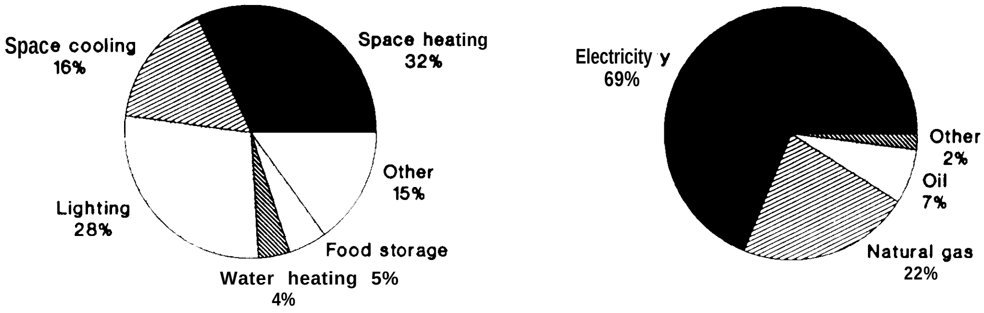
[33] Source is OTA 1992; see app. 1-B. The commercial sector is difficult to define but can be thought of as encompassing all buildings that durable products are not made in and that people do not live in. This includes energy used in offices, stores, schools, churches, and hospitals but excludes energy used in factories and apartment buildings.

Figure 1-8-Energy Prices in the Residential Sector Rose From 1970 to 1985, Then Dropped From 1985 to 1990



SOURCE: U.S. Department of Energy, Energy Information Administration, *Annual Energy Review 1990,* DOE/EIA-0384(90) (Washington, DC: May 1991), pp. 179, 225; U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States: 1991* (Washington, DC: 1991), p. 476.

Figure 1-7—Commercial Sector Energy Use by End Use and Fuel Type, 1988



NOTE: Includes energy losses associated with electricity generation (see app. 2-C).
SOURCE: Office of Technology Assessment, 1992 (see app. 1-B).

percent (figure 1-9).[34] As in the residential sector, a number of factors contributed to this growth (table 1-4), the most important being the rapid growth in new commercial buildings. The stock of commercial buildings, as measured by total square footage, grew more than 50 percent from 1970 to 1989 (figure 1-10). Heating, cooling, and lighting these new buildings has considerably increased energy consumption in the commercial sector. Furthermore many of these new buildings are offices, retail/service buildings, and other commercial buildings that are, on average, relatively energy intensive (i.e.,

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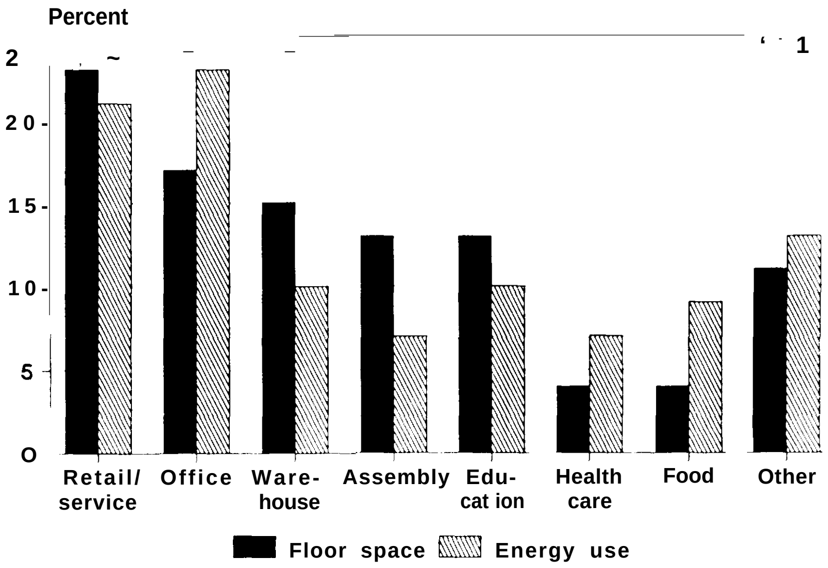
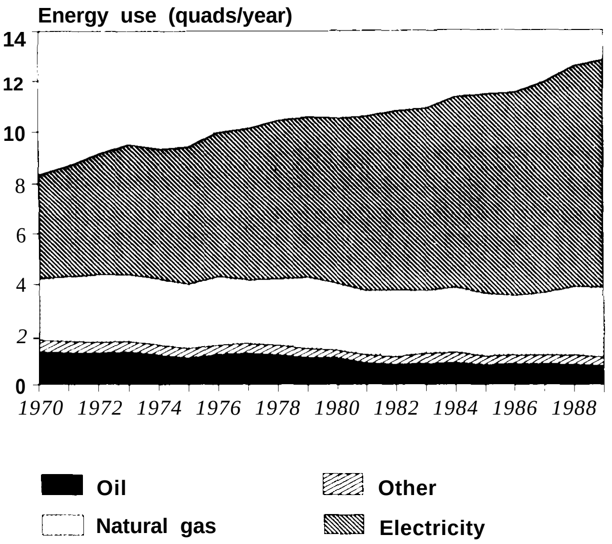
[34] Source for consumption data is OTA 1992; see app. 1-B. Note that GNP grew even more quickly in the same period—at average annual rates between 2.8 and 2.9 percent, in constant dollars. U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States: 1991* (Washington DC: 1991), p. *433.*

Figure 1-8-Breakdown of Energy Use and Square Footage by Commercial Building Type, 1986



SOURCE: U.S. Department of Energy, Energy Information Administration, *Commercial Building Consumption and Expenditures 1986,* DOE/EIA-0318(86) (Washington, DC: May 1989), p. 29.

Figure 1-9-Commercial Sector Energy Use by Fuel Type, 1970-89



NOTE: Includes energy losses associated with electricity generation (see app. 2-C).

SOURCE: U.S. Department of Energy, Energy Information Administration, *State Energy Data Report: Consumption Estimates, 1960-1989,* DOE/EIA-0214(89) (Washington, DC: May 1991), p. 25.

Table 1-4-Major Factors Influencing Commercial Building Energy Use

Factors causing an increase in consumption:
- More buildings
- More service demand-such as space cooling and office equipment

Factors causing a *decrease* in consumption:
- New buildings more efficient
- New appliances more efficient
- Retrofits to existing buildings

Factors causing fluctuations in consumption:
- Fuel shifts-more electricity and less oil
- Price changes

SOURCE: Office of Technology Assessment, 1992.

requiring more energy use per square foot per year) as compared to the sector as a whole (figure 1-8). Increased demand for energy-intensive services has further increased commercial building energy use. Most commercial buildings constructed in the past 20 years were built with air conditioning, while many older commercial buildings were not. There has been rapid growth in the use of computers and related electronic office equipment-in 1984 there were about 1.8 million personal computers in use in businesses; by 1989 this had climbed to 14.0 million.[35]

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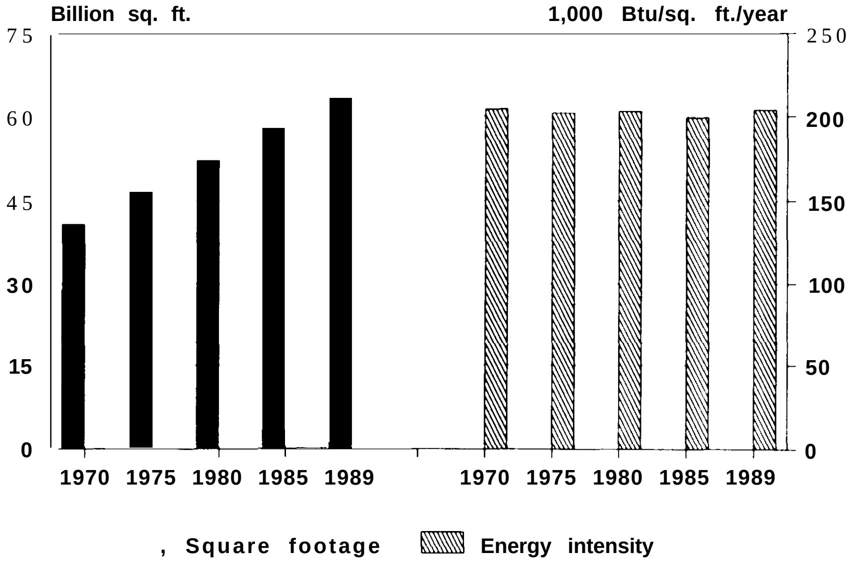
[35] U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States: 1990* (Washington, DC: January 1990), p. 951. For the commercial sector as a whole, however, office equipment is still a small energy user, accounting for only 3 to 4 percent of total commercial-sector electricity use. See ch. 2.

Figure I-l O-The Stock of Commercial Buildings (as measured by total square footage) Has Grown Rapidly, But the Energy Intensity (energy use per square foot per year) Has Held Steady.



SOURCE: U.S. Department of Energy, Energy Information Administration, *State Energy Data Report: Consumption Estimates, 1960-1969,* DOE/EIA-0214(89) (Washington, DC: May 1991), p. 25; D. Belzer, Pacific Northwest Laboratories, personal communication, September 19, 1991.

Despite growth in the number of energy-intensive buildings (e.g., offices and stores) and increases in air conditioning and other equipment, energy *intensity* (energy use per square foot per year) actually stayed flat in the commercial sector from 1970 to 1990 (figure 1-10). As in the residential sector, improved technology has helped to dampen the growth in commercial building energy use. New commercial buildings use improved windows and shells, more efficient space conditioning equipment, and better lighting systems. For example, commercial buildings constructed from 1980 to 1989 made greater use of ceiling and wall insulation, multipane and reflective windows, and shadings or awnings compared to buildings constructed in earlier years.[36] Computer hardware and software improvements allowed for more use of computer-aided building design and analysis methods. In addition, the energy efficiency of the existing building stock has been improved through retrofits (table 1-5).

Table 1-5-Commercial Building Retrofits

Action	Percent of floor space[a]
Energy management system.	12
Efficient light ballasts..	24
Ceiling insulation.	20
Weatherstrip/caulk.	22

[a] The percent of all commercial building floor space for which the associated action was added after construction, as of 1986.

SOURCE: U.S. Department of Energy, Energy information Administration, Characteristics of Commercial Buildings *1986,* DOE/EIA-0246(86) (Washington, DC: September 1988), p. 24.

Several other factors have influenced energy use in commercial buildings. Electricity has replaced oil and natural gas to a considerable extent.[37] As in the residential sector, a greater share of new commercial building construction has been in the South and West,[38] which may have led to a slight net increase in energy consumption due to an increased need for

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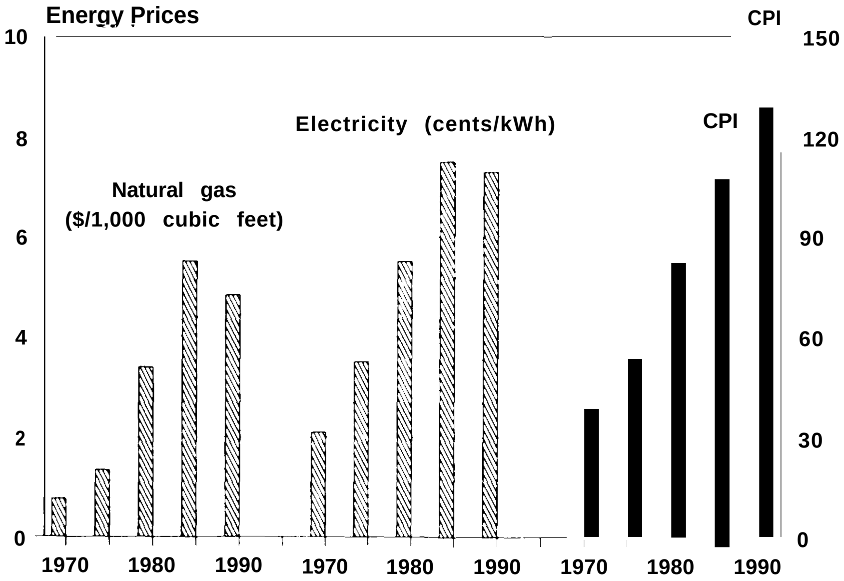
[36] U.S. Department of Energy, Energy Information Administration, *Commercial Building Characteristics 1989,* DOE/EIA-0246(89) (Washington, DC: June 1991), p. 202.

[37] In 1970, 49 percent of energy used in commercial buildings was in the form of electricity; by 1988 this had increased to 69 percent (primary equivalent, see app. 2-C). Source is OTA 1992; see app. 1-B. The efficiency implications of this shift depend on the technologies used (see footnote 29 above).

[38] U.S. Department of Energy, Energy Information Administration, *Characteristics of Commercial Buildings 1989,* DOE/EIA-0246(89) *(Washington DC:* June 1991), p. 42. Commercial buildings tend to need more energy for space cooling and less for space heating than residential buildings; therefore this geographic shift would be more likely to increase overall consumption in commercial buildings than in residential buildings.

Figure 1-1 l—Energy Prices in the Commercial Sector Rose From 1970 to 1985, Then Dropped From 1985 to 1990.



SOURCE: U.S. Department of Energy, Energy Information Administration, *Annual Energy Review 1990,* DOE/EIA-0384(90) (Washington, DC: May 1991), pp. 179, 225; U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States: 1991* (Washington, DC: 1991), p. 476.

space cooling. Finally, energy prices in the commercial sector increased from 1970 to 1985 but dropped after that (figure 1-1 1).

Summary

Energy use in both the commercial and residential sectors has grown in the last 20 years. Sheer increases in numbers underlie much of this growth—more people, more households, and more offices. Increased service demand-more air conditioning, more computers, larger houses—has contributed as well. However, the application of improved technology has moderated this growth. Better building shells (windows and insulation), better appliances (furnaces, air conditioners, refrigerators), and better building design have lowered energy intensity in residences (energy use per household per year) and stabilized energy intensity in the commercial sector (energy use per square foot per year).

BUILDING ENERGY USE IN THE NEXT 20 YEARS: THE ENERGY SAVINGS POTENTIAL

Where Are We Headed?

As in the past, building energy use in the future will be driven by technological change but will be influenced by other factors as well, including population and economic growth, changes in household size, changes in lifestyle, and migration patterns. The complexity and interactions of these factors make it difficult to predict accurately future levels of building energy use. Nevertheless, it is useful to project these levels under different conditions to illuminate potential policy issues.

One way to consider future energy use is in terms of *intensity* (defined as energy use per household per year in residential buildings, and energy use per square foot per year in commercial buildings). As discussed above, since 1970 residential intensity dropped and then increased (figure 1-5), while commercial intensity stayed relatively constant (figure 1-10). OTA has modeled future intensity levels in terms of scenarios-projections of possible futures, based on differing assumptions about future levels of intensity and other factors. Uncertainties in household size and new commercial building construction rates make it difficult to specify precisely the levels of future consumption; however assuming that recent historical trends continue-specifically that commercial sector intensity remains flat, and that residential sector intensity drops slowly—yields a residential consumption of 18.9 quads per year in 2010 and a commercial sector consumption of 19.9 quads per year in 2010. A complete description of the model used to build the scenarios is in appendix l-A.

The scenarios presented here can be compared to those made by other groups. Figures 1-12 and 1-13 show the OTA estimates, as well as those by five other groups (see appendix 1-C for a detailed table and sources for these other estimates). The simple mathematical average of these consumption scenarios is 20.2 quads for the residential sector and 18.5 for the commercial sector. This is not to say that the mathematical average is the ‘‘correct’ number, for all the estimates may be wrong; but the average does provide a single number summarizing the different estimates. While there is a range of estimates, there is reasonable agreement on future business-as-usual consumption in 2010; the difference between the average and the outlier (i.e., the estimate farthest from the average) is less than 16 percent for both sectors.[39]

Where Could Technology Take Us?

The preceding discussion summarized different forecasts of building energy use in a business-as-usual assumption. An alternative method of forecasting future energy use is to consider what energy use could be if greater use was made of energy efficient technologies. At one extreme is the true technical potential-i. e., the energy savings that would result from maximum use of all technologies, regardless of cost. From a policy perspective, however, it is more useful to consider the energy savings resulting from optimal use of all cost-*effective* technologies.

Estimating cost-effective savings is a difficult task. Technology is just one of many factors affecting energy use, and the effects of technological change may be masked by population increases, demographic shifts, and other factors. Technology is not stagnant; costs, performance, and efficiencies change as technology is improved and refined. The diversity of the building stock, climatic variations, and uncertainty over future fuel costs all make estimates of technical and economic potential for energy savings a very uncertain exercise. Furthermore, defining ‘‘cost-effective” can be problematic. There are several measures of cost-effectiveness, including the cost of conserved energy (CCE), net present value, and payback (these terms are defined in appendix 2-B). One can consider different perspectives, such as the consumer, the utility, and society as a whole. Finally one can vary the values of inputs to these definitions, notably the discount rate. There is little agreement on the best measure, perspective, or assumptions to use in projecting energy use.

Nevertheless, it is useful to review estimates of the energy savings that could result from greater use of cost-effective technologies, recognizing the effects of different definitions of cost-effective. If there is general agreement that a significant gap between the business-as-usual forecasts and the cost-effective forecasts exists, then one may reasonably conclude that the market is not performing optimally and that policy change may be appropriate. Alternatively, if there is general agreement that there is little or no gap between the two forecasts, then policy intervention may not be appropriate.

Previous work by OTA has estimated that energy use in buildings could be reduced about one-third by 2015, relative to a business-as-usual scenario, through the use of technologies with a positive net present value to the consumer.[40] Adjusting this model’s results to the projected business-as-usual consumption discussed above yields a 2015 cost-effective consumption of about 27.7 quads per year (figure 1-14). This is about a 2 quad *decrease* from 1989 to 2015,[41]

Numerous other estimates of this savings potential have been made:

- A modeling effort by the Energy Information Administration,[42] conducted as part of the National Energy Strategy, estimated the business-

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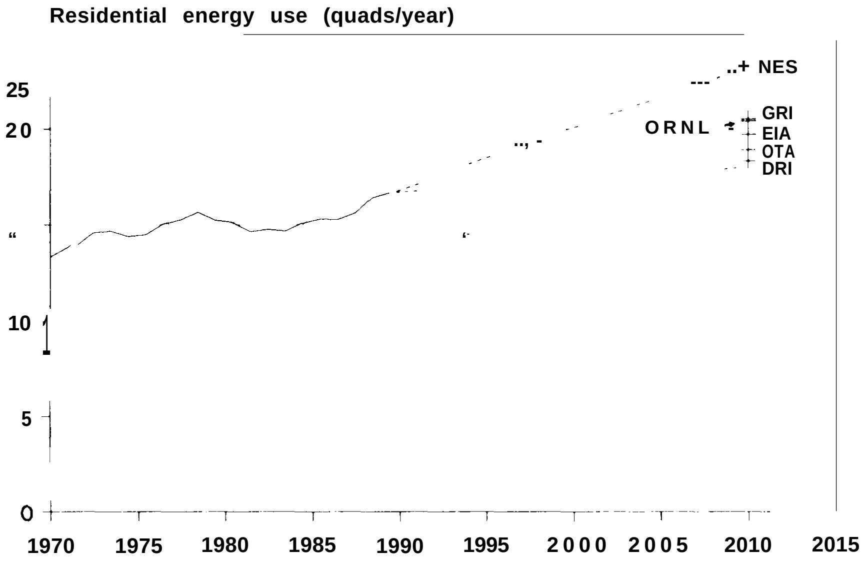
[39] Much of these differences can be traced to different assumptions—for example, the National Energy Strategy estimates assume that GNP grows at an average annual rate of 2.9 percent from 1990 to 2010, while the DRI study assumes a rate of 2,3 to 2,0 percent in the same period. See app. 1-C for sources.

[40] Based on an OTA model described in U.S. Congress, Office of Technology Assessment, *Changing by* Degrees: *Steps To Reduce Greenhouse Gases, OTA-O-482* (Washington, DC: U.S. Government Printing Office, February 1991), app. A, pp. 313-326. This model assumes full penetration of all cost-effective technologies and a 7 percent real discount rate.

[41] The ‘‘bus~ess+.+usu~’ estimates discussed above were recalculated for 2015, yielding 19.4 quads per year (residential) and 22.1 quads per year (commercial). The one-third reduction, therefore, corresponds to a 13,8 quad savings in 2015.

[42] The Energy Information Administration (EIA) is an independent statistical and analytical agency within the U.S. Department of Energy @E)”

Figure I-12—Residential Energy Use in 2010: Comparison of Different Business-as-Usual Forecasts

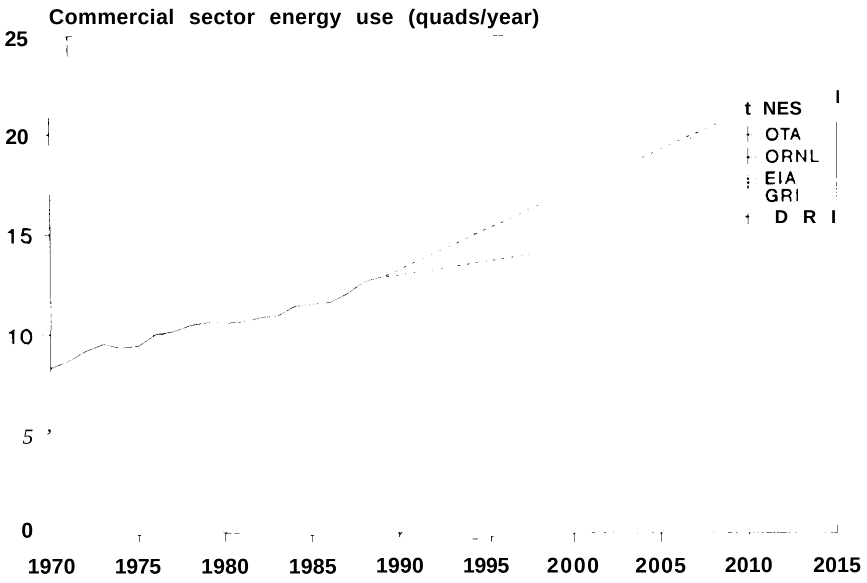


KEY: DRI = Data Resources, Inc., EIA = Energy Information Administration, GRI = Gas Research Institute, NES = National Energy Strategy, ORNL = Oak Ridge National Laboratory, OTA = Office of Technology Assessment.

NOTE: Includes losses associated with electricity generation (see app. 2-C).

SOURCE: Office of Technology Assessment, 1992 (see app. 1 -C).

Figure I-13-Commercial Sector Energy Use in 2010: Comparison of Different Business-as-Usual Forecasts

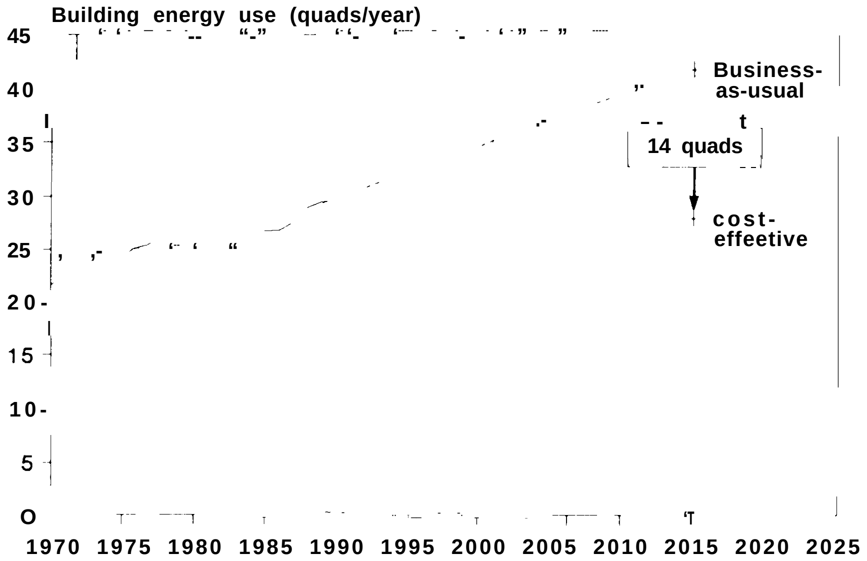


KEY: DRI = Data Resources, Inc., EIA = Energy Information Administration, GRI = Gas Research Institute, NES = National Energy Strategy, ORNL = Oak Ridge National Laboratory, OTA = Office of Technology Assessment.

NOTE: Includes losses associated with electricity generation (see app. 2-C).

SOURCE: Office of Technology Assessment, 1992 (see app. 1 -C).

Figure 1-14-Building Energy Use: Two Possible Futures



NOTE: Business-as-usual is OTA's estimate of future consumption without policy change. Cost effective is OTA's estimate of future consumption if all energy efficient technologies with a positive net present value are implemented. There is considerable uncertainty in both estimates. See text for details. Includes losses associated with electricity generation (see app. 2-C).

SOURCE: Office of Technology Assessment, 1992.

as-usual and cost-effective (see table 1-6 for definition) levels of energy use in buildings in 2010. This study estimated that, relative to the predicted business-as-usual 2010 consumption, 13 percent of energy used in buildings could be saved with cost-effective technologies, and that 26 percent of energy could be saved with technically feasible, but not necessarily cost-effective technologies (table 1-6).[43] These estimates are at the low end of the range of cost-effective savings found in other studies, probably due in part to conservative assumptions concerning building shell retrofits.[44]

- A recent study by the National Academies examined the energy and carbon savings potential in the residential and commercial sectors.[45] The study examined a range of supply curves[46] and examined in depth data from the Electric Power Research Institute (EPRI). The Academies' analysis of the EPRI data found an aggregate electricity savings potential of 45 percent in existing buildings at a cost of conserved energy of less than or equal to 7.5 cents per kWh.[47] Natural gas and oil savings of 50 percent in existing buildings were claimed, at a cost of less than $5.63 per MBtu.[48] These results are not directly comparable to those of

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[43] The EIA notes that costs for the technical Potential case may not be prohibitive, due to the economies of scale resulting from large production runs and cost reductions from R&D. U.S. Department of Energy, Energy Information Administration, *Energy Consumption and Conservation Potential.' Supporting Analysis for the National Energy Strategy,* SR/NES/90-02 (Washington, DC: December 1990), p. 7.

[44] The EIA assumes that pre-1975 residential buildings yield a 16 percent reduction in heating service demand and a 4 percent reduction in cooling service demand in the "high conservation" case by 2030, while OTA assumes a 20 percent savings by 2010 in the "moderate" case. Ibid., p. 6; U.S. Congress, Office of Technology Assessment *Energy Technology Choices: Shaping Our Future, OTA-E-493* (Washington, *DC:* U.S. Government Printing Office, July 1991), p. 130.

[45] The National Academies are the National Academy of Sciences (NAS), the National Academy of Engineering (NAE), and the Institute of Medicine (IOM). The report is "Policy Implications of Greenhouse Warming,' Report of the Mitigation Panel, prepublication manuscript, National Academy Press, Washington DC, 1991.

[46] A supply curve is a graphical method Of summarizing the costs and energy savings potential of energy efficient technologies.

[47] Sensitivity analyses feud the 45 percent savings at discount rates of 3,6, and 10 percent. ''Policy Implications of Greenhouse Warming," Report of the Mitigation Panel, prepublication manuscript, National Academy Press, Washington, DC, 1991, ch. 3, p. 3-3 and table 3.7 (chapter dated 613/91).

[48] Ibid.

Table 1-6—Forecasts of Building Energy Use by the Energy Information Administration

Sector	Energy Use (quads/year)			
	1990	2010 Business-as-usual	2010 Cost-effective	2010 Technical potential
Residential. . .	10.7	11.7	10.2	8.3
Commercial. .	6.8	8.7	7.5	6.8
Total.	17.5	20.4	17.7	15.1

NOTE: Does not include losses associated with electricity generation.

SOURCE: U.S. Department of Energy, Energy Information Administration, *Energy Consumption and Conservation Potential: Supporting Analysis for the National Energy Strategy,* SR/NES/90-02 (Washington, DC: December 1990). Business-as-usual forecast assumes "current government policies and programs remain in effect" (p. 56). Cost-effective forecast is the "high conservation excursion," and assumes "full penetration of cost-effective, energy efficient technologies and other conservation measures" where "cost-effectiveness is defined as an energy savings investment that generates a positive net present value." (p. 59). A 10 percent discount rate is assumed (p. 68). Technical potential is the "very high conservation excursion," and assumes that the most efficient technologies are installed when in-place units fail. There is no premature scrapping of capital equipment in either case (p. 3).

OTA or the Energy Information Administration (EIA). This study assumes a "frozen efficiency' baseline; in other words no allowance is made for efficiency improvements expected to occur under existing economic and political conditions. However the specific measures proposed in the Academies' study appear to fall somewhere in between the OTA moderate and tough scenarios, suggesting that the Academies' measures would yield savings of from 20 to 38 percent in 2010, relative to a business-as-usua1 scenario. A separate OTA analysis of all energy-using sectors found that the Academies' results, when forecasted relative to a base case, yielded results comparable to OTA's moderate scenario .[49]

- A study entitled *America's Energy Choices* estimated the energy savings resulting from greater use of technologies for which the additional frost cost is less than the cost of new supply, at both existing supply prices and those estimated by including environmental and security costs in energy supply prices. Relative to reference consumption in 2010, estimated energy savings were 28 and 37 percent.[50]
- Several other studies have examined energy savings for specific fuels, sectors, or geographic regions. A comprehensive analysis of electricity use in U.S. residences, for example, found that 37 percent of residential electricity could be saved by 2010 at a cost below that of supplying the electricity.[51] A comprehensive study of electricity use in Michigan estimated that a 29 percent savings by 2005 would be ''achievable' at a reasonable cost.[52] A study of electricity use in New York State found that present day consumption could be reduced by 34 percent in the residential sector and 48 percent in the commercial sector at a cost below that of supplying the electricity .[53]

The results of some of these studies are summarized in table 1-7. The results vary widely, as do the analytical techniques, assumptions about cost and performance, and definitions of cost-effectiveness.

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[49] See John Andelin, Assistant Director, U.S. Congress, Office of Technology Assessment, testimony before the House Committee on Science, Space, and Technology, July 17, 1991.

[50] The 28 percent savings is under the ''Market' scenario, defined as, "making use of cost-effective energy-efficiency and renewable energy technologies, assuming market penetration rates, and with no accounting for environmental or security costs beyond those embodied in current trends and policies. " The 36 percent savings corresponds to the "Environment" scenario, which includes additional technologies, "to the extent justified by the environmental and security costs of fossil fuels, and assuming more rapid penetration rates." *America's Energy Choices,* Executive Summary (Cambridge, MA: The Union of Concerned Scientists, 1991). A 3 percent real discount rate is assumed. Savings estimates include losses in electricity generation and exclude solar and geothermal energy. *America's Energy Choices,* Technical Appendixes (Cambridge, MA: The Union of Concerned Scientists, 1991), pp. A-1, G-4 to G-7.

[51] That is, with a cost of conserved energy (CCE, see app. 2-B for definition) below 7.6 cents/kWh. The baseline is a' 'frozen efficiency' one, which does not give credit for efficiency improvements that would result from naturally occurring efficiency improvements (it does, however, exclude from the baseline predicted savings resulting from future appliance efficiency standards). A 7 percent real discount rate is assumed. J. Koomey, C. Atkinson, A. Meier, J. McMahon, S. Boghosian, B. Atkinson, I. Turiel, M. Levine, B. Nordman, P. Chan, *The Potential for Electricity Efficiency Improvements in the U.S. Residential Sector, LBL-30477* (Berkeley, CA: Lawrence Berkeley Laboratory, July 1991), pp. 35-36.

[52] Calculations are relative to a ''business as usual'' baseline. The "achievable' potential assumes the use of commercially available technologies and aggressive conservation programs. F. Krause, J. Brown, D. Connell, P. DuPont, K. Greely, M. Meat, A. Meier, E. Mills, B. Nordman, *Final Report: Analysis of Michigan's Demand-Side Electricity Resources in the Residential Sector,* Volume 1: Executive Summary, LBL-23025 (Berkeley, CA: Lawrence Berkeley Laboratory, April 1988).

[53] Conservation measures With a cost of saved electricity below 7 cents/kWh are included. Costs are for technology and titillation only, and do nOt include marketing and other implementation costs. Interestingly, however, adding a 50-percent implementation "penalty' to the cost of saved energy for these measures would still allow savings of 32 percent (residential) and 41 percent (commercial). A 6-percent discount rate is assumed. American Council for an Energy-Efficient Economy (ACEEE), ''The Potential for Electricity Conservation in New York State, ' published by the New York State Energy Research and Development Authority (NYSERDA), report 89-12, September 1989, pp. S-5, S-6.

Table 1-7-Summary of National Cost-Effective Savings Estimates

Source	Percent savings relative to baseline	Year	Coverage	Definition of cost-effective
Office of Technology Assessment. . .	33	2015	Residential/commercial all fuels	Positive net present value
National Academies.		1986	Existing buildings	
	45		Electricity	CCE less than or equal to 7.5 cents/kWh
	50		Gas and oil	CCE less than or equal to $5.63/MBtu
Energy Information Administration. . .	13	2010	Residential/commercial all fuels	Positive net present value
Union of Concerned Scientists.	28	2010	Residential/commercial all fuels	CCE less than cost of supply “Market” scenario
Lawrence Berkeley Laboratory.	37	2010	Residential electricity	CCE less than 7.6 cents/kWh

NOTE: Results are not directly comparable. See text for sources and limitations. CCE - cost of conserved energy.

SOURCES: See text.

As discussed above, the Academies’ results appear to fall between the OTA moderate and tough scenarios, corresponding to 20 and 38 percent savings, respectively. The EIA savings estimate of 13 percent is lower than the OTA moderate scenario, due in part to their more conservative assumptions concerning shell retrofits. While there is considerable uncertainty in all of these modeling efforts, there is general agreement that, despite gains made to date, there remain significant opportunities for increased energy efficiency in U.S. buildings through the use of cost-effective technologies.[54]

The gap between what appears to be cost-effective and what is actually used suggests that there maybe a role for Congress in ensuring that cost-effective efficiency improvements are implemented. There are many benefits of such actions, the most important being they save both energy and money. Furthermore, calculations of cost-effectiveness discussed above generally do not incorporate environmental and other externalities, and doing so would most likely increase the gap between cost-effective and actual energy use. overcoming barriers to wider use of these technologies may require direct policy actions, as the existence of barriers suggests that current market conditions will not result in optimal use of cost-effective energy efficiency opportunities.

The remainder of this report focuses on the critical question of *implementation* of energy efficient technologies. Chapter 2 takes a closer look at the technologies themselves, with a focus on their availability, costs, and other attributes. Chapter 3 examines how the markets function, with a focus on why energy efficient technologies are often not used despite their apparent cost-effectiveness. Chapter 4 reviews past Federal efforts to encourage energy efficiency in buildings, and Chapter 5 distills the analyses of the first four chapters in a discussion of policy issues and options for Congress.

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[54] The studies discussed above use a variety of definitions of cost-effective. Although the sw@ potential varies by the specific definition used, by most definitions it is clear that a considerable potential exists for saving energy through greater use of technologies with positive net benefits. However, some argue that these studies calculate costs incorrectly, and that there is little evidence of market imperfections that would yield such a potential. W. David Montgomery, “The Cost of Controlling Carbon Dioxide Emissions, ’ Charles River Associates Inc., Washington, DC, December 1991.

Appendix 1-A

Scenarios of Future Energy Use

The scenarios of future energy use in the residential and commercial sectors presented in this chapter are based on two factors: changes in the energy intensity of the buildings and growth in the number and size of buildings.

For the residential sector, changes in household energy intensity (energy use per household) and changes in the number of people per household (which when combined with population growth yields the number of households) are analyzed. For household energy intensity, three levels are considered:

- There is no further improvement in intensity—energy use per household stays at its current level.
- Intensity drops at half the rate it has dropped in the past. As noted in figure 1-5 intensity has actually increased in recent years; it is not clear if this trend will continue. It appears unlikely, however, that intensity will continue to drop as it has over the last two decades; therefore this level is, in OTA's view, the most likely future path for intensity.
- Intensity continues to drop at the rate it has dropped in the past two decades (-0.9 percent per year).

Population growth is assumed to be 0.61 percent per year.[1] In order to reflect uncertainty in future changes in household size, three different assumptions of future trends in household size are considered:

- Low: Household size (number of people per household) stays at its current level (2.68 people per household).
- Middle: Household size shrinks at half the rate it has shrunk in the past (-0.45 percent per year, half of 0.9 percent per year), leading to more (but smaller) households. As the historical shrinkage in household size has slowed in recent years, this is in OTA's view the most likely trend.
- High: Household size continues to shrink at the historical rate observed from 1970 to 1989 (-0.9 percent per year), leading to many more households.

The results are summarized in table l-A-l. For each intensity scenario, three levels of 2010 consumption are shown corresponding to the three different assumptions as to household size.

A similar analysis is shown below in table l-A-2 for the commercial sector. The two variables analyzed are changes in intensity and growth in square footage. Intensity scenarios are as in the residential sector:

- There is no future improvement in intensity (energy use per square foot). As shown in figure 1-10 this is consistent with trends since 1970, and is therefore, in OTA's view, the most likely future path for intensity.
- Future improvements in intensity are slow.
- Future improvements in intensity are moderate.[2]

Table I-A-l—Energy Intensity and Household Density: Effects on Residential Building Energy Use

Actual consumption, 1989 (quads): 16.8	Consumption in 2010 (quads)		
	Low	Middle	High
If there are no further drops in intensity:	18,9	20.7	22.7
At half historical rates:	17.2	18.9	20.7
If historical intensity drops continue:	15.6	17.2	18.9

SOURCE: Office of Technology Assessment, 1992. See app. l-A.

Table I-A-2—Energy Intensity and Square Footage: Effects on Commercial Building Energy Use

Actual consumption, 1989 (quads): 12.6	Consumption in 2010 (quads)		
	Low	Middle	High
If there are no further drops in intensity:	16.2	19.9	24,4
At half historical rates:	14.8	18.2	22.3
With moderate future intensity drops:	13.4	16.5	20.3

SOURCE: Office of Technology Assessment, 1992. See app. l-A.

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[1] This is a weighted average of population projections as reported in U.S. Department of Commerce, Bureau of the Census, *Projections of the Population of States by Age, Sex, and Race: 1989 to 2010*, Series P-25, No. 1053 (Washington, DC: January 1990), p. 2.

[2] As shorn in figure 1-10, energy intensity in commercial buildings has been relatively flat in the last 20 years. Therefore as a proxy for slow and moderate future improvements in intensity, the observed historical intensity change from the residential sector (-0.9 percent/year) is applied to the commercial sector as well. As in the residential sector, "slow" is set at half the historical rate and ''moderate" set at the historical rate.

Uncertainty in future growth of the building stock (the total square footage of commercial buildings) is incorporated via three different assumptions of growth rates in the building stock:

- Low: Annual growth of 1.1 percent per year in total commercial building square footage.
- Middle: Annual growth is 2.1 percent per year.[3] This is, in OTA's view, the most reasonable assumption.
- *High:* Annual growth is 3.1 percent per year.

As in the residential sector, for each intensity scenario three levels of2010 consumption are shown corresponding to the three different assumptions as to commercial building square footage (table l-A-2).4

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[3] This is the value used in the National Energy Strategy; see *National Energy Strategy Technical Annex 2*, draft (Washington, DC: May 1991), p. A-5.

[4] It is interesting t. note that, for both sectors, the lower the intensity the lower the uncertainty in final consumption due to different assumptions as to the size of the building stock. In other words, lower intensity means both lower *energy use* and lower uncertainty. Uncertainty in energy demand has a cost, difficult to determine but surely nonzero; therefore decreased uncertainty can be seen as a benefit of lower intensity.

Appendix 1-B

Data Sources

References to "OTA 1992" in this report refer to databases assembled by OTA from many different sources. These sources are listed below.

D. Belzer, Battelle, Pacific Northwest Laboratories, personal communication, September 19, 1991.

Gas Research Institute (GRI), *Baseline Projection Data Book*, *1991* ed. (Chicago, IL: April 1991).

Pacific Northwest Laboratory, *Residential and Commercial Data Book—Third Edition,* PNL-6454 (Richland, WA: February 1988).

U.S. Department of Commerce, Bureau of the Census, *Characteristics of New Housing: 1990, C25-9013* (Washington, DC: June 1991).

U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States: 1990* (Washington, DC: January 1990).

U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States: 1991* (Washington, DC: 1991).

U.S. Department of Energy, Energy Information Administration, *Annual Energy Review 2990*, *DOE/EIA-0384(90)* (Washington, DC: May 1991).

U.S. Department of Energy, Energy Information Administration, *Commercial Building Characteristics 1989,* DOE/EIA-0246(89) (Washington, DC: June 1991).

U.S. Department of Energy, Energy Information Administration, *Commercial Building Consumption and Expenditures 1986,* DOE/EIA-0318(86) (Washington, DC: May 1989).

U.S. Department of Energy, Energy Information Administration, *Household Energy Consumption and Expenditures 1987--Part 1: National Data, DOE/EIA-0321(87)* (Washington, DC: October 1989).

U.S. Department of Energy, Energy Information Administration, *State Energy Data Report: Consumption Estimates, 1960-1989,* DOE/EIA-0214(89) (Washington, DC: May 1991).

U.S. Department of Energy, Office of Conservation and Renewable Energy, *Energy Conservation Multi-Year Plan 1990-1994* (Washington, DC: August 1988).

Appendix 1-C

Sources for “Business-as-Usual” Forecasts

Table l-C-l-Comparison of Residential Energy Use Forecasts (quadrillion Btu)

Forecast	1990	1995	2000	2010	Percent change (1990 to 2010)
DRI/McGraw-Hill (DRI) (1991)	15.5	16.7	17.5	18.3	+18
Energy Information Administration (EIA) (1991)	16.6	17.7	18.3	19.7	+19
Gas Research Institute (GRI) (1991)	16.7	17.5	18.6	20.5	+23
National Energy Strategy (1991)	18.2	—	—	23.3	+28
Oak Ridge National Laboratory (1990)	17,2	—	18.4	20.4	+19

NOTE: To allow direct comparisons, OTA has adjusted the DRI, EIA, and GRI end-use forecasts of residential energy consumption for all years to primary units to reflect electricity generation losses.

SOURCES: See app. l-C.

Table l-C-2-Comparison of Commercial Energy Use Forecasts (quadrillion Btu)

Forecast	1990	1995	2000	2010	Percent change (1990 to 2010)
DRI/McGraw-Hill (DRI) (1991)	12.2	13.3	14.3	15.8	+30
Energy Information Administration (EIA) (1991)	12.4	13.6	14.8	17.7	+43
Gas Research Institute (GRI) (1991)	12.3	13.3	14.5	17.5	+42
National Energy Strategy (1991)	13.8	—	—	21.3	+54
Oak Ridge National Laboratory (1990)	13.1	—	16.0	18.8	+44

NOTE: To allow direct comparisons, OTA has adjusted the DRI, EIA, and GRI end-use forecasts of commercial energy consumption for all years to primary units to reflect electricity generation losses.

SOURCES: See app. l-C.

Tables l-C-l and l-C-2 summarize the data presented in figures 1-12 and 1-13, Sources for these figures and tables include:

DIU/McGraw-Hill, *Energy Review: Winter* 1990-91 (Lexington, MA: 1991).

Gas Research Institute, *Baseline Projection Data Book, 1991* ed. (Chicago, IL: April 1991), pp. 38, 121.

U.S. Department of Energy, *National Energy Strategy: Powerful Ideas for America,* 1st ed. 1991/1992 (Washington, DC: February 1991), p. C-15.

Oak Ridge National Laboratory, *Energy Efficiency: How Far Can We Go?, ORNL/TM-*11441 (Oak Ridge, TN: January 1990), p. 7.

U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 1991, DOE/EIA-0383(91)* (Washington, DC: March 1991), Reference Case, p. 44.

Chapter 2

Technologies for Improving Energy Efficiency in Buildings

Box 2-A--Chapter Summary

Recent advances in equipment design have yielded remarkable efficiency improvements, and there is considerable potential for further gains. For example, while the typical new gas furnace in the 1970s was only 63 percent efficient, new gas furnaces are now available with 97 percent efficiency. New windows are available with an insulating value of R-8—an eight-fold improvement over the old R-1 single-pane window-and window designs in the laboratory suggest R-10 to R-15 may soon be available. Computerized controls can cut commercial building energy use by 10 to 20 percent. Improved design can reduce both energy use and construction costs in large office buildings.

In many cases these improved technologies are commercially available yet are rarely used, even though they offer attractive paybacks (the amount of time needed for the initial investment to be recovered by the reduced energy costs). For. example, highly efficient electronic ballasts for fluorescent lights typically pay back in 3 to 4 years-yet accounted for less than 4 percent of U.S. balIast shipments in 1990.

- If these efficient technologies were used more widely, energy use in buildings would be reduced considerably.
- The large gap between what is already available on the market and what is actually used suggests that implementation, rather than just technical advancement, is key to increasing energy efficiency.

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Chapter 2

Technologies for Improving Energy Efficiency in Buildings

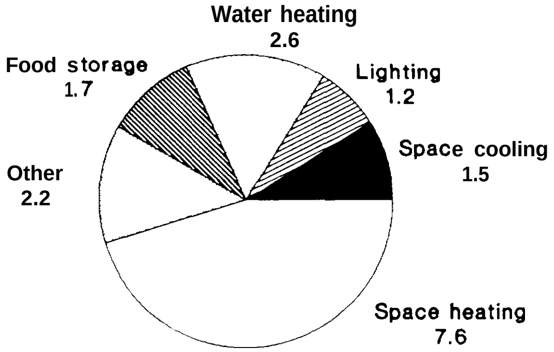
INTRODUCTION

Chapter 1 discussed how changes in technology influenced past energy use in buildings and argued that technology will continue to influence strongly future energy use. This chapter examines specific technologies used to convert energy into useful services (heating, cooling, lighting, etc.) in buildings. The discussion focuses *on three specific* questions:

- What technologies are currently used to provide energy services in buildings?
- Are there technologies available that can provide the desired services while using less energy?
- What are the costs and other attributes of these energy saving technologies?

The discussion is organized by end-use service, starting with space conditioning, followed by lighting, water heating, food refrigeration and freezing, and other energy services (figures 2-1 and 2-2).[1]

Figure 2-1—Residential Sector Energy Use by End-Use Service, 1989 (quads/year)



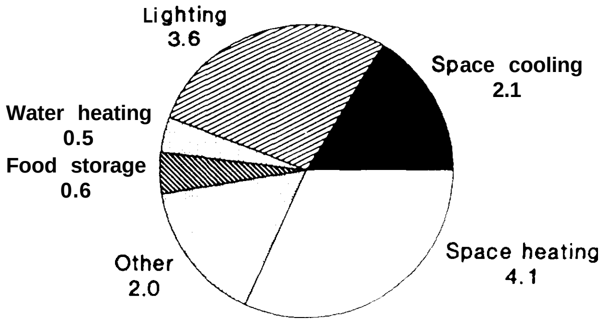
NOTE: Primary conversion used (see app. 2-C).
SOURCE: Office of Technology Assessment, 1992 (see app. 1 -B).

SPACE CONDITIONING

Space conditioning (heating, cooling, ventilation, and humidity control) requires more energy than any other service in both residential and commercial buildings, accounting for more than half of total residential/commercial energy use. In the residential sector space heating accounts for about 46 percent, and space cooling for about 9 percent, of energy use; while in commercial buildings space heating and cooling account for about 32 percent and 16 percent, respectively, of energy use.[2]

There have been impressive advances in the efficiency of space-conditioning equipment in recent years. New residential gas furnaces, for example, are now available that are 97 percent efficient, a vast improvement compared to the 63 percent efficient units commonly sold in the 1970s. New room air conditioners are now available that require only half the energy to provide the same amount of cooling as units sold in 1972. The efficiency of building shells has advanced as well: one can now purchase windows with an R-value of 8, an eight-

Figure 2-2—Commercial Sector Energy Use by End-Use Service, 1989 (quads/year)



NOTE: Primary conversion used (see app. 2-C).
SOURCE: Office of Technology Assessment, 1992 (see app. 1-B).

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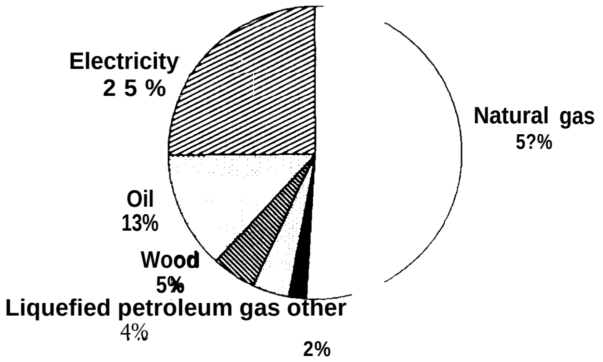
[1] This chapter is intended to be comprehensive and broad rather than exhaustive and to provide a sense of the opportunities rather than a complete list of all technologies. This report focuses on efficiency improvements; a separate OTA report in preparation will address renewable energy technologies.

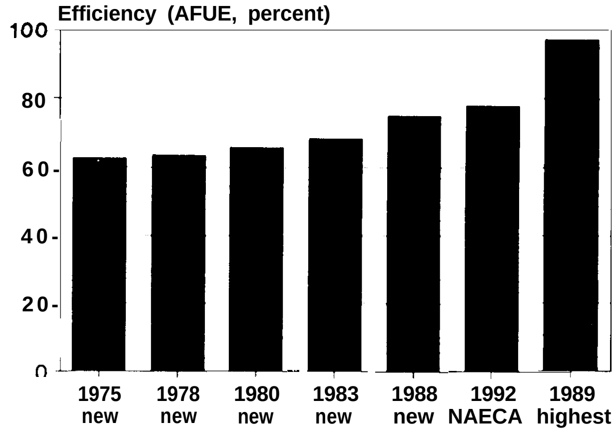
[2] For sources, see app. 1-B. Unless otherwise noted, energy consumption data in this report refer to primary energy-i. e., electricity is converted to energy units using a conversion factor that reflects the energy used to generate the electricity, as well as the energy equivalent of the electricity itself. See app. 2-C for a comparison and discussion of different methods of converting energy units.

Figure 2-3—Residential Space Heating Fuels (percent of households, 1989)



SOURCE: U.S. Department of Commerce, Bureau of the Census, *American Housing Survey for the United States in 1989,* H150/89 (Washington, DC: U.S. Government Printing Office, July 1991), p. 42.

Figure 2-4-Trends in the Efficiency of Natural Gas Furnaces



NOTES: 'New' is shipment-weighted average of all units shipped in that year. 'NAECA' is the minimum allowable according to the national standard. 'Highest' is the most efficient commercially available. See app. 2-A for a definition of AFUE.

SOURCES: 1975 to 1983: SAIC, *Trends in the Energy Efficiency of Residential Electric Appliances,* EPRI EM-4539 (Palo Alto, CA: Electric Power Research Institute, April 1988), pp. 2-9. 1988 and 1989: American Council for an Energy-Efficient Economy, *The Most Energy Efficient NewAp@iances-1989-90 edition* (Washington, DC: 1989), pp. 21-22.1992 NAECA: Public Law 100-12.

fold improvement over the single-pane windows still found in many buildings.[3]

This section reviews space conditioning and shell technologies-those currently in use, those improved technologies commercially available, and those still under development. It is found that highly efficient, commercially available technologies are often not utilized, despite their technical and economic advantages over conventional technologies.

Space Conditioning in Residential Buildings

Both the efficiency of the space conditioning equipment and the design of the building itself influence the amount of energy needed to maintain comfort in a residential building. A very efficient furnace will still use a lot of energy to heat a poorly insulated, drafty building, while a well-insulated building in a moderate climate may need no additional energy for space conditioning. This section discusses equipment and shell technologies separately.

Residential Space Heating Equipment

A variety of fuels and technologies are used to heat U.S. residences (figure 2-3). More than half (51 percent) of U.S. households use natural gas for space heating; the remainder use electricity (25 percent), oil (13 percent), and other fuels.[4]

Natural gas fired warm-air furnaces, currently found in about41 percent of households,[5] have made impressive gains in energy efficiency in recent years (figure 2-4). The use of electronic ignition, vent dampers, and other design improvements contributed to an efficiency increase of 12 percent in new units between 1975 and 1988. Further improvement is mandated by the National Appliance Energy Conservation Act (NAECA, Public Law 100-12), which sets minimum efficiency standards for gas furnaces.[6]

There are many commercially available gas furnaces, however, that are far more efficient-in the range of 95 to 97 percent. These units use ' 'condensing' ' technology, in which the latent heat of the

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[3] R-value is a measure of resistance to heat flow. The higher the R-value, the better the insulation value. These R-values are for center-of-glass.

[4] These other fuels include wood (5 percent), liquefied petroleum gas (LPG) (4 percent), and various other fuels. Data refer to percent of occupied households using that fuel as their main space heating fuel. U.S. Department of Commerce, Bureau of the Census, *American Housing Survey for the United States in 1989,* H150/89 (Washington DC: U.S. Government Printing Office, July 1991), p. 42.

[5] U.S. Department of Energy, Energy Information Administration, ***Housing Characteristics 1987,*** DOE/EIA-0314(87) (Washington, DC: May 1989), p. 33.

[6] As required by NAECA, units manufactured on or after January 1, 1992 must have a minimum efficiency of 78 percent. NAECA is discussed in more detail in ch. *4.*

combusted gas is recovered. At present, sales of condensing furnaces are low, due in part to their high price--typically about $1,500 to $2,000, or about $500 more than a noncondensing furnace.[7] These costs may drop, however, if production volumes increase. The cost-effectiveness of these furnaces depends on the climate; however, economic analyses of measured energy savings resulting from condensing furnace installations in colder climates found simple paybacks of 4 to 7 years.[8]

Electric resistance space heating units are relatively simple and inexpensive to install but are quite expensive to operate and therefore are more common in milder climates. Electricity costs about 2.3 cents per 1,000 Btus of delivered heat, while natural gas costs about 0.8 cents per 1,000 Btus; that is, heat from an electric resistance heater costs two to three times as much as heat from a natural gas furnace.[9] There are essentially no opportunities for technical improvement in the heating units themselves, as efficiencies are about as high as physically possible.

Electric heat pumps, however, hold considerable promise for future energy savings. A heat pump is essentially an air conditioner in reverse. Just as an air conditioner pumps heat from a relatively cool room into the warmer outside air, a heat pump moves heat from the cooler outside air into the warmer room.[10] The efficiency of a heat pump is typically about twice that of an electric resistance heater.[11] Most heat pumps installed in residential buildings can be run as air conditioners as well, meaning that one device provides both heating and cooling. Heat pumps are growing in popularity. Although they are found in only about 7 percent of U.S. households,[12] heat pumps were installed in 23 percent of all new single-family homes in 1990.[13] The typical heat pump sold today has a heating efficiency (HSPF) of about 6.9 Btus per watthour and a cooling efficiency (SEER) of about 9.1 Btus per watthour.[14] The best units currently on the market have efficiencies of about 9.2 and about 16.4, respectively (table 2-1).15 These best units cut heating and cooling costs by

Table 2-1—Electric Heat Pump Efficiencies and Annual Operating Costs

	Heating efficiency		Cooling efficiency	
	HSPF	cost/yr	SEER	cost/yr
Average for new units sold, 1988	6.9	$380	9.1	$170
Best commercially available, 1989	9.2	290	16.4	90
NAECA standard, effective 1992	6.8	390	10.0	150

NOTE: HSPF and SEER are defined in app. 2-A.

SOURCES: Average 1988: "Integrated Heat Pump System," *EPRI Journal*, vol. 15, No. 2, March 1990, p. 41. Best commercially available: American Council for an Energy-Efficient Economy, The *Most Energy Efficient New Appliances—1989-90* edition (Washington, DC: 1989), p. 18. NAECA standard: for split systems, from NAECA (Public Law 100-12), sec. 5. Operating costs are for energy only, and assume a heating load of 33.8 MBtus/yr and a cooling load of 19.6 MBtus/year (from J. Koomey, J. McMahon, and C. Wodley, *Improving the Thermal Integrity of New Single-Family Detached Residential Buildings*, LBL-29416 (Berkeley, CA: Lawrence Berkeley Laboratory, July 1991), p. 32). Electricity price of 7.8 cents/kWh assumed.

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[7] S. Cohen, C. Goldman, and J. Harris, *Measured Energy Savings and Economics of Refitting Existing Single-Family Homes: An Update of the BECA-B Database*, LBL-28147, vol. 1 (Berkeley, CA: Lawrence Berkeley Laboratory, February 1991), p. 22.

[8] Simple payback is defined in app. 2-B. The 4-to 7-year payback discussed here is based on the additional first cost and savings of the condensing unit over a new, 75-percent efficient baseline unit. Ibid., p. 15.

[9] Assuming an electricity price of 7.8 cents/kWh, 100 percent of electricity consumed is converted to heat, a natural gas Price of $5.61/l@ Btu, and a 70-percent natural gas furnace conversion efficiency (AFUE, see app. 2-A for definition).

[10] Heat Preps can extract heat from the ground or from outside water (typically from a well or pond), but usually use outside air as the heat source.

[11] The 1992 NAECA requirement for heat pumps sets a minimum Heating Seasonal Performance Factor (HSPF) of 6.8 (there are several measures of heat pump efficiency currently in use, see app. 2-A). This corresponds to about 6,800 Btus of heat for each kWh consumed. An electric resistance heater will deliver at most 3,412 Btus for each kWh consumed.

[12] U.S. Department of Commerce, Bureau of the Census, American *Housing Survey for the United States in 1989*, H150/89 (Washington, DC: U.S. Government Printing Office, July 1991), p. 40.

[13] U.S. Department of Commerce, Bureau of the Census, *Characteristics of New Housing: 1990*, C25-9013 (Washington DC: June 1991), p. 22.

[14] HSPF and SEER are defined in app. 2-A.

[15] An alternative heat pump design is the thermally activated heat pump, which uses a fuel such as natural gas rather than electricity. This design has the potential to offer even higher efficiencies, although costs and performance are uncertain. See Oak Ridge National Laboratory, *Energy Technology R&D: What Could Make a Deference,* ' vol. 2, Part l of 3, End-Use Technology, ORNL-6541/V2/P1 (Springfield, VA: National Technical Information Service, December 1989), p. 33.

about $160 per year, relative to units meeting the 1992 NAECA standard, in a typical new house. With heat pumps, as with most other residential energy-using equipment, there is a large efficiency gap between units currently being installed and the most efficient units commercially available.

Oil-fired space heating systems are currently used in 13 percent of U.S. households but are being installed in only about 5 percent of new single-family homes and 1 percent of new multifamily units.[16] These new installations are found almost entirely in the Northeast, presumably in areas without natural gas service. The high perceived variability in oil prices has limited the demand for oil furnaces in new construction. The 1992 NAECA standard for oil furnaces is 78 percent (AFUE). Currently available units, however, perform far better. The best on the market achieve efficiencies over 90 percent.[17]

Distribution systems and controls are frequently overlooked opportunities for improving the efficiency of space heating and cooling systems. For example leaky air distribution ducts can result in significant energy losses, suggesting that greater attention to quality control in duct installation is warranted. Although much of the research to date has focused on space cooling, the findings apply in principle to space heating as well. For example, a study of air-conditioned homes in Florida found that air conditioner energy use was reduced 18 percent simply by repairing leaky ducts. The payback for this relatively easy fix was less than 2 years.[18] Similarly, measured data in a study of California households indicated that 20 to 40 percent of peak cooling day consumption was due to duct leakage.[19] Night setback, dual zone, and programmable thermostats can all reduce energy use through better system control. In multifamily buildings, the addition of reset and cutout controls can increase efficiency as well.[20]

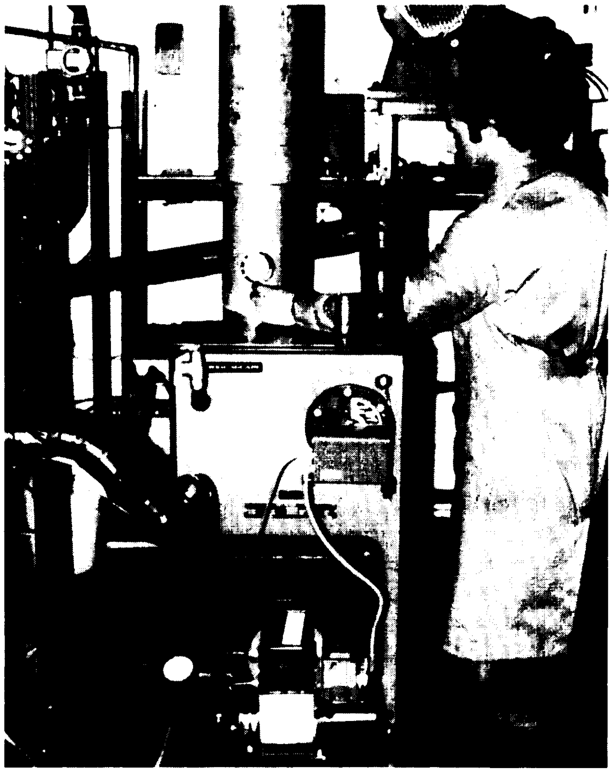

Photo credit: U.S. Department of Energy

Oil-fired space heating systems are used in 13 percent of U.S. households, mostly in the Northeast.

Retrofits to improve the efficiency of space heating systems already in place are usually limited to simple maintenance, such as replacing filters, oiling motors, and cleaning burners. Older oil-fired furnaces can benefit from the use of a flame-retention burner head, which better atomizes the fuel and thereby allows more complete burning; paybacks for this simple retrofit were 2 to 5 years in

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[16] U.S. Department of Commerce, Bureau of the Census, *Characteristics of New Housing: 1990, C25-9013* (Washington, DC: June 1991), PP. 20, 39.

[17] American Council for an Energy-Efficient Economy, *The Most Energy Efficient New Appliances—1989-90 edition* (Washington, DC: 1989), P. *23.*

[18] J. Cummings, J. Tooley Jr., N. Moyer, R. Dunsmore, "Impacts of Duct Leakage on Infiltration Rates, Space Conditioning Energy Use, and Peak Electrical Demand in Florida Homes, ' *Proceedings of the ACEEE 1990 Summer Study on Energy Efficiency in Buildings* (Washington, DC: American Council for an Energy-Efficient Economy, 1990), p. 9.65.

[19] M. Modera, "Residential Duct System Leakage: Magnitude, Impacts, and Potential for Reduction," *ASHRAE Transactions,* vol. 96, Part 2, 1989.

[20] A reset allows boiler hot water temperature t. change in response to outside temperature, and a cutout allows the boiler to shut off when outside temperature is such that no space heat is needed. See F. Jablonski, "Rethinking Multifamily Resets and Cutouts, " *Home Energy, vol. 8, No, 4,* July/August 1991, p. 40.

recent evaluations using measured consumption data.[21]

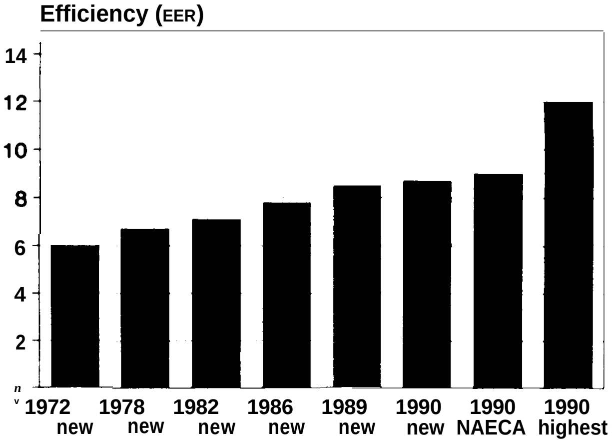
Residential Space Cooling Equipment

Over two-thirds (69 percent) of U.S. households have air conditioning-+0 percent with central systems and 29 percent with room units.[22] The trend in new construction has clearly been toward greater use of central air conditioning; about 76 percent of new single-family homes and 78 percent of new multifamily buildings have central air conditioning.[23]

Central air conditioning systems are integrated into the building ductwork and come in two basic designs: cooling-only systems and heat pumps (discussed above). Cooling-only systems typically have an outdoor unit housing the compressor, condenser coil, and fan; and an indoor unit built into the existing ductwork containing the evaporator coil. Central air conditioning systems show a trend of increased efficiency; the average unit sold in 1981 had a SEER of 7.8 Btus per watthour,[24] while the best units available in 1989 achieved SEERS of up to 16.9.[25] This impressive efficiency increase came from continual free-tuning and adjustment: larger condenser and evaporator coils, better motors, improved insulation, reduced airflow-path resistance, and better fan blade design.[26] NAECA sets a minimum SEER of 10 for split systems manufactured on or after January 1, 1992.

Room air conditioners, like refrigerators, are free-standing appliances that are generally selected and installed by consumers. The energy efficiency of room air conditioners has improved, due to higher efficiency compressors, improved fan designs, and larger heat exchangers.[27] The average new unit bought today needs about 30 percent less electricity to deliver the same cooling as the average unit bought in 1972; even more efficient units are commercially available in some size categories (figure 2-5). Note that the most efficient new units in 1990 consume only about half the electricity to deliver the same cooling as the average unit bought in 1972.

Figure 2-5—Trends in the Efficiency of Room Air Conditioners



NOTES: 'New' is shipment-weighted average of all units shipped in that year. 'NAECA' is the minimum allowable according to the national standard. 'Highest' is the most efficient commercially available. See app. 2-A for a definition of EER.

SOURCES: 1972 to 1989: Association of Home Appliance Manufacturers (AHAM), *Major Home Appliance Industry Fact Book 1990/91,* (Chicago, IL), p. 27.1990 new: R. Gants, Vice President, Association of Home Appliance Manufacturers, personal communication, Oct. 18, 1991.1990 highest: Association of Home Appliance Manufacturers (AHAM), "1 991 Directory of Certified Room Air Conditioners," Edition No. 1, October 1990, 1990) p. 10.1990 NAECA: Public Law 100-12, sec. 5; refers to a 8,000 to 13,999 Btu/hr unit without reverse cycle, with louvered sides.

The incremental costs of high-efficiency air conditioners are unclear. Highly efficient models often come with additional features such as better

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[21] S. Cohen, C. Goldman, and J. Harris, *Measured Energy Savings and Economics of Retrofitting Existing Single-Family Homes: An Update of the BECA-B Database,* LBL-28147, vol. 1 (Berkeley, CA: Lawrence Berkeley Laboratory, February 1991), p. 15.

[22] U.S. Department of Commerce, Bureau of the Census, *American Housing Survey for the United States in* 1$'&?, H150/89 (Washington, DC: U.S. Government Printing Office, July 1991, p. 40.

[23] U.S. Department of Commerce, Bureau of the Census, *Characteristics of New Housing: 1990,* C25-9013 (Washington, DC: June 1991), pp. 4, 36.

[24] SAIC, *Trends in the Energy Efficiency of Residential Electric Appliances,* EPRI EM-4539 (Palo Alto, CA: Electric power Research Institute, April 1986), p. 2-2. See app. 2-A for a definition of SEER.

[25] American Council for an Energy-Efficient Economy, The *Most Energy Efficient New Appliances—1989-90 edition* (Washington, DC: 1989), pp. 16-17.

[26] Battelle-Columbus Division and Enviro-Management and Research, Inc., *DSM Technology Alternatives,* EPRI EM-5457 (Palo Alto, CA: Electric Power Research Institute, October 1987), p. A-42.

[27] SAIC, *Trends in the Energy Efficiency of Residential Electric Appliances,* EPRI EM-4539 (Palo Alto, CA: *Electric* Power Research Institute, April 1986), p. 2-5.

Photo credit: Electric Power Research Institute

Wall insulation can significantly reduce energy use for space heating and cooling.

temperature control, more fan speeds, and improved air circulation, making it inappropriate to charge the additional cost of the efficient unit solely to the efficiency feature. Nevertheless if one considers only the energy savings benefit, the payback to the consumer of buying the most efficient unit, relative to a standard unit, is about 6.4 years.[28]

Residential Shell Technologies

The amount of energy needed to keep people comfortable is determined in part by the efficiency of the heating and cooling equipment, discussed above, but also by features of the building shell. A well-constructed building with plenty of insulation, tight-fitting doors and windows, well-designed windows, and other energy saving features can use significantly less energy than a poorly constructed building. For example superinsulated houses, which often have double the usual amounts of insulation, can use 80 to 90 percent less space-conditioning energy than conventional houses.[29]

Opportunities to enhance the energy efficiency of a building shell occur throughout a building's lifetime. Prior to construction, siting and orienting a building with careful attention to natural features—sunlight, wind, earth-sheltering-can reduce energy use. In the design of a building, specifying adequate insulation levels, designing overhangs to block out

Box 2-B—How a Building Gains and Loses Heat

Heat can be lost from a building several ways.[1] Much of the heat in a typical single-family residence is lost as conduction through the ceiling, walls, windows, and floor. Increasing the insulating value of all surfaces can reduce these conductive losses. Some heat is lost from air infiltration through gaps in windows, doors, and other areas. Reducing infiltration losses by reducing air flows throughout the building reduce heat losses as well. A building gains heat from its occupants, from the space heating equipment, from the Sun, and from other interior equipment (all the energy consumed by a refrigerator, for example, ends up as heat in the kitchen.)

The space conditioning requirements of a building are strongly influenced by the climate-and climatic conditions vary widely in the United States. Heating requirements are often measured by heating degree-days,[2] which vary from 100 in southern Florida to over 10,000 in mountainous areas. Cooling requirements, measured by cooling degree-days, also vary tremendously.

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[1] This discussion of heat loss applies to "cool" losses (more accurately heat gains) as well.

[2] Degree-days are typically measured relative to a base temperature, usually 65 degrees F. If the daily average temperature one day is 60 degrees F, then that day has 5 (65 minus 60) heating degree-days. Degree-days are usually given on an annual basis, by adding up 1 year's worth of daily degree-days.

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[28] Based on retail prices quoted in Washington, DC in 1991; assuming Washington, DC climate and electricity price of 7.8 cents/kWh. Payback period will of course depend heavily on climate. Another perspective on the economic analysis is that of the electric utility. Since residential space-cooling often occurs at or near times of peak demand, the additional first cost of the most efficient unit can be compared to the cost of on-peak generation to meet the demand of the standard unit. For the two air conditioners considered here, the most efficient unit costs about $70 more but uses about 250 watts less of power, which works out to about $280/kW. For comparison a gas-turbine for electricity generation costs about $400/kW (Electric Power Research Institute, *TAG Technical Assessment Guide, Electricity Supply-1989,* EPRI P-6587-L (Palo Alto, CA: Electric Power Research Institute, September 1989), p. 7-56).

[29] D. Hafemeister and L, Wall, "Energy Conservation in Buildings and Appliances," in R. Howes and A. Fainberg (eds.), *The Energy Sourcebook (New* York, NY: American Institute of Physics, 1991), p. *445.* The additional construction costs of superinsulation vary, but one estimate puts them at about $4,000 to $7,500 for a 1,500-square-foot house. 1991 *Residential Building Cost Guide,* Boeckh/American Appraisal Associates (Milwaukee, WI: *1991), p. R75.*

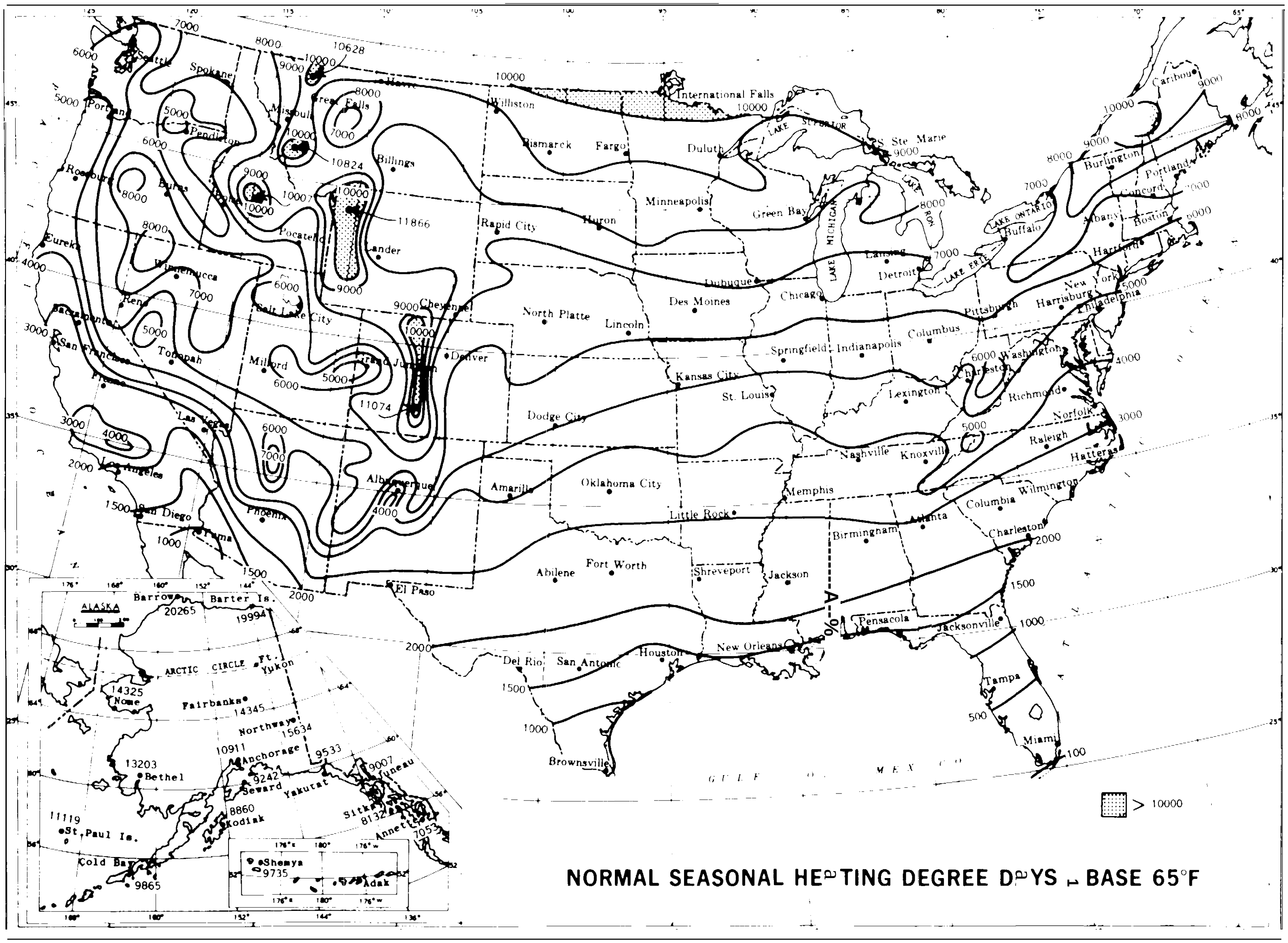

Photo credit: U.S. Department of Commerce

Space heating requirements in the United States, shown here in annual heating-degree-days, vary from less than 100 in southern Florida to over 20,000 in northern Alaska.

unwanted sunlight in summer, specifying high-quality windows, and installing whole-house fans where appropriate will reduce energy use. In construction, careful attention to sealing joints and corners, window and door fits, and ensuring adequate and well-distributed insulation is important. In operation, keeping doors and windows closed when appropriate, using blinds to block out unwanted sunlight in summer, and other occupant actions will affect energy use. And retrofit--one-time actions taken to improve the energy efficiency of an existing building, such as the addition of caulk and weather-stripping, insulation, and storm doors and windows—can help as well.

Technologies for improving building shell efficiencies are discussed in two earlier OTA reports.[30] The best ways to improve building shells—generous and careful installation of insulation, careful caulking and weatherstripping, taking natural features such as trees and terrain into account, using high-quality windows—have been recognized since at least the 1970s.[31] Recent research has essentially refined these ideas. For example, methods for sealing buildings to reduce infiltration have improved, and the use of greater insulation levels in walls and ceilings is becoming more common. The use of factory-assembled components and structures has increased, which has allowed for tighter tolerances and therefore reduced infiltration.[32]

Significant efficiency advances have occurred in window technologies. These improvements are important, as by one estimate 25 percent of the heating and cooling requirements in the United States are due to losses through windows.[33] A single pane of glass has an insulating value of about R-1, which is very low relative to the R-15 typical of a wall in a new house.[34] One way to increase the insulating value of a window is to add a second or even a third pane, increasing the R-value to about R-2 and R-3, respectively. However more panes add weight, limit natural light, and raise costs considerably. A recent innovation has been the addition of clear coatings to glass surfaces. These so called low-emissivity (or low-e) coatings allow the transmission of solar radiation into the interior, but reduce radiative heat losses back out again. The addition of a low-e coating can increase the insulating value of a double-pane window from R-2 to about R-2.5 to R-3.2. Low-e windows cost 10 to 20 percent more than regular windows but are quite popular. About half of all new double-pane windows incorporate the low-e coating.[35] Large window manufacturers now offer low-e glass in many of their products.[36] Window frames have improved as well, with greater use of thermal breaks to limit conduction losses through the frame.

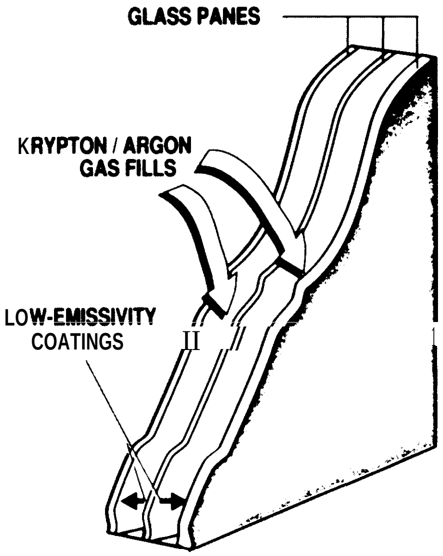

Photo credit: Lawrence Berkeley Laboratory

New window technologies offer up to eight times the insulating value of old single-pane windows.

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[30] U.S. Congress, Office of Technology Assessment, *Energy Efficiency of Buildings in Cities, OTA-E-168* (Washington, DC: U.S. Government Printing Office, March 1982); U.S. Congress, Office of Technology Assessment, *Residential Energy Conservation,* OTA-E-92 (Washington, DC: U.S. Government Printing Office, July 1979).

[31] See, e.g., R. Socolow (cd.), *Saving Energy in the Home* (Cambridge, MA: Ballinger, 1978).

[32] 155ue5 of automation in the construction industry are discussed in U.S. Congress, Office of Technology Assessment, *Technology and the Future of the US. Construction Industry* (Washington, DC: AIA Press).

[33] R. Bevington and A. Rosenfeld, "Energy for Buildings and Homes,' *Scientific American,* vol. 263, No. 3, September 1990, p. 80.

[34] "R" is a measure of resistance t. heat flow, with units of hour-square feet-degree F per Btu. The higher the R-value, the better the insulating value.

[35] Advanced Sciences, Inc., "Wtidow Innovations," CARIERS, Silver Spring, MD, February 1990.

[36] "Wtidow Company Standardizes Low-E Glass,' *Home Energy,* vol. *7, No. 3, May/June* 1990, p. *6.*

Several additional window innovations are commercially available. Gas-filled windows, which substitute argon for air in the space between the panes, offer insulating values of about R-4. A window using gas-filled spaces and two suspended reflective films achieves R-8.[37] However these very advanced windows are expensive, which suggests they may be economically justified only in severe climates.[38]

Retrofits: Energy efficiency improvements can be applied to existing buildings as well. Many older residential buildings in the United States were built with little regard for energy efficiency. Retrofitting these buildings could save considerable energy; however, the cost-effectiveness of these retrofits depends on the specific design of a building, the climate, energy costs, and other factors. Estimating the cost-effectiveness of a shell retrofit with simple engineering calculations is not as straightforward as it may seem; buildings are surprisingly complex, and engineering estimates of energy savings are often inaccurate. Measuring actual savings-the difference in energy use before and after the retrofit--is preferable.[39] The most comprehensive effort to collect and analyze actual savings from building retrofits has been conducted by Lawrence Berkeley Laboratories (LBL), where information and data on building retrofits from across the United States are collected and analyzed. A summary of some typical results is shown in table 2-2. Results vary considerably, however it appears that additions to insulation offer typical paybacks of about 5 to 7 years (table 2-2).

Photo credit: U.S. Department of Energy

Caulking gaps around windows and doors can reduce infiltration, and thereby reduce energy use for space heating and cooling.

In addition, there are numerous case studies of building retrofits. Although the results of these case studies may not be applicable to all buildings, they do illustrate the potential and diversity of retrofit opportunities.

- In the Twin Rivers study performed at Princeton University in the 1970s, a cluster of typical

Table 2-2-Cost-Effectiveness of Residential Shell Retrofits

Action	Average cost (1989 dollars)	Average savings (percent of main space heat fuel)	Typical payback (years)
Ceiling insulation.	500 to 970	12 to 21	6.0
Wall insulation.	810 to 1,600	12 to 17	6.8
Foundation insulation.	1,020	NA	5.7

NOTE: Foundation insulation data are for interior of conditioned spaces.

SOURCE: S. Cohen, C. Goldman, and J. Harris, *Measured Energy Savings and Economics of Retrofitting Existing Sing/e-Family* Homes: An *Update of the BECA-B* Database, LBL-28147, vol. 1 (Berkeley, CA: Lawrence Berkeley Laboratory, February 1991), p. 2. Paybacks are calculated at the midpoint of t he costs and savings estimates, and assume the saved fuel is natural gas at a price of $5.61/106 Btu.

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[37] A. Wilson, ''An Improved Outlook' ***Architecture,*** August 1990, p. 95. All R-values given are center-of-%'indow values.

[38] U.S. Congress Office of Technology Assessment, *Energy Technology Choices: Shaping Our Future,* OTA-E-493 (Washington, DC: U.S. Government Printing 'Office, July 1991), p. 33.

[39] 'fil$ method also has its problems. Weather fluctuations, changes in occupant behavior, and data requirements complicate savings estimates; however innovative evaluation tools, notably the PRISM (PRInceton Scorekeeping Model), have improved the accuracy of these estimates. See M. Fels, "PRISM: An Introduction, ' *Energy and Buildings, vol. 9, Nos. 1/2,* February/May **1986,** pp. 5-18.

Photo credit: U.S. Department of Energy

Many houses in the United States still lack basic efficiency features such as storm windows.

townhomes were retrofitted with movable window insulation, careful sealing of joints and corners, and increased insulation throughout. The result was a two-thirds reduction in the energy needed for space heating, with no change in indoor temperature and no changes in the space heating furnace.[40]

- In a comprehensive research project in the Pacific Northwest in the mid-1980s (known as the Hood River Conservation Project), homes were retrofitted with increased insulation, improved windows and doors, and several other measures. The result was an average reduction in space heating electricity use of 36 percent.[41]

Given the diversity in the building stock, climate and energy price variability, and the dependence of costs on the building design, it is difficult to provide blanket recommendations on building retrofits. Adding insulation can offer reasonable paybacks (table 2-2), but final determinations must be site-specific. When replacing space conditioning equipment, highly efficient equipment should be considered, but again the optimal level of efficiency will depend on the building, climate, energy prices, occupant behavior, and other site-specific factors.

There is some evidence that many residences in the United States lack basic efficiency features. For example 39 percent of U.S. households lack storm doors, 22 percent lack wall insulation, and 12 percent lack ceiling insulation.[42] Although the economic justification for such features will depend on climate and other factors, these data suggest that there is considerable potential to improve the energy efficiency of the existing building stock, As further evidence of this potential, the Hood River Conservation Project (mentioned above) resulted in homes that use about one-fourth less energy for space heating than the average U.S. home.[43]

Space Conditioning in Commercial Buildings

Larger commercial buildings are quite different from residential buildings.[44] They have much larger and more complex heating and cooling systems, they usually have active ventilation systems (since natural airflow is insufficient to maintain air quality), and

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[40] R. Socolow (cd,), *Saving Energy in the Home* (Cambridge, MA: Ballinger, 1978), p. xx.

[41] Space heating electricity consumption, pre- versus post-, all housing types. The economics of these retrofits are dependent on lifetime assumptions* discount rates, and other assumptions, but the cost of conserved energy (CCE, see app. 2-B for definitions) was about 7.1 to 7.9 cents/kWh. E. Hirst, *The Hood River Conservation Project,* DOE/BP-11287-18 (Washington, DC: U.S. Department of Energy, June 1987), pp. 34,41.

[42] U.S. Department of Energy, Energy Information Administration, *Housing Characteristics 1987,* DOE/EIA-0314(87) (Washington DC: May 1989), p. 109.

[43] The Hood River Project achieved a post-retrofit intensity of 2.6 Btu per square foot-degree-day (S. Cohen, C. Goldman, and J. Harris, *Measured Energy Savings and Economics of Retrofitting Existing Single-Family Homes: An Update of the BECA-B Database,* LBL-28147, vol. 1 (Berkeley, CA: Lawrence Berkeley Laboratory, February 1991), p. 74), while the average electrically heated single-family home required 3.4 Btu per square foot-degree-day (U.S. Department of Energy, Energy Information Administration, *Household Energy Consumption and Expenditures 1987--Part 1: National Data,* DOE/EIA-0321(87) (Washington DC: October 1989), p. 11).

[44] ‘‘Larger” refers to commercial buildings with more than 10,000 square feet, representing about 79 percent of total commercial floor space. U.S. Department of Energy, Energy Information Administration *Commercial Building Characteristics 1989, DOE/EIA-0246(89)* (Washington DC: June 1991), p. 17.

Box 2-C—Indoor Air Quality

Homes obtain fresh air through natural infilltration—uncontrolled airflow through doors, windows, and leaks in the building shell. Recent efforts to reduce energy use by reducing infiltration, however, have raised concerns about indoor air quality. In some situations, concentrations of pollutants such as carbon monoxide, nitrogen oxides, radon, and various organic compounds can reach unhealthy and even dangerous levels-for example, when gas stoves or unvented kerosene heaters are used for space heating, or in very "tight" (low infiltration) houses.

Field research has shown that the strength of the pollutant source maybe more important than the tightness of the building, as tight buildings can have no indoor air problems while leaky buildings can have severe problems. There are several methods for responding to air quality concerns, but the best method is often to isolate and remove the source of the problem, rather than merely to increase the ventilation rate. In the case of radon, active ventilation systems may be necessary regardless of building tightness.

Determining minimum ventilation rates for residences is difficult; however, there is some agreement that a minimum of 0.3 air changes per hour is acceptable.[1] In very tight houses some advocate the use of active ventilation such as air-to-air heat exchangers to maintain minimum air exchange rates.

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[1] See J, Nisson and G. Dutt, The *Superinsulated Home Book* (New York, NY: Wiley, 1985), ch. 4.

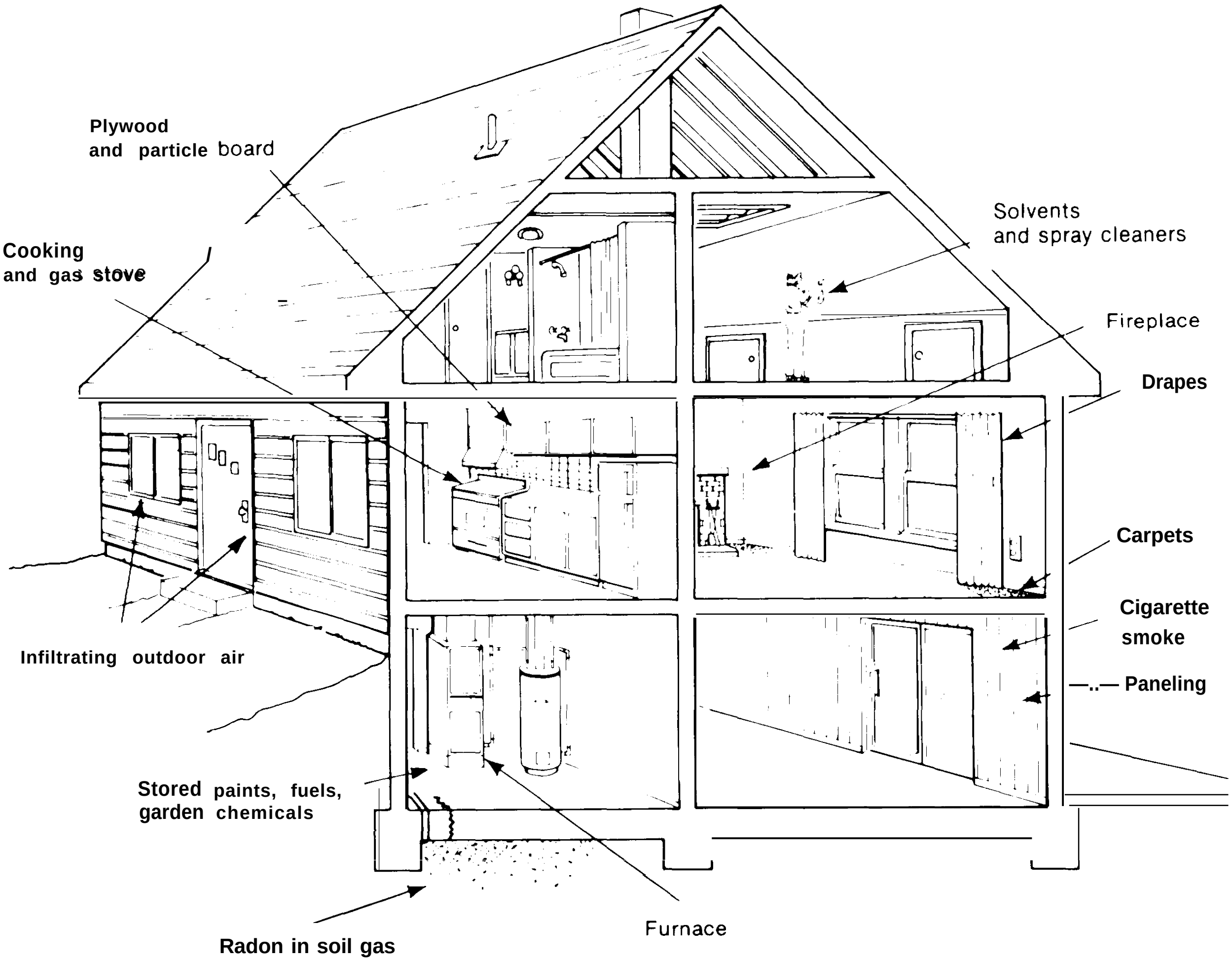

Photo credit: U.S. Department of Energy

Indoor air quality problems often are best dealt with by addressing the source of the problem.

Table 2-3—Space Heating Technologies in Commercial Buildings

Technology/type	Percent[a]
Gas furnace/boiler	48
Oil furnace/boiler	25
Electric boiler	22
Electric heat pump	2
Other	3

[a] The percent of all commercial square footage heated with the technology, in 1988.

SOURCE: Gas Research Institute, "Baseline Projection Data Book," 1991 ed., Washington, DC, p. 127.

Table 2-4—Selected Technologies for Improving Energy Efficiency in Commercial Space Conditioning

Space heating
- High efficiency furnaces and boilers
- Substitute heat pumps for electric resistance heat
- Heat exchangers to reclaim heat from vented air
- Packaged cogeneration systems

Space cooling
- High efficiency electric chillers
- Direct evaporative cooling
- Outside air economizers

Air handiing
- Variable air volume (VAV) systems
- Energy efficient motors
- Variable-speed drive motors
- Reduced outside air ventilation if excessive
- Improved duct layout
- Reduced duct leakage, reduced air flow if excessive

Overall system
- Dual fuel heat pump
- Ground source heat pump
- Energy efficient motors
- Variable-speed drive motors
- Improved system control/energy management system
- System shut-off/set-back during unoccupied hours
- Heat recovery systems

SOURCE: Office of Technology Assessment, 1992.

they are "load-dominated," meaning that much of the space conditioning needs arise from the activity within the building-people, lights, and energy-using equipment—rather than from the influence of the outside (ambient) conditions. In a large commercial building, the space conditioning (commonly called HVAC, for heating, ventilating, and air conditioning) system might simultaneously be heating an exterior office, cooling a computer room, and ventilating a kitchen. HVAC systems in commercial buildings can be extraordinarily complex, and the opportunities for efficiency improvements complex as well. In general, energy efficiency improvements can come from:

- improving the efficiency of the energy-using device (e.g., using a higher efficiency chiller);
- improving the design of the overall system (e.g., routing and designing ducts to minimize losses);
- switching to a different system (e.g., using a heat pump rather than electric resistance heating);
- improving the control of the system (e.g., by using outside air for cooling when appropriate);
- improving maintenance (e.g., by changing filters as needed); and
- reducing demand for the services provided by the system (e.g., installing more efficient lights to reduce the need for space cooling).

Space Heating in Commercial Buildings

A range of technologies is used to provide space heating in commercial buildings, including residential-style oil and natural gas furnaces in smaller buildings, oil and natural gas boilers, heat pumps, and electric boilers (table 2-3). Energy use for space heating in commercial buildings is almost double that of space cooling;[45] however, much Of the recent research on improving energy efficiency has focused on the latter. Despite the relative lack of research, opportunities for efficiency improvements in commercial building space heating do exist (table 2-4). Gas boilers and furnaces produce almost half of all commercial space heat (table 2-3), and high-efficiency units are available in the smaller sizes (less than about 150,000 Btu per hour). A typical commercial gas furnace has an efficiency of about 70 percent, while a high-efficiency unit can achieve over 90 percent efficiency.[46] The diversity of commercial buildings makes it difficult to generalize about the energy savings potential, however there is some evidence that this potential is large. For example, a computer simulation of a new office building in New England found that the addition of

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[45] In 1988, primary conversion used. For sources, see app. 1-B.

[46] Decision Focus Inc., *TAG Technical Assessment* Guide, EPRI P-4463-SR, vol. 2, Part 2 (Palo Alto, CA: Electric Power Research Institute, October 1988), p. 5-60.

a heat recovery device reduced heating energy use by 44 percent. The estimated payback on the investment was about 8 years.[47]

Very large commercial buildings in warmer climates often require very little space heat during occupied periods. A large office building in Tennessee, for example, generates all its space heat from internal sources—lights, computers, and people.[48] The only energy needed for space heating is that required to move the heat from the warmer interior offices to the cooler exterior offices. Smaller buildings and those in colder climates, however, do require space heating.

District heating is an entirely different approach to space heating in commercial buildings and involves the production of heat (in the form of hot water or steam at a central plant), which is then distributed directly to buildings through underground pipes. Such systems currently heat 11 percent of commercial building floor space in the United States.[49] Many European countries apply these systems more widely—in Denmark, for example, almost half of all building space heating needs are met with district heating systems.[50] Such systems are appropriate mainly in colder climates with large space heating needs. The efficiency of such a system depends on the method used to produce the heat. If a cogeneration system is used to produce both heat and electricity, for example, the overall system efficiency can be quite high,[51] but one must have a demand for hot water large enough to justify the system.

Space Cooling/Air Transport in Commercial Buildings

Space cooling technologies for commercial buildings have been the focus of considerable research and development, as a large portion of peak electricity demand is due to commercial building space cooling. Many commercially available technologies could provide space cooling with less energy; some of these technologies are listed in table 2-4. The applicability and energy savings potential of these technologies will vary from building to building. Case studies, however, have shown that better cooling system design and operation can save significant amounts of energy. The use of variable speed drive motors in the air distribution system of a large office building in New Jersey reduced fan energy consumption by 52 percent, with a payback of 5 years.[52] Improved valving and control of a large space cooling system in a hospital cost $32,000 and saved $45,000 in electricity costs, with a payback of less than 9 months.[53]

A number of technologies can improve the energy efficiency of both space heating and space cooling systems (table 2-4). Energy management systems provide computerized control of space conditioning equipment and can reduce energy use by 10 to 20 percent.[54] The use of an energy management system in a large office building in New Jersey reduced energy costs by about $57,000 per year, with a payback of less than 4 years.[55] Despite attractive paybacks, less than one-quarter of all commercial building floor space is controlled by energy management systems.[56]

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[47] Northeast Utilities, *Energy and Economics—Strategies for Office Building Design* (Hartford, CT), p. 45.

[48] M. McCarley, ''Tune-up of a Modem Office Building, ' *Proceeding From the International Symposium Energy Options for the Year 2000,* Center for Energy and Urban Policy Research, University of Delaware, Newark, DE, 1988, p. 3-181.

[49] U.S Department of Energy, Energy Information Administration, *Commercial Building Characteristics 1989*, DOE/EIA-0246(89) *(Washington* DC: June 1991), p. 128.

[50] P. Kunjeer, ''District Heating and Cooling: Solution for the Year 2000, ' *Proceedings From the International Symposium Energy Options for the Year 2000,* Center for Energy and Urban Policy Research, University of Delaware, Newark, DE, 1988, p. 1-109.

[51] Cogeneration is discussed in detail in U.S. Congress, Office of Technology Assessment, *Industrial and Commercial Cogeneration*, OTA-E-912 (Washington, DC: U.S. Government Printing Office, February 1983).

[52] With static pressure reduction. S. Englander and L. Norford, "Fan Energy Savings: Analysis of a Variable Speed Drive Retrofit, " *Proceedings of the ACEEE 1988 Summer Study on Energy Efficiency in Buildings* (Washington, DC: American Council for an Energy-Efficient Economy, 1988), p. 3.51.

[53] R.J. Parson, ' 'Simplified Retrofit of a Large chilled Water System, " in F. Payne (cd.), *Strategies for Energy Efficient Plants and Intelligent Buildings* (Lilburn, GA: Fairmont Press, 1987), p. 599.

[54] Decision Focus Inc., *TAG* Technical *Assessment Guide*, EPRI P-4463-SR (Palo Alto, CA: Electric Power Research Institute, October 1988), vol. *2,* Part 2, p. **5-106.**

[55] A Usibelli, S. Greenberg M. Meal, A. Mitchell, R. Johnson, G. Sweitzer, F. Rubinstein, D. Arasteh, *Commercial-sector Conservation Technologies,* LBL-18543 (Berkeley, CA: Lawrence Berkeley Laboratory, February 1985), p. A-9.

[56] In 1989. U.S. Department of Energy, Energy Information Administration, *Commercial Building Characteristics 1989*, DOE/EIA-0246(89) (Washington, DC: June 1991), p. 211.

There are numerous examples of other innovative technologies to reduce space conditioning energy use. Energy efficient motors can reduce motor energy use by 3 to 8 percent at a cost of $100 to $300 per kW, by one estimate.[57] A combination of improved maintenance and improved scheduling of HVAC equipment reduced energy costs at the Houston airport by 20 percent, saving $400,000 per year with no capital investment.[58] Electronic controls for space conditioning systems (often called direct digital controls, or DDC) offer improved management of temperature and air flow; in one analysis, the paybacks for using electronic controls instead of pneumatic controls in new construction were 1 to 3 years.[59] Heat recovery technologies, which recover the waste heat from space cooling equipment and use it to supply hot water, space heating, or other needs, can offer considerable energy savings.

Commercial Shell Technologies

Opportunities for shell improvements in smaller commercial buildings are similar to those in residential buildings. Increased insulation to reduce heat transfer, tighter construction to reduce infiltration, and the use of high-R windows can all reduce energy requirements for space conditioning.

Larger commercial buildings often have somewhat different requirements; their space conditioning needs are typically influenced more by internal loads (lights, people, office equipment, etc.) than by external loads (sun, outdoor temperature), as shown in table 2-5. For a typical office building in San Francisco, for example, more cooling energy would be saved from a 25 percent reduction in lighting energy use than from completely eliminating all the windows (table 2-5). This is not to suggest that shell and window design are trivial components of energy efficient building design; only that as building size increases internal loads become increasingly important.

Table 2-5-Annual Cooling Loads for a Typical Large Office Building in San Francisco

Load Component	Percent of load
Internal loads	
Lights	*55*
People	*21*
Air handling system	*19*
Miscellaneous equipment	*9*
External loads	
Windows	13
Roof	-1
Walls	- 0
floor	-1
Outside air ventilation	-15
Total	100

SOURCE: A. Usibelli, S. Greenberg, M. Meal, A. Mitchell, R. Johnson, G. Sweitzer, F. Rubinstein, D. Arasteh, *Commercial-Sector Conservation Technologies*, LBL-1 8543 (Berkeley, CA: Lawrence Berkeley Laboratory, February 19S5), p. 2-105. Office equipment, notably computers, is becoming an important additional cooling load in offices. See "Other Energy Services" section of this chapter.

LIGHTING

Lighting is the single largest consumer of electricity in commercial buildings. About 41 percent of electricity, and 28 percent of total energy, consumed in the commercial sector is for lighting. In the residential sector, lighting energy use is small though not trivial, representing about 7 percent of residential energy use.[60] The opportunities for improved lighting efficiency-delivering the same or better quality of light with less energy—are considerable. Using technologies already on the market, electricity use for residential lighting could be cut by about one-third.[61] Similarly, electricity use for commercial lighting could be reduced considerably—with estimates of 39 to 83 percent—using commercially available technologies.[62]

These energy savings come largely from the use of new, efficient lighting technologies. Lamps, ballasts, reflectors, and lighting control technologies

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[57] A. Usibelli, S. Greenberg, M. Meal, A. Mitchell, R. Johnson, G. Sweitzer, F. Rubinstein, D. Arasteh, *Commercial-Sector Conservation Technologies,* LBL-18543 (Berkeley, CA: Lawrence Berkeley Laboratory, February 1985), p. 2-73.

[58] R. Bevington and A. Rosenfeld, ''Energy for Buildings and Homes, ' *Scientific American,* vol. 263, No. 3, September 1990, p. 78.

[59] C.E. Lundstrom, "Comparison of Cost and Performance of HVAC Controls, " in F. Payne (ed.), *Strategies for Energy Efficient Plants and Intelligent Buildings* (Lilburn, GA: Fairmont Press, 1987), p. 55.

[60] See app. 1-B for data sources.

[61] See calculations in this section.

[62] ''Lighting the Commercial World,'' *EPRI Journal,* vol. 14, No. 8, December 1989, p. 6; estimates 39 to 55 percent savings. M.A. Piette, F. Krause, and R. Verderber, *Technology Assessment: Energy -Efficient Commercial Lighting,* LBL-27032 (Berkeley, CA: Lawrence Berkeley Laboratory, March 1989), p. 6-2; estimate 78 to 83 percent technical potential for savings.

Box 2-D—Smart Design Reduces First Cost by $500,000 and Cuts Operating Costs in Half

Anew office building in Pittsburgh cost $500,000 less to build, and about half as much to operate, due to the use of smart design and innovative energy-efficient technologies. The 10-story, 175,000 square foot (gross) Comstock building, completed in 1983, uses heat pumps to provide heating and cooling, innovative air-return windows, high-efficiency light fixtures, and an energy management system. High insulation levels and careful placement and design of windows allowed for the use of a smaller HVAC (heating, ventilating, and air conditioning) system than would otherwise be needed; and the heat pump system cost about half as much as a conventional system. Net savings, even after covering the additional costs of the windows, exceeded $500,000. Careful monitoring of building energy use has shown that consumption is well below the target, and operating costs are about one-half those of other large office buildings in the area.[1]

Similarly, a detailed computer simulation of a new 60,000-square-foot office building in the Northeast found that a well-designed building using commercially available equipment would cost the same to build as a standard new building, yet would cost 37 percent less to operate.[2]

Photo credit: Burt Hill Kosar Rittelmann Associates

Smart design allowed this building to be less expensive to both build and operate.

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[1] P. Rittelmann and P. Scanlon, "HVAC Design Delivers Twin Benefits," *Building Design and Construction,* November 1984.

[2] Northeast Utilities, *Energy and Economics—Strategies for Office Building Design* (Hartford, CT,), pp. 96-97.

have all advanced considerably in recent years. This section reviews some of these recent technical advances and provides an indication of the costs and benefits of energy efficient lighting.

Lighting in Residential Buildings

Improved Incandescent Lamps

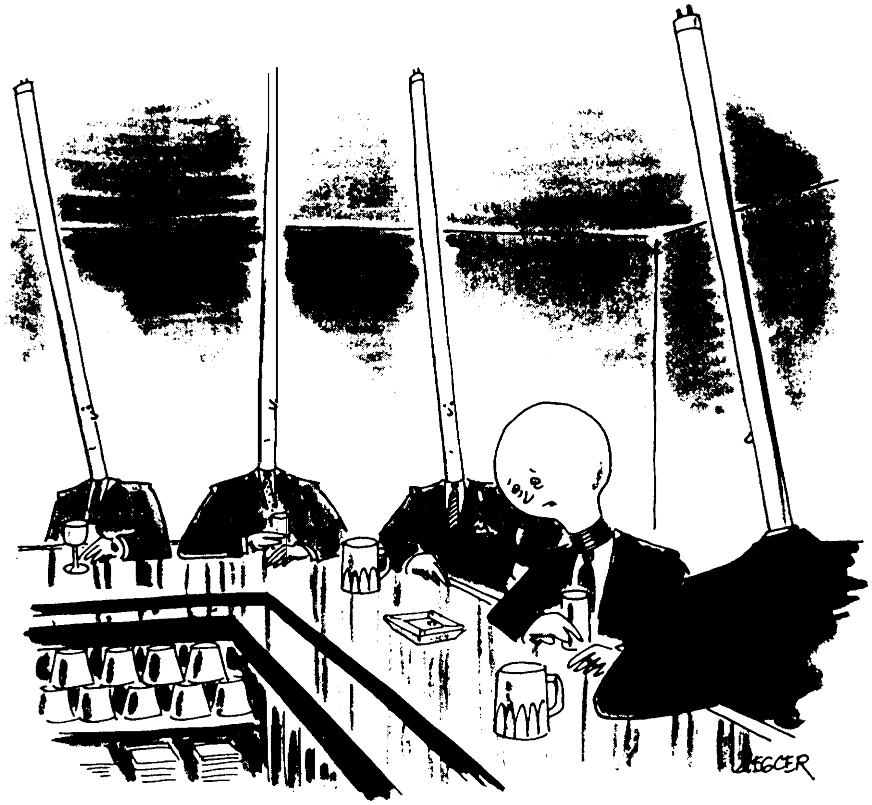
Incandescent lamps provide most lighting in the residential sector (box 2-E). There are several technologies available to improve incandescent lamp efficiency (table 2-6), although even the advanced incandescent lamps are still far less efficient than fluorescent lamps. Improved filaments and the use of krypton gas inside the bulb provide a modest efficiency improvement. Other technological improvements on the standard incandescent technology include infrared-reflective coatings and the use of halogen-filled tubes inside the bulb. This halogen lamp offers a modest efficiency gain and a significantly longer life than the standard incandescent.

Table 2-6-Characteristics of Improved Incandescent Lamps

	Standard	Improved	Halogen
Rated energy consumption (watts). .	100	90	100
Rated light output (lumens).	1,750	1,620	1,925
Efficiency (lumens per watt).	17,5	18.0	19.3
Rated life (hours). ... ., ...	750	750	2,250
Retail purchase price (dollars).	0.67	0.90	4.19

NOTE: Data and prices are for lamps available in Washington, DC, in 1991.

SOURCE: Office of Technology Assessment, 1992.



"Laugh if you will, but my kind once ruled the earth."

Drawing by Ziegler; @1991 The New Yorker Magazine, Inc.

Compact fluorescent

Fluorescent lamps are about four times more efficient than incandescent lamps, but their use in residences has been limited by their higher frost cost, unattractive light, and inability to fit in incandescent fixtures. In 1984, however, a lighting manufacturer introduced the compact fluorescent, a lamp providing reasonably attractive light and fitting regular incandescent fixtures yet using the efficient fluorescent technology .[63] The compact fluorescent achieves an efficiency of 61 lumens per watt, or 3.8 times the efficiency of a comparable incandescent (table 2-7), This means that a compact fluorescent can provide the same light as a standard incandescent with just one-fourth of” the energy.[64] In addition, the life Of a compact fluorescent is typically about 10,000 hours, about 13 times as long as a standard incandescent (table 2-7).

Table 2-7—Technical Comparison of Incandescent and Compact Fluorescent Lamps

	Standard incandescent	Compact fluorescent
Rated energy consumption (watts). . . .	75	18
Rated light output (lumens).	1,190	1,100
Efficiency (lumens per watt).	15.9	61.1
Rated life (hours).	750	10,000
Retail purchase price (dollars).	0.67	20.00

NOTE: Data and prices are for lamps available in Washington, DC, in 1991.

SOURCE: Office of Technology Assessment, 1992.

The technical potential for energy savings from using compact fluorescent lamps is considerable. Compact fluorescent are not suitable for all residen-

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[63] Compact fluorescent are a different size and shape than the standard incandescent and therefore may not fit all lamps or fixtures designed for incandescent.

[64] The compact fluorescent shown in table 2-7 supplies slightly less light, as measured in lumens, than the 75-watt standard incandescent. However, lumens are only one measure of light. Light has several other qualities, including color and shadowing patterns, which may differ for the two technologies shown in table 2-7.

Box 2-E—Introduction to Lighting Technology

Most lighting in the residential sector is performed by standard pear-shaped incandescent lamps. These lamps use a simple filament that produces light when an electric current passes through it. These lamps are simple to install, cheap to manufacture, familiar to consumers, and widely available. Their disadvantages are short life (typically 1,000 hours) and very low energy efficiency. Lighting energy efficiency is typically measured in lumens per watt, where lumens can be thought of as the quantity of light[1] and watts are the electric power input. A typical incandescent lamp achieves only about 18 lumens per watt, far lower than other technologies. The low efficiency is due to much of the energy input being converted to heat, rather than light, which is easily demonstrated by touching a lit incandescent lamp.

Fluorescent lights represent an entirely different approach to producing light from electricity. These lights consist of two components—a ballast, which regulates current and voltage, and the lamp itself. When a fluorescent lamp is switched on, a current is generated between two electrodes in the lamp. Mercury ions in the lamp emit ultraviolet energy in the presence of this current. This ultraviolet energy then strikes the inner walls of the lamp, which are coated with a phosphor powder. This powder then emits radiation seen by the human eye as light. The efficiency of this complex process is quite high--typically about 60 to 80 lumens per watt, or 3 to 5 times as efficient as the incandescent lamp. Fluorescent lamps usually have much longer lives as well—typically 10,000 to 20,000 hours, or 10 to 20 times longer than incandescent. Disadvantages include a higher initial cost due to increased complexity and a differing quality or type of light. In the past, fluorescent light has been perceived as cold or sterile, although recent improvements have narrowed the gap between the quality of light emitted by fluorescent and incandescent lamps. Fluorescent lamps are widely used in commercial buildings.

A third lighting technology is HID, or high intensity discharge. This includes high-pressure and low-pressure sodium lamps, as well as metal-halide lamps. These lamps are very efficient (table 2-E-l), but their use is limited to areas where light quality is less crucial, such as street lighting, parking garages, and warehouses. They typically require several minutes to warm up and are not designed for frequent on-off cycles.

Table 2-E-l—Efficiencies and Lifetimes of Lighting Technologies

Technology	Typical lighting efficiency (lumens per watt)	Typical lifetime (hours)
Incandescent.	17 to 20	750 to 1,000
Fluorescent.	60 to 85	10,000 to 20,000
HID[a].	100 to 125	24,000+

[a] HID - High Intensity Discharge.

SOURCE: Office of Technology Assessment, 1992.

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[1] One linen on an area of 1 square foot is equivalent to one footcandle. Lumens per watt can be thought of as analogous to miles per gallon for cars-a useful way to compare different technologies, where larger is more efficient.

tial applications, however if compact fluorescent replaced just half of all residential lighting presently supplied by incandescent, electricity consumption would drop 36 terawatt-hours per year, which is approximately equivalent to the combined annual output of six full-size coal-burning powerplants.[65] The payback for a compact fluorescent is 1.7 years for a light used 6 hours per day.[66]

In summary, there are alternative technologies that can significantly reduce lighting energy use. These come at an increased first cost but offer reasonable paybacks—for example less than 2 years for compact fluorescent.

Operation and Design

Improved lighting operation and design—turning off lights when not needed, using automatic (dusk-to-dawn) switches on outdoor lights, and designing fixtures that reflect rather than absorb light--can improve lighting efficiency. These opportunities are difficult to quantify, and their savings potential will depend on the specific situation.

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[65] In 1990 residential lighting consumed about 105 TWh. Assuming 90 percent of this is consumed by incandescent lamps, and half Of this incandescent lighting is supplied instead with compact fluorescents, 47.3 TWh of incandescent are replaced with 11.3 TWh of compact fluorescent. The net savings is 36 TWh. A 900-megawatt (MW) coal-burning powerplant operating at 80 percent capacity factor produces about 6.3 TWh/yr. Note that half of incandescent lighting energy, not incandescent lights, are replaced with compact fluorescents in this example.

[66] Assuming electricity price of 7.8 cents/kWh, O labor costs, and the values shown in table 2-7.

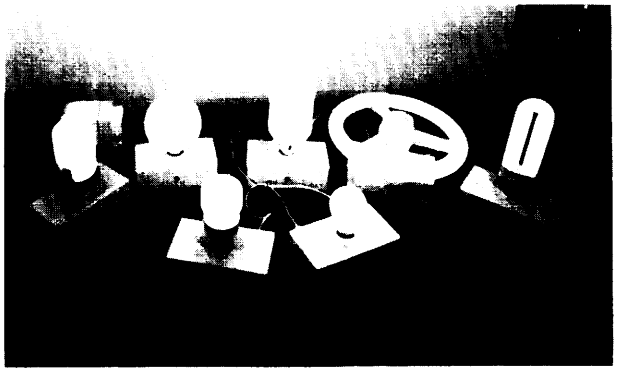

Photo credit: U.S. Department of Energy

Compact fluorescent, which use 75 percent less energy than standard incandescent lamps, are available in a variety of designs.

Lighting in Commercial Buildings

Lighting is the single largest user of electricity in commercial buildings, accounting for about 41 percent of commercial sector electricity use.[67] The lighting technologies currently used in commercial buildings mirror the diversity of the sector itself: standard fluorescent lamps in offices, high-intensity lamps highlighting merchandise in retail stores, a mix of fluorescent and incandescent lamps in restaurants, and so on. This section provides basic information on widely used commercial lighting technologies, their alternatives, and their costs and other attributes.[68]

Lamps

Fluorescent lamps consume about 55 percent of lighting electricity in the commercial sector (table 2-8), Fluorescent lamps vary widely, but many are the familiar 4-foot cylindrical-shaped units. These lamps typically consume 34 to 40 watts of electricity and supply about 3,000 lumens of light. Other popular fluorescent lamps are the 8-foot long cylinders, typically consuming 75 to 100 watts and producing 6,000 to 9,000 lumens; and the U-shaped lamp, typically at 40 watts and 3,000 lumens. Most fluorescent lamps found in commercial buildings are one of these three types.

Table 2-8—Lighting Technologies in Use in Commercial Buildings (1989)

Type of lighting	Percent of floor space[a]	Percent of lighting electricity[b]	Total electricity (TWh per year)
Incandescent. , .	15	41	141
fluorescent.	77	55	190
HID[c].	9	4	14
Total.	100	100	345

[a] The approximate percent of commercial building floor space that is lit predominantly by that technology.

[b] The approximate percent of electricity used for lighting in the commercial sector that is consumed by that technology. Assumes all technologies are used the same number of hours per year, all technologies deliver the same number of lumens per square foot, and the following energy efficiencies: Incandescent 18 lumens per watt, fluorescent 70 lumens per watt, HID 110 lumens per watt.

[c] HID - High Intensity Discharge.

SOURCES: U.S. Department of Energy, Energy Information Administration, *Commercial Building Characteristics 1989,* DOE/EIA-0246(89) (Washington, DC: June 1991), p.195. Floor space total does not sum to 100 due to rounding. Total electricity for lighting from OTA 1992; see app. I-B.

There are countless variations on the regular fluorescent technology. Color of light, starting technology, shape of electrical connector, diameter, length, and of course energy consumption can all vary, depending on the specific model and manufacturer. The focus here is on those technologies that can influence energy consumption.

There is some evidence that many older commercial buildings are overlit, meaning that the installed lighting fixtures supply more light than needed.[69] In such buildings the standard 4-foot, 40-watt fluorescent lamp may be replaced with a 'high-efficiency' 34-watt lamp, recognizing that much of the energy savings from this lamp comes from reduced output, not higher efficiency. The reduced wattage lamp described in table 2-9, for example, is filled with a higher fraction of krypton than a standard lamp and is therefore slightly more efficient than the standard lamp. It uses 15 percent less energy, but delivers 12 percent less light (as measured in lumens). Despite their reduced output, these lamps now supply about one-third of the total U.S. market for new 4-foot

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[67] See app. 1-B fo sources. This does not include indirect effects on HVAC consumption.

[68] Those interested in a more detailed technical discussion of lighting technologies are referred to M.A. Piette, F. Krause, and R. Verderber, Technology *Assessment: Energy-Efficient Commercial Lighting, LBL-27032* (Berkeley, CA: Lawrence Berkeley Laboratory, March 1989).

[69] A Usibelli, S. Greenberg, M. Meal, A. Mitchell, R. Johnson, G. Sweitzer, F. Rubinstein, D. Arasteh, *Commercial-Sector Conservation Technologies,* LBL-18543 (Berkeley, CA: Lawrence Berkeley Laboratory, February 1985), p. 5-26. The Illuminating Engineering Society (IES) sets recommendations for lighting levels, but there is some evidence that in the past most commercial building lighting systems supplied much more light than the IES recommends.

Table 2-9—Standard and Reduced Wattage Versions of the 4-Foot, 40-Watt (T-12) Fluorescent Lamp

Description	Energy use (watts)	Light output (lumens)	Efficiency (lumens per watt)
Standard.	40	3,250	81
High efficiency, . .	34	2,850	84

NOTE: Both are rapid start, T-12 (1.5 inch diameter) lamps with a rated lifetime of 20,000+ hours.

SOURCE: GE Lighting, "Selection Guide for Quality Lighting," Form 9200, 20th ed., Cleveland, OH, 1990, pp. 90-91.

fluorescent lamps.[70] As with all lighting retrofits, however, careful attention is required to maintain a level and quality of light that meets occupant needs.

Several fluorescent lamp technologies offer additional efficiency improvements. Smaller diameter lamps (known as T-8, with a 1 inch diameter) are somewhat more efficient, due to their greater surface-to-volume ratio. Lamps with improved phosphors also offer efficiency gains.

Ballasts

The fluorescent lamp requires a ballast, which regulates the voltage and current received by the lamp. Ballasts consume energy internally and also affect the energy efficiency of the lamp through their voltage and current control. There are two major types of ballast technologies—magnetic and electronic. For many years, ballasts used a simple iron core and aluminum core windings to regulate voltage and current. This magnetic technology was well-proven and in universal use but was relatively inefficient. The use of larger iron cores and copper rather than aluminum windings provides about a 10 percent improvement in energy efficiency,[71] with no change in light output or quality.

The use of electronic (solid-state) ballasts, which control voltage and current electronically, can both increase the energy efficiency of the ballast it self and improve the operation of the lamp through improved current control. The efficiency of the ballast-lamp system is typically improved 20 to 25 percent when electronic ballasts are used.[72] These ballasts *come* at a higher frost cost—typically about $10 more than an efficient magnetic ballast[73]—but offer typical paybacks of 3 to 4 years.[74] In addition, electronic ballasts are often smaller, lighter, and quieter. Despite their benefits, electronic ballasts have yet to acquire a large market share-less than 4 percent of all ballasts shipped by U.S. manufacturers in 1990 were electronic.[75] Although some early models of electronic ballasts had moderately high failure rates,[76] these ballasts have since been improved and are now routinely offered with long-life warranties. Their reputation for unreliability still persists, however, and may be contributing to their slow market penetration.

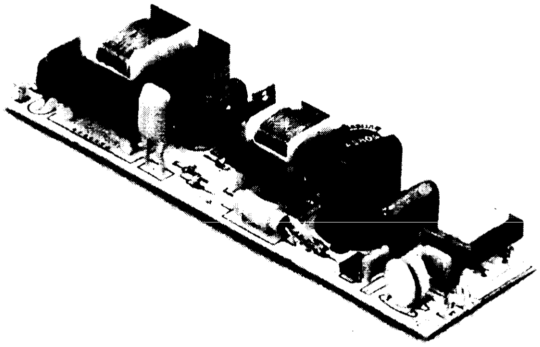

Photo credit: Advance Transformer Co.

Electronic ballasts can cut fluorescent lighting energy use by 20 to 25 percent.

In 1988 the U.S. Congress passed the NAECA amendments (Public Law 100-357), which set minimum efficiency levels for ballasts. Standards were set for four types of ballasts, representing about 85

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[70] A. Lovins and R. Sardinsky, *The State of the Art: Lighting* (Old Snowmass, CO: Competitek, Rocky Mountain Institute, March 1988), p. 122.

[71] A. Usibelli, S. Greenberg, M. Meal, A. Mitchell, R. Johnson, G. Sweitzer, F. Rubinstein, D. Arasteh, *Commercial-Sector Conservation Technologies, LBL-18543* (Berkeley, CA: Lawrence Berkeley Laboratory, February 1985), p. 5-4.

[72] Relative to standard magnetic ballasts. R. Verderber, *Status and Application of New Lighting Technologies,* LBL-25043 (Berkeley, CA: Lawrence Berkeley Laboratory, June 1988), p.3.

[73] The incremental additional first cost of an electronic ballast over an efficient (that is, one meeting the NAECA Amendment Standards) magnetic ballast, based on quotes from manufacturers for large purchase orders in 1991.

[74] Assuming $10 incremental first cost, 15 watt savings, operation for 10 hours per day and 250 days per year, and an electricity cost of 7.3 cents/kWh.

[75] U.S. Department of commerce, Bureau of the Census, Current Industrial Reports, "Fluorescent Lamp Ballasts—Summary for 1990," MQ36C(90)-5, Washington, DC, issued July 1991.

[76] R. Verderber, *Status and Application of New Lighting Technologies,* LBL-25043 (Berkeley, CA: Lawrence Berkeley Laboratory, June 1988), p. 3.

Table 2-10—Alternative Lighting Designs for a Large Office

	Standard design	High efficiency design
Lamps	40-watt fluorescent	34-watt 'miser' fluorescent
Ballasts	Standard magnetic	Dimmable electronic
Fixtures	4 lamp, flat lens	2 lamp, parabolic reflector
Initial cost (per square foot-year)	$2.77	$4.08
Operating cost (per square foot-year)	$0.54	$0.34

NOTE: Electricity price assumed: 7.3 cents per kWh.

SOURCE: Decision Focus Inc., *TAG Technical Assessment Guide,* EPRI P-4463-SR (Palo Alto, CA: Electric Power Research Institute, October 1988), vol. 2, Part 2, pp. 6.29-6.33.

percent of the ballast market.[77] Efficiency levels set by this legislation will probably prevent the use of the very inefficient standard magnetic ballasts, but will allow for the use of improved magnetic ballasts and electronic ballasts.[78]

Fixtures

The design of the entire lighting fixture can significantly influence performance, A poorly designed fixture will absorb light and reduce useful output. Conversely, a well-designed fixture will reflect light to where it is needed, thereby reducing wasted output. Fixtures consist of several parts: the lamp itself, the ballast, the reflector to direct the light in the desired direction, the lens or louver to reduce glare, and the housing. There are thousands of fixtures on the market, each with its own design and characteristics. The quality of light given off by a fixture is difficult to measure, making it difficult to quantify the effectiveness or value of various fixture designs. There are some general design features, however, that clearly contribute to energy efficiency.

The addition of a specular reflector can increase the light output of a fixture. For example, removing two lamps from a four-lamp fixture and then adding a specular reflector will yield about 60 to 80 percent of the initial light output with a 50 percent reduction in energy use, and a payback of usually less than 1 year.[79] Locating fixtures nearer to areas needing light can reduce wasted output. Changing, cleaning, or removing the lens covering fixtures can increase light output.

The potential savings from combining improved fixtures, lamps, and ballasts is significant. For example, an analysis by the Electric Power Research Institute (EPRI) found that the use of commercially available lighting technologies, including electronic ballasts, reflectors, and reduced wattage lamps, reduced energy consumption by 37 percent relative to a standard design with no reduction in light output and with a payback of less than 7 years (table 2-10). Actual installation of similar technologies in an office building in New York City yielded significant savings, with a payback of 6.2 years.[80]

Controls

Lighting controls can reduce lighting energy use by ensuring that lights are used only when and where required. Options include manual or automatic dimming to reduce output when appropriate, manual switches to allow lights to be turned off when not needed, occupancy sensors to switch lights on automatically when a room is occupied, and scheduled switches to turn lights on and off on a prearranged schedule. The economic attractiveness of improved controls are building-specific, as they depend on hours of operation, occupant behavior,

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[77] U.S. Congress, Senate Committee on Energy and Natural Resources, ''Senate Report No. 100-345 on the National Appliance Energy Conservation Amendments of 1988," May 13, 1988, p. 3.

[78] The NAECA amendments set performance standards, rather than technical requirements, so one cannot conclude from the legislation itself exactly which technologies will be used. The performance standards, however, are set at levels that seem to prohibit the least efficient magnetic ballasts. It is interesting to note that, when the NAECA amendments were passed, seven States had already set their own statewide ballast standards, which were then superseded by the Federal standard.

[79] Decision Focus Inc., *TAG Technical Assessment Guide,* EPRI P-4463-SR (Palo Alto, CA: Electric Power Research Institute, October 1988), vol. 2, Part 2, pp. 6-27.

[80] Based on predicted energy savings and excluding predicted maintenance savings. R. Watson, ''Case Study in Energy Efficient Office Renovation: NRDC'S Headquarters in New York City," *Proceedings of the ACEEE 1990 Summer Study on Energy Efficiency in Buildings* (Washington, DC: American Council for an Energy-Efficient Economy, 1990), p. 3.225.

electricity prices, and other factors. Examples include the installation of occupancy sensors in a section of the World Trade Center, which reduced lighting energy use by 57 percent,[81] and lighting control retrofits in eight commercial buildings that yielded an average 19 percent energy savings, with an average payback of 3.7 years.[82]

Daylighting

The use of natural sunlight, rather than light from electricity, has many attractions. In addition to the electricity savings, daylighting typically offers better views and the feeling of more space, The potential electricity savings are quite high+. g., a 70 percent reduction in perimeter lighting electricity y use,[83] In one case study, a retail/office Space was retrofit with daylighting technologies to provide a more attractive space, and although energy savings were not the primary intent, lighting energy use was reduced 59 percent.[w] There can be increased first costs, however, due to the need for additional windows and, depending on climate, an increased space cooling load.[85] Designing a building to exploit daylighting is complex and can require specialized skills.[86]

WATER HEATING

Water heating accounts for about 15 percent of residential and 4 percent of commercial energy use. Slightly more than half of U.S. households use natural gas to heat water and 37 percent use electricity (table 2-11). In residences, hot water is used for personal washing (in showers and baths), clothes washing, dish washing, and other miscellaneous uses, The bulk of hot water use in the commercial sector is in the service sector—in restaurants, laundromats, and other facilities requiring hot water as part of their business.

Table 2-1 I—Water Heating Fuels in **Residential Buildings (1989)**

Type	**Percent of households**
Natural gas	**52**
Electricity	**37**
Oil	**7**
Bottled gas	**3**
Other	1
	100

SOURCE: U.S. Department of Commerce, Bureau of the Census, *American Housing Survey for the United* States *in 1989,* HI 50/89 (Washington, DC: U.S. Government Printing Office, July 1991), p. 42.

Residential Water Heating Technologies

Essentially all U.S. households have hot water service. In single-family homes and in some multifamily buildings, 40 to 50 gallon water heater tanks are used both to heat and to store hot water. Natural gas-fired tanks typically have somewhat higher first (purchase) costs than electric units,[87] and can cost more to install as well, as they require gas service and external ducting.[88] The costs of operation, however, are typically about 50 percent lower for gas-fired tanks (this will vary depending on fuel costs and unit efficiency).

The efficiency of residential-size water heaters has improved in recent years (figure 2-6), due largely to increased tank insulation, smaller pilot lights, and improved heat transfer from combustion gases to the water in the tank. The most efficient commercially available water heaters sold today use thick polyurethane foam insulation, carefully designed heat trans-

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[81] M.A. Piettc, F. Krause, and R. Verderber, *Technology Assessment: Energy-Efficient Commercial Lighting,* LBL-27032 (Berkeley, CA: Lawrence Berkeley Laboratory, March 1989), p. 5-4.

[82] K. Greely, J. Harris, and A. Hatcher, ' 'Measured Energy Savings and Cost-Effectiveness of Conservation Retrofits in Commercial Buildings, " *Proceedings of the ACEEE 1990 Summer Study on Energy Efficiency in Buildings* (Washington, DC: American Council for an Energy-Efficient Economy, 1990), p. 3.103, table 3.

[83] A. Usibelli, S. Greenberg, M. Mea], A, Mitchell, R. Johnson, G, Sweitzer, F. Rubinstein, D, Arasteh, *Commercial-Sector Conservation Technologies,* LBL-18543 (Berkeley, CA: Lawrence Berkeley Laboratory, February 1985), p. 6-3, Perimeter refers to the area near the windows in a building, as distinct from the core where daylighting often cannot penetrate.

[84] M. A, Piette, F. Krause, and R, Verderber, *Technology Assessment:* Energy *-Efficient Commercial* Lighting, LBL-27032 (Berkeley, CA: Lawrence Berkeley Laboratory, March 1989), p. 5-2.

[85] The use of fewer electrical lights will reduce space cooling needs; however, this may be more than offset by the increased heat coming from the sun.

[86] A Usibelli S. Greenberg M. Meal, A, Mitchell, R. Johnson, G, Sweitzer, F, Rubinstein, D, Arasteh, *Commercial-Sector Conservation Technologies,* LBL-18543 (Berkeley, CA: Lawrence Berkeley Laboratory, February 1985), p. 6-2.

[87] Natural gas Units are typically about 20 to 30 percent more expensive than comparable electric units, excluding installation and operating costs.

[88] Approximately one-third of households in the United States do not have **access to** natural **gas.** U.S. **Department of** Energy, Energy Information **Administration,** *Housing Characteristics 1987,* DOE/EIA-0314(87) (Washington, DC: May 1989), p. 35.

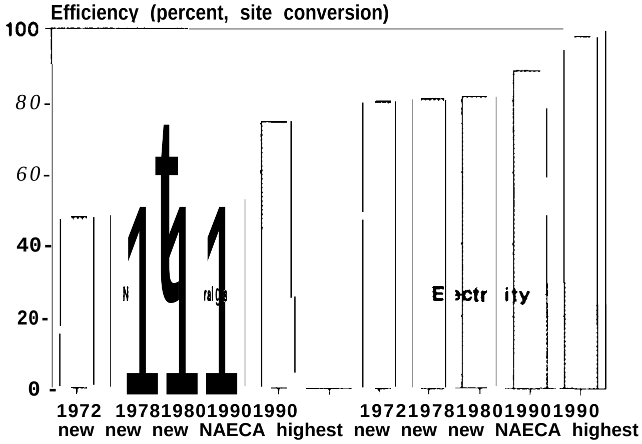
fer surfaces, and electronic ignition, but these features are found only in a few models. As was found for other residential appliances, there is a considerable efficiency difference between the average new water heater and the most efficient commercially available new water heater (figure 2-6).

The costs of the very efficient units are quite high-but it is not appropriate to attribute this additional cost solely to energy efficiency. For example, a 40-gallon gas water heater with an efficiency of 74 percent costs about $780, but this unit has a lifetime warranty,[89] special design to eliminate corrosion, and several other features not found on a $35061 percent efficient unit.[90] According to a sales manager for a water heater manufacturing firm, the main marketing advantage of the highly efficient unit is the warranty and not the energy efficiency.[91] (chapter 3 of this report discusses in more detail how energy-using devices are marketed and selected.)

Other methods of improving water heating efficiency include demand reductions, retrofits to existing units, and technical improvements in new units. The simplest method to reduce energy use for water heating is by reducing consumption of hot water. The largest users of hot water in residences are showers and baths (41 percent of hot water), clothes washing (24 percent), and kitchens (27 percent), with the remainder (8 percent) used in bathroom sinks.[92] Low-flow showerheads can reduce shower flow rates by about 50 percent.[93] Although consumer acceptance of these devices is a concern, designs have improved in recent years and consumer satisfaction is reported to be quite high.[94]

Retrofits to existing hot water systems can reduce their energy use. Popular retrofits include tank wrapping (adding a layer of insulation to the outside of the hot water tank), reducing tank temperature, and insulating hot water pipes. Adding R-11 insulation blankets to water heaters in homes in the Pacific Northwest, at a cost per blanket of about $20, resulted in an average annual savings of 714 kWh per household.[95] A separate study found water heater wrapping to be the most cost-effective building retrofit measure, with an average payback of 0.6 years.[96]

Figure 2-6-Trends in the Efficiency of Water Heaters



NOTES: 'New' is shipment-weighted average of all units shipped in that year. 'NAECA' is the minimum allowable according to the national standard. 'Highest' is the most efficient commercially available.

SOURCES: 1972 to 1980: Pacific Northwest Laboratory, *Residential and Commercial Data Book—Third Edition,* PNL-6454 (Richland, WA: February 1968). 1990 NAECA: Public Law 100-12, for a 50 gallon tank. 1990 highest: Gas Appliance Manufacturers Association, "Consumer's Directory of Certified Efficiency Ratings," October 1990, Arlington VA, pp. 134, 163.

Several new water heating technologies show considerable promise for improved efficiency. Heat pump electric water heaters, which pump heat from an external heat source (usually outside air) into a hot water tank, are commercially available from

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[89] For example, one company provides a warranty in effect for as long as the original purchaser owns his or her home.

[90] Costs and efficiencies from "Sears Spring/Summer 1991 Catalog," Sears Roebuck Co., Downers Grove, IL, pp. 1073-1077.

[91] The simple payback considering only the difference in energy efficiency is an unimpressive 15 years.

[92] W. Kempton, "Residential Hot Water: A Behaviorally-Driven System," in W. Kempton and M. Neiman (eds.), *Energy Efficiency: Perspectives on Individual Behavior* (Washington, DC: American Council for an Energy-Efficient Economy, 1987), p. 233.

[93] Measured data from actual showers in Washington State, as reported in B. Manclark, "Low-Flow Showers Save Water," *Home Energy,* vol. 8, No. 4, July/August 1991, p. 28. This does not necessarily mean that the use of low-flow showerheads will reduce shower hot water consumption by 50 percent, as people may take longer showers once the low-flow showerhead is installed.

[94] In one study, the percent of consumers reporting that they were "very satisfied" with their showerheads went from 37 to 56 percent after replacement of old showerheads with new low-flow units. Ibid., p. 29.

[95] M. Brown, D. White, and S. Purucker, *Impact of the Hood River Conservation project on Electricity Use for Residential Water Heating,* ORNL/CON-238 *(Oak* Ridge, TN: Oak Ridge National Laboratory, October 1987), pp. xii, 8.

[96] S. Cohen, "Fifty Million Retrofits Later," *Home Energy,* vol. *7, No. 3,* May/June 1990, p. 16.

Box 2-F—Plastic Tanks: A Technical Advance That May Hinder Energy Efficiency

The natural turnover in appliance stock has allowed newer, more efficient appliances to penetrate the market. Recent developments in materials, however, may decrease turnover and thereby slow the implementation of new, efficient appliances.

Almost all residential-size hot water storage tanks are made of steel. These tanks typically last 10 to 15 years, and when they fail it is almost always due to corrosion of the steel seam. Recently, however, plastic-lined one-piece tanks have appeared on the market. These tanks are available with warranties that are good for as long the purchaser owns the tank, implying that the manufacturer does not expect these units to fail. Although these units are at present quite efficient-with efficiencies of 94 to 97 percent due to the use of thick insulation, heat traps, and other devices-their use may reduce the use of improved technologies such as heat pump water heaters in the future, as the replacement market will shrink drastically. Furthermore as plastic-lined tanks become more popular and less expensive, they may find use in less efficient electric water heaters.

several U.S. firms. The energy efficiency of these units is in the range of 150 to 340 percent.[97] Costs are quite high—about $900 to $2,000[98]-but may drop in the future if production volumes increase.[99] Add-on heat pump units, which can be retrofit to existing water heaters, can also be used, but here again prices are high.[100] Heat recovery water heaters, which capture waste heat from space conditioning equipment, are available for an installed cost of about $550.[101] Performance of these units depends heavily on climate. A prototype condensing gas water heater, which recaptures the latent heat in the combustion gases, has been built with an efficiency of 83 percent.[102]

Table 2-12—Water Heating Fuels in Commercial Buildings

Fuel	Percent[a]
Natural gas	49
Electricity	40
District heat	9
Fuel oil	4
Propane	2

[a] The approximate percent of commercial building floor space whose hot water is supplied by the corresponding fuel. Total sums to more than 100 as some commercial buildings use more than one fuel for hot water. Excludes commercial buildings with no hot water.

SOURCE: U.S. Department of Energy, Energy Information Administration, *Commercial Building Characteristics 1989,* DOE/EIA-0246(89) (Washington, DC: June 1991), p. 150.

Commercial and Multifamily Water Heating Technologies

As in residential buildings, natural gas and electricity are the leading fuels for water heating in commercial buildings (table 2-12).[103] The methods and systems used for heating water in commercial buildings vary widely. Many older buildings have a hot water tank that is heated by a submerged coil, heated in turn by the main space-heat boiler. This design is rarely used in new buildings, as it requires the main boiler to be operated year-round to provide hot water. A second design is a storage tank with a smaller, dedicated boiler. This boiler can provide only hot water or can provide both hot water and space heating as necessary. A third type of system is a commercial tank, which is essentially a large-scale version of a residential tank. This last design is increasingly popular, as it is simple and relatively inexpensive to install.

The options for improvements are similar to those for residential systems. Demand reductions, including repairing leaks and reducing temperature settings, can reduce energy use. Retrofits to systems

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[97] Efficiencies of over 100 percent are possible as the useful output includes the pumped heat obtained from another source, while the only input is the electricity used to pump the heat from one place to another. Source is EPRI, *Electric Water Heating News,* vol. 4, No. 1, spring 1991, p. 4.

[98] Average costs for an integral (i.e., includes tank) heat pump water heater. Ibid.

[99] Economies of scale in production require higher sales volumes, yet these volumes will not be achieved as long as prices are high.

[100] Probably $450 to $800. EPRI, *Electric Water Heating News,* vol. 4, No. 1, spring 1991, p. 4.

[101] Installed costs vary widely, depending on the specific equipment Used and the difficulty of installation. Average value of $550 from Synergic Resources Corp., *Review of Energy-Efficient Technologies in the Residential Sector,* EPRI EM-4436, vol. 1 (Palo Alto, CA: Electric Power Research Institute, February 1986), p. 1-12.

[102] E. Hirst, J. Clinton, H, Geller, W. Kroner, Energy *Efficiency in Buildings. Progress and Promise* (Washington, DC: American Council for an Energy-Efficient Economy, 1986), p. 85.

[103] Much of this discussion applies to large multifamily buildings as well.

can include those used in the residential sector, such as increasing tank insulation, as well as some more innovative features including electronic ignitions, electronic flue dampers, and boiler tune-ups. For example, the addition of an electric flue damper to a 70-gallon natural-gas-fired water heater tank in a recent field test increased effficiency from 61 to 65 percent, with a payback period of 5.3 years.[104]

New technologies for commercial water heating include the use of heat pumps, heat recovery devices, and other methods for integrating water heating into other heating and cooling systems. For example, a heat recovery heat pump recently installed at a large resort complex in Arizona uses heat from the chillers (space cooling devices) to heat water for the laundry, swimming pool, and spa. The new system replaces a natural-gas water heating system and thereby reduces the annual natural gas costs by about $61,000 per year. The estimated payback for the system is 3.5 years.[105]

FOOD REFRIGERATION/ FREEZING

Keeping food cold requires a significant amount of energy—about 10 percent of residential energy use and about 5 percent of commercial sector energy use [106] The energy efficiency of food refrigeration equipment has improved tremendously in the last 10 to 20 years, and considerable potential for further improvement remains. This section reviews the recent history of refrigeration equipment, the present-day technologies, and the most promising technologies for the future. Residential equipment is emphasized, as it uses the bulk of food refrigeration energy, but commercial technologies are mentioned as well.

Residential Refrigeration and Freezing

Almost every U.S. household has at least one refrigerator, and some-about 14 percent—have two or more.[107] The energy consumption of residential refrigerators tripled from 1950 to 1972, due to increased size (from 7 to 17 cubic feet), addition of energy-consuming features such as automatic defrost, and reduced insulation.[108] In the 1970s, however, several factors led to a sharp drop in refrigerator energy consumption. Increased energy prices, energy consumption labels (required by the Energy Policy and Conservation Act of 1975, Public Law 94-163), and State-level energy efficiency standards (California set minimum refrigerator energy efficiency standards in 1976) all led to the use of improved, more efficient refrigerator technologies. A number of innovations and improvements, rather than a single technical breakthrough, led to a 55 percent drop in the energy consumption of the typical refrigerator from 1972 to 1990 (table 2-13, figure 2-7). Among these improvements were the use of polyurethane foam rather than fiberglass insulation, more efficient motors and compressors, improved door seals, and improved air flow between cold coils and food compartments.

The typical refrigerator sold today is an 18-cubic-foot, top-mount (meaning the freezer is above the refrigerator), automatic defrost unit using about 900 kWh per year.[109] Although this energy use level is far below that of the typical units sold in the 1970s, it is far above that which the Department of Energy (DOE) has determined to be ‘‘technically feasible’ (table 2-13). According to DOE, it is technically feasible to build a refrigerator using less than 500 kWh per year that retains the features expected by consumers-including 18-cubic-foot interior volume and automatic defrost. A 16-cubic-foot manual

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[104] R. Nevitt and V. Stefanson, ‘‘Evaluating the Performance of a New High Efficiency Commercial Tank Water Heater, ’ *Proceedings of the ACEEE 1988 Summer Study on Energy Efficiency in Buildings* (Washington DC: American Council for an Energy-Efficient Economy, 1988), p. 2.155.

[105] EPRI, *Electric Water Heating News,* vol. *3, No. 3,* winter 1990-91, *pp.* 1, 3.

[106] Primary equivalent, see app. 1-B for sources.

[107] U.S. Department of Energy, Energy Information Administration, *Annual Energy Review 1990*, DOE/EIA-0384(90) (Washington, DC: May 1991), p. 45. The term “refrigerator” refers to a combination refrigerator-freezer, unless noted otherwise.

[108] “Appliance Efficiency on the Fast Track,’’ *EPRI Journal*, *vol. 12, No. 2,* March 1987, p. 33.

[109] Sizes given here refer to the sum of the refrigerator and freezer volumes. The adjusted volume (AV), defined as refrigerator volume plus 1.63 times freezer volume, is 20.8 cubic feet.

Table 2-13—Trends in the Energy Consumption of Refrigerators

Description	Energy use (kWh/year)	Annual operating cost[a]
1. Average new 1972	1,990	$155
2. Average new 1978	1,440	112
3. Average new 1981	1,200	94
4. Average new 1986	1,070	83
5. Average new 1987	970	76
6. Average new 1990	880	69
7.1990 NAECA standard	960	75
8. 1993 NAECA standard	690	54
9. 1990 technically feasible (DOE)	490	38

[a] Electricity price of 7.8 cents/kwh assumed.

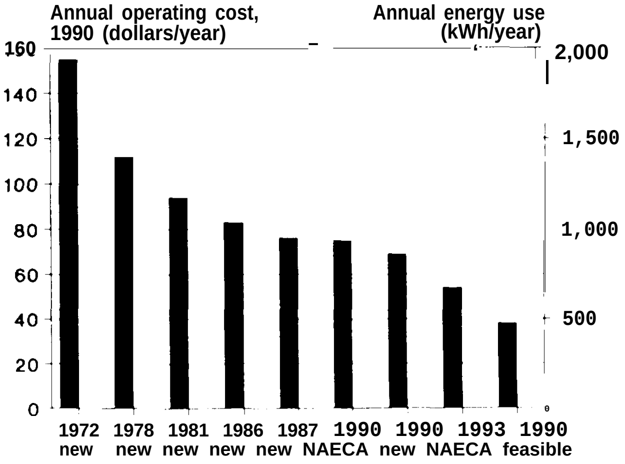
NOTE: Entries 1 to 6 are shipment-weighted averages; 7 to 9 are for top-mount automatic defrost units, no through-the door ice, 18 cubic feet actual volume, 20,8 cubic feet adjusted volume.

SOURCES: 1 to 6: R. Gants, Vice President, Association of Home Appliance Manufacturers, personal communication, Oct. 18, 1991.7 to 9: 54 *Federal Register 47918 (Nov.* 17, 1989).

defrost refrigerator using only about 280 kWh per year is commercially available.[110] The NAECA standards, which include both technical and economic considerations, will require energy use levels no higher than 690 kWh per year by 1993.[111]

Several technologies could further improve refrigerator energy efficiency. Refrigerators use energy to maintain a temperature difference between the food storage area and the surrounding environment; by reducing the amount of heat that penetrates into the refrigerator, one can reduce the energy use. This can be done by improving the insulation surrounding the food storage area. The foam insulation used in refrigerators today has an insulating value of about R-8 per inch.[112] Simply adding more insulation may not be practical, as increasing the external dimensions of the refrigerator makes it difficult to fit the unit in kitchens, while decreasing the internal dimensions reduces the available food storage space. Therefore materials that provide more insulating value while still fitting in the narrow shell of the refrigerator are needed. A further constraint on refrigerator insulation is related to the use of chlorofluorocarbons (CFCS). Foam insulation commonly used in refrigerators contains CFCS, which are being phased out of international production due to their harmful effects on the stratospheric ozone layer.

Figure 2-7—Trends in the Energy Consumption of Refrigerators



NOTES: Operating cost includes energy only. An electricity cost of 7.8 cents/kWh is assumed. 'New' is shipment-weighted average of all units shipped in that year. 'NAECA' is the *maximum* allowable according to the national standard. 'Feasible' is DOE's estimate of the lowest technically feasible unit. Applies to a top-mount automatic defrost unit, no TTD (through-the-door) ice, 18.0 cubic feet actual volume, 20.8 cubic feet adjusted volume.

SOURCES: 1972 to 1990 new: R. Gants, Vice President, Association of Home Appliance Manufacturers, personal communication, Oct. 18, 1991. NAECA: 54 *Federal Register 47918 (Nov.* 17, 1989). Feasible: U.S. Department of Energy, *Technical Support Document: Energy Conservation Standards for Consumer Products: Refrigerators and Furnaces,* DOE/CE-0277 (Washington, DC: November 1989), p. 3-36.

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[110] Manufacturer's data at 70 degree F ambient temperature, from Sunfrost, Arcata, CA, model RF-19. Actual interior dimensions of 8.0 cubic feet for refrigerator and 8,0 cubic feet for freezer. This unit has larger than usual exterior dimensions, is hand-built, and costs about $2,500. The manufacturer claims that mass-production would drop the per-unit cost to about $1,000. M. Shepard, A. Lovins, J. Neymark, D. Houghton, H. Heede, *The State of the Art Appliances* (Old Snowmass, CO: Competitek, Rocky Mountain Institute, August 1990), p. 76.

[111] For a top-mount automatic defrost refrigerator/freezer with an adjusted volume of 20.8 cubic feet.

[112] U.S Department of Energy, *Technical Support Document: Energy Conservation Standards for Consumer Products: Refrigerators and Furnaces,* DOE/CE-0277 (Washington, DC: November 1989), p. 3-4.

Table 2-14—improved Refrigerator Technologies Considered by DOE in Setting the NAECA Standards (partial list)

Double door gasket
Improved insulation
Evacuated panels
High efficiency compressor
Adaptive defrost
Fan and fan motor improvement
Anti-sweat heater switch
Condensor gas heating
Improved evaporator
Improved expansion valve
Two-compressor system
Relocation of components
Variable-speed compressor

SOURCE: U.S. Department of Energy, *Technical Support Document: Energy Conservation Standards for Consumer Products: Refrigerators and Furnaces,* DOE/CE-0277 (Washington, DC: November 1989), p. 3-4.

In an effort to develop insulation that is both compact and CFC-free, much of the recent R&D has focused on the use of vacuums. One such technology, compact vacuum insulation, uses two thin sheets of steel held apart by glass beads, with a vacuum between them.[113] Several prototype panels using this technology have been built, however costs, performance, and feasibility of large-scale production are still uncertain. Other promising vacuum-related technologies under development include powder-filled vacuum panels and silica aerogels, both at about R-20 per inch.[114]

Many other technologies could be considered to improve further the energy efficiency of refrigerators (table 2-14). Improving compressor design, installing separate compressors for the freezer and the refrigerator (dual compressors), and moving the compressor from the bottom to the top of the refrigerator to reduce heat flow from the compressor into the refrigerator, can all improve energy efficiency. Some of the highly efficient technologies provide additional consumer value as well. Vacuum panels, for example, could allow for thinner walls, thereby providing more interior storage space without increased exterior dimensions.

Photo credit: National Renewabie Energy Laboratory

Compact vacuum insulation panels (shown on the left) can provide an insulating value of R-10 in just 1/10 inch. Over 1 inch of standard insulation is required to provide the same insulating value.

Some of these technologies, such as dual compressors, are already in commercial use, and therefore their costs are known. Others, notably vacuum panels, are not yet commercially available, and therefore costs are uncertain. It should be noted, however, that according to DOE it is possible to meet the 1993 NAECA standard through the use of commercially available technologies.[115]

Approximately 34 percent of U.S. households have separate freezers.[116] As with refrigerators, the energy consumption of freezers has dropped sharply

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[113] The expected insulating value for this technology is R-10 per 1/10 inch. T. Potter and D. Benson, "Performance Tests of Compact Vacuum Insulation for Refrigerators,' *Proceedings of the ACEEE 1990 Summer Study on Energy Efficiency in Buildings* (Washington, DC: American Council for an Energy-Efficient Economy, 1990), p. 1.177.

[114] U.S. Department of Energy, Technical Support Document: Energy *Conservation Standards for Consumer products: Refrigerators and Furnaces,* DOE/CE-0277 (Washington, DC: November 1989), p. 3-5.

[115] Ibid., p. 3-37,

[116] In 1987. U.S. Department of Energy, Energy Information Administration, *Annual* Energy *Review 1990*, DOE/EIA-0384(90) (Washington, DC: May 1991), p. 45.

in recent years (table 2- 15). The prospective technologies for residential freezer improvement are quite similar to those for refrigerators.

Commercial Refrigeration and Freezing

In commercial buildings requiring food refrigeration and freezing, such as supermarkets and other retail food stores, refrigeration systems can account for about half of total electricity use.[117] The design and use of this equipment, unlike residential refrigerators, varies widely from site to site. This section reviews some promising technologies for improving the design of this equipment.

Commercial refrigeration systems, like space cooling systems, are used to move heat from one place to another. Energy efficiency opportunities include reducing the amount of heat requiring transfer, capturing the transferred heat and using it to perform useful work, and designing the equipment to move heat more efficiently.

Reducing the amount of heat that needs to be moved, or load reduction, is often the simplest improvement. The addition of plastic strips on refrigerated display cases can reduce energy use by 15 to 45 percent.[118] Glass doors, although more expensive, can reduce energy use by 30 to 60 percent.[119] It is Sometimes *thought* that these devices will reduce sales by making the product less accessible, and also make product loading more difficult. As with other energy efficiency improvements, the perception that they reduce comfort or convenience is a significant barrier to widespread use.

Heat recovery devices, which capture the waste heat from refrigeration systems and use it for space and/or water heating, are being installed in most new systems. Although they do not contribute to the energy efficiency of the refrigeration system per se, they do capture energy that would otherwise be wasted and thereby reduce overall energy use. Their value is limited by the on-site need for heat. For example, a supermarket may have a limited need for hot water, and may need space heating only in winter.

Table 2-15-Trends in Energy Consumption of Residential Freezers

Description	Energy use (kWh/year)	Annual operating cost[a]
1. Average new 1972.	1,300	$101
2, Average new 1978.	1,080	84
3. Average new 1987.	780	61
4. Average new 1990.	680	53
5. NAECA 1990 standard.	710	55
6. NAECA 1993 standard.	530	42
7. Technically feasible.	420	33

[a] Electricity price of 7.8 cents/kWh assumed.

NOTE: For an upright manual defrost freezer with an interior volume of 15.1 cubic feet (26.1 cubic feet adjusted volume),

SOURCES: 1 to 4: R. Gants, Vice President, Association of Home Appliance Manufacturers, personal communication, Oct. 18, 1991.5 to 7:54 *Federal Register 47918, 47919 (Nov. 17,* 1989).

Improvements to the refrigeration system itself offer the largest energy savings. The list of possible technologies is quite long, and just a few of the most promising options are mentioned here. Compressors use much of the energy of commercial refrigeration systems. These compressors operate most efficiently at full load, therefore the use of several, unequally sized compressors in parallel, along with microprocessor controls to match the compressor operation with the load, can reduce energy use 13 to ,27 percent.[120] Variable-speed drive for compressors, along with pressure and temperature controls, could provide significant energy savings.[121] Most refrigeration systems operate at a fixed pressure, set to meet the load on the hottest days. Allowing this pressure to float, or drop to meet actual demand, led to a 23 percent drop in compressor energy use in a recent field test.[122]

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[117] Battelle-Columbus Division and Enviro-Management and Research, Inc., *DSM Technology Alternatives*, EPRI *EM-5457* (Palo Alto, CA: Electric Power Research Institute, October 1987), p. B-31.

[118] A Usibelli, S Greenberg, M. Meal, A. Mitchell, R. Johnson, G. Sweitzer, F. Rubinstein, D. Arasteh, *Commercial-Sector Conservation Technologies*, LBL-18543 (Berkeley, CA: Lawrence Berkeley Laboratory, February 1985), p. 3-2.

[119] Ibid.

[120] Ibid., p. 3-1,

[121] Ibid., **p.** 3-6.

[122] G. Wheeler and G. Smith, ' 'Refrigeration Energy Savings With Floating Head Pressure, '' *Proceedings of the ACEEE 1988 Summer Study on Energy Efficient in Buildings* (Washington, DC: American Council for an Energy-Efficiency Economy, 1988), p. 4.123

Table 2-1 6-Approximate Energy Consumption of Selected Appliances

Appliance	Approximate annual consumption—1 988, primary trillion Btus	Percent of total sectoral energy use
Residential		
Clothes dryers	480	about 3
Clothes washers[a]	100	less than 1
Dishwashers	70	less than 1
Cooking appliances	570	about 3
Other	740	about 4
Total	1,960	13
Commercial		
Electronic office equipment	260	about 2
Other	1,600	about 12
Total	1,860	15

[a] Does not include energy for water heating.

NOTE: Individual numbers may not sum to totals due to rounding.

SOURCES: Office of Technology Assessment, 1992 (see app. I-B); J. Harris, J. Roturier, L. Norford, A. Rabl, *Technology Assessment: Electronic Office Equipment*, LBL-25558 Rev. (Berkeley, CA: Lawrence Berkeley Laboratory, November 1988).

The technical and economic savings potential is well illustrated in a recent field test of advanced commercial refrigeration technologies. An advanced system (utilizing floating pressure, unequally sized compressors, and other innovative technologies) was installed next to a conventional system in a large supermarket in northern California. The two systems were alternately operated in order to measure performance and energy use under the same conditions. Actual energy savings were 23 percent, or about $10,000 per year with the new system. The initial cost premium of the system was estimated at about $20,000, yielding a 2-year payback.[123]

OTHER ENERGY SERVICES

In addition to the previously discussed energy services (space conditioning, lighting, water heating, food refrigeration and freezing), there is a wide range of other energy services in buildings. For the residential sector this includes clothes washing and drying, cooking and cleaning (including dishwashers), home entertainment (notably televisions), and various other uses such as waterbeds and humidifiers. For the commercial sector this includes cooking and cleaning in restaurants, office equipment (computers, copy machines, printers, etc.), clothes washing and drying in laundromats, and so on. These miscellaneous energy services account for about 13 percent of residential energy use and 15 percent of commercial energy use (table 2-16).[124]

For most of these individual appliances the energy use is quite small; however in aggregate their energy use can be considerable. Residential electric clothes dryers, for example, use about 41 TWh of electricity per year,[125] or the combined annual output of 6.5 large coal-burning powerplants.[126] Office electronic equipment uses about 25 TWh per year (1988),[127] or the equivalent of about four large coal-burning powerplants. Furthermore some of these appliances, notably computers in offices, are growing in popularity and may become significant energy users in the future. This section discusses technologies for reducing the energy use of three energy users in the miscellaneous category---clothes washers, clothes dryers, and office equipment (table 2-16).

Clothes Dryers

About 68 percent of U.S. households have clothes dryers,[128] and about 4.5 million new clothes dryers

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[123] "Putting the Freeze on Refrigeration Costs,' *EPRI Journal*, vol. 13, No. 8, December 1988, p. 21.

[124] In 1988, using primary conversion factors. See app. 1-B for sources.

[125] In 1988. See app. 1-B for sources.

[126] Assuming a 900-MW plant operating at 80 percent capacity factor.

[127] J. Harris, J. Roturier, L. Norford, A. Rabl, *Technology Assessment: Electronic Office Equipment*, LBL-25558 Rev. (Berkeley, CA: Lawrence Berkeley Laboratory, November 1988), p. 3-20.

[128] U.S. Department of Energy, Bureau of the Census, *American Housing Survey for the United States in 1989*, H150/89 (Washington, DC: U.S. Government Printing Office, July 1991), p. 40.

are shipped each year.[129] The energy efficiency of dryers increased moderately over the years, showing a 7.8 percent efficiency increase from 1972 to 1980.[130] Technologies are available for greater improvements in dryer efficiency. Some of these technologies are addressed by NAECA (Public Law 100-12) and subsequent DOE rulings. The original NAECA prohibited the use of pilot lights in gas dryers, and subsequent rulings by DOE set minimum efficiency standards for dryers manufactured after May 13, 1994. These standards could be met with the use of automatic moisture or temperature termination and increased insulation, but as they are performance, not prescriptive, standards they do not require the use of any specific technology. Additional technologies considered and rejected by DOE in setting standards include the use of heat-pump clothes dryers (a technology already used for commercial drying), microwave clothes dryers (prototypes do exist),[131] and recycling of exhaust heat. These technologies were rejected for economic, not technical reasons; although DOE found that the life-cycle costs of these appliances were lower than that of dryers without these technologies, they determined that the increased first cost may reduce sales and thereby reduce manufacturers' return on equity.[132]

There are other options to reduce dryer energy use. The use of natural gas rather than electricity as the primary fuel for the dryer can be much more financially attractive; gas units typically cost about ***$40 more to*** purchase but about $90 less to operate per year, with a payback period of less than 6 months.[133] Faster spin speeds for washers could help as well, by reducing the amount of water the dryer would need to remove.[134]

Clothes Washers

About 76 percent of U.S. households have electric clothes washers,[135] and about 5.9 million new units are shipped each year.[136] The energy efficiency ‘f washers improved considerably in recent years-by over 50 percent from 1972 to 1989.[137] Most of this efficiency increase came from more cold wash and rinse options, less hot and more cold in the warm water mix, and improved control of washer water level.[138]

As in dryers, there are several technologies that could further increase washer efficiency, some of which are addressed by NAECA and subsequent DOE rulings. The original NAECA legislation required that a cold rinse option be available, and subsequent rulings set minimum efficiency levels effective in 1994 that could be met with the elimination of warm water rinse.[139] One promising technology, the use of horizontal axis rotation, was not included by DOE, because there was insufficient

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[129] 1989 U.S. industry shipments minus exports plus imports, from Association of Home Appliance Manufacturers (AHAM), *Major Home* Appliance *Industry Fact Book 1990/91* (Chicago, IL), pp. 11, 15, 17.

[130] Units are pounds water removed per kWh consumed. From SAIC, *Trends* in *the Energy Efficiency of Residential* *Electric Appliances*, EPRI EM-4539 (Palo Alto, CA: Electric Power Research Institute, April 1986), p. 2-18.

[131] DOE found that microwave clothes dryers Were ‘‘technically feasible” (see 56 *Federal Register 22265 [May 14, 1991]);* however, manufacturers have raised questions of safety and performance (R. Gants, Vice President, Association of Home Appliance Manufacturers, personal communication, Oct. 18, **1991).**

[132] See 56 *Federal Register* 22273 (May 14, 1991).

[133] Assumptions: electric unit uses 5,800 watts, gas unit Uses 500 watts electricity plus 22,000 Btu/h of natural gas, electricity at $.078/kWh and gas at $5.63/l@ Btu, 6 hours use pcr week. Purchase prices from ‘‘Scars Spring/Summer 1991 Catalog, ’ Sears Roebuck Co., Downers Grove, IL.

[134] By one estimate, removing water mechanically (by spinning) requires only 1/70th the energy required to remove the same amount of water thermally (with heat}. From I. Turiel, D. Berman, P. Chan, T. Chan, J. Koomey, B. Lebot, M. Levine, J. McMahon, G. Rosenquist, S. Stoft, “U.S. Residential Appliance Energy Efficiency: present Status and Future Directions, ’ *Proceedings of the ACEEE 1990 Summer Study on Energy Efficiency in Buildings* (Washington, DC: American Council for an Energy-Efficient Economy, 1990), p. 1.230.

[135] U.S. Department Of commerce, Bureau of the Census, *American Housing Survey for* the United States in *1989*, H150/89 (Washington, DC: U.S. Government Printing Office, July 1991), p. 40.

[136] 1989 U.S. shipments minus exports plus imports, from Association of Home Appliance Manufacturers (AI-JAM), *Major Home Appliance Industry Fact Book 1990/91* **(Chicago, IL),** pp. 11, 15, 17.

[137] Shipment Weighted average energy factors, as estimated by Association of Home Appliance Manufacturers (AHAM), ibid., p. 29.

[138] The bulk of energy use in clothes washers is for water heating.

[139] 56 *Federal Register* 22267, 22279 (May 14, 1991). Note that the standard could be met with the elimination of warm water rinse but could be met in other ways as well, and according to DOE there are currently models on the market with warm rime that already meet the standard. 56 *Federal Register 22264 (May 14, 199* 1).

information during the public comment period.[140] Higher washer spin speeds (to reduce dryer energy use) were also not considered, as the test procedure for washers does not appear to give credit for reductions in clothes dryer energy use.

Office Equipment

Although the energy use of office equipment is quite small-only about 3 to 4 percent of total commercial electricity use 141—it is growing rapidly and is an important new energy user in office buildings, where it sometimes consumes more energy than lighting. A typical personal computer uses about 100 to 170 watts[142]-about the same as the typical refrigerator. The technology of office equipment changes rapidly, making it difficult to forecast future demand. However one estimate suggests that office equipment energy use could increase 160 to 360 percent by 1995 (relative to 1988).[143]

There are a number of technologies available that could sharply reduce the electricity needs of office equipment. These include greater use of laptops, CMOS chips (which, unlike the traditional NMOS technology, uses almost no power when not in use),[144] liquid-crystal display (LCD) screens, and various alternatives to laser printing. Software allowing computers to shift to a dormant mode after a period of inactivity would help reduce energy use as well. The use of these and other technologies, most of which are already commercially available, could hold office equipment electricity use at about its current level,[145] despite the continued rapid proliferation of computers and other electronic devices.

SUMMARY AND CONCLUSIONS

Recent advances in equipment design have yielded remarkable efficiency improvements, and there is considerable potential for further improvement. For example, while the typical new gas furnace in the 1970s was only 63 percent efficient, new gas furnaces are now available with 97 percent efficiency. New windows are available with an insulating value of R-8-an eight-fold improvement over the old R-1 single-pane window-and window designs in the laboratory suggest R-10 to R-15 may soon be available. Computerized controls can cut commercial building energy use by 10 to 20 percent. Improved design can reduce both energy use and construction costs in large office buildings.

As discussed in chapter 1, there is some disagreement on the amount of energy that could be saved through the use of cost-effective energy efficient technologies. Reasons for this disagreement include differing definitions of cost-effective and different assumptions as to technology costs and performance. There is general agreement, however, on the following points:

- Technical advances have led to impressive improvements in the energy efficiency of energy-using equipment, and further improvement is likely.
- If these efficient technologies were used, energy use in buildings would be reduced considerably.
- A variety of highly energy efficient equipment is commercially available but is not being used,

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[140] According t. one analysis, *a* horizontal axis washer uses 61 percent less energy and 39 percent less water than a standard vertical-axis washer (B. Lebot, I. Turiel, G. Rosenquist, “Horizontal Axis Domestic Clothes Washers: An Alternative Technology That Can Reduce Residential Energy and Water Use,” Proceedings *of the ACEEE 1990 Summer Study on Energy Efficiency in Buildings* (Washington, DC: American Council for an Energy -Efficient Economy, 1990), p. 1.155.); however, manufacturers have expressed concerns about retooling costs and consumer preferences.

[141] By one estimate, office electronic equipment consumed about *25* TWh/year in *1988.* J. Harris, J. Roturier, L. Norford, A. Rabl, Technology *Assessment: Electronic Office Equipment,* LBL-25558 Rev. (Berkeley, CA: Lawrence Berkeley Laboratory, November 1988). This corresponds to about 3 percent of commercial sector electricity use, or about 12 percent of office building electricity consumption (for sources, see app. l-B). The U.S. Census Bureau estimates that about 37 million keyboards (including electric typewriters, CRT terminals, and personal computers) were in use in offices in 1988. U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United Stares: 1990* (Washington, DC: January 1990), p. 948. Assuming 150 watts per keyboard, 12 hours per day, 250 days per year, and a doubling for printers, copy machines, and other equipment yields about 33 TWh/year or about 4.1 percent of commercial sector electricity use.

[142] An IBM XT with a hard disk uses about 115 watts, an IBM AT with a hard disk uses about 165 watts. J. Harris, J. Roturier, L. Norford, A. Rabl, *Technology Assessment: Electronic Office Equipment,* LBL-25558 Rev. (Berkeley, CA: Lawrence Berkeley Laboratory, November 1988), p. 3-2.

[143] J. Harris, J. Roturier, L. Norford, A. Rabl, *Technology Assessment: Electronic Office Equipment,* LBL-25558 Rev. (Berkeley, CA: Lawrence Berkeley Laboratory, November 1988), p. 3-20, scenarios 1995(a) and 1995(b).

[144] CMOS stands for complement metal-oxide semiconductor; NMOS stands for n-channel metal-oxide semiconductor.

[145] J. Harris, J. Roturier, L, Norford, A. Rabl, Technology *Assessment: Electronic Office Equipment,* LBL-25558 Rev. (Berkeley, CA: Lawrence Berkeley Laboratory, November 1988), p. 3-20, 1995(c) scenario.

even though it would be cost-effective to do so.[146]

- Improved efficiency does not mean reduced comfort or lifestyle changes. More efficient technologies produce the same product—heat, cool, refrigeration, etc.—but with less energy.

Technologies for improving energy efficiency can be conceptualized into three types: 1) those that are cost-effective (but perhaps not used), 2) those available or technically proven but not cost-effective at present fuel prices, and 3) those not yet available or not yet technically feasible. Policy implications for improving or encouraging the use of these three types of technologies differ:

1. The gap between what appears to be cost-effective and what is actually used is due in part to mixed incentives, capital constraints, and other factors. Furthermore, calculations of cost-effectiveness generally do not incorporate environmental and other externalities, and doing so would most likely increase the gap between cost-effective and actual energy use. The barriers to wider use of these technologies may require explicit policy actions, as their existence suggests that the current market structure may not make optimal use of cost-effective energy efficiency opportunities.
2. The gap between the most efficient technologies and the cost-effective technologies can be narrowed by decreasing technology costs (through subsidies, R&D, or market pull [147]), increasing energy costs (through taxes or other fees),[148] or changing the definition of cost-effective.
3. Research and development can further increase efficiency levels or generate new technologies. Existing technologies generally do not approach the theoretical limits for energy efficiency, and the technical frontier for energy efficiency could be pushed well beyond current levels.[149]

The large gap between what is already available on the market and what is actually used suggests that implementation, rather than just technical advancement, is key to increasing energy efficiency. There are many commercially available technologies and methods that can reduce energy use while still providing needed energy services. The key to increasing energy efficiency lies in implementing these technologies, and that in turn requires an understanding of how the market for energy services functions, and how energy-related decisions—selecting and operating energy-using equipment—are made. This is the focus of chapter 3.

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[146] The studies discussed in ch. 1 use a variety of definitions of cost-effective. Although the savings potential does vary depending on the specific definition used, by most definitions a considerable cost-effective savings potential exists.

[147] In many cases, highly efficient technologies are expensive (and therefore not cost-effective) because demand for them is small. Increasing the market demand (market pull) for high efficiency products could reduce costs of these products by taking advantage of economics of scale in production.

[148] For example, some argue that cost-effectiveness criteria should incorporate the environmental costs of energy production and use.

[149] One might argue that gas furnaces at 97 percent efficiency provide little room for technical improvement, however gas-fired heat pumps could provide space heating at efficiencies of over 100 percent.

Appendix 2-A

Definitions of Energy and Energy Efficiency

Energy

Btu: British thermal unit, the amount of heat needed to raise the temperature of one pound of water 1 degree F.[1] Equivalent to 252 calories.

Quad: 1 quadrillion, or 10^{15}, Btus.

kWh: Kilowatthour, the amount of energy contained in 1,000 watts consumed for one hour. Usually used for electricity. For example, a 100-watt light bulb burning 10 hours will use 1 kWh of electricity.

Efficiency

Efficiency is a useful way to think about energy technologies, but there are numerous ways to define it. Here some of the common measures used to measure the efficiency of energy-using devices found in buildings are defined.

AFUE: Annual fuel utilization efficiency. The fraction of the energy content in the incoming fuel (typically natural gas) consumed that is converted into useful heat. No units, usually expressed as a percent. A typical new natural gas furnace has an AFUE of about 78 percent, and the most efficient commercially available furnaces achieve an AFUE of 97 percent.

COP: Coefficient of performance. The number of Btus a device can supply to or remove from the conditioned space per Btu of energy consumed (where electricity is converted to Btus at 3.412 Btus per watthour). No units. Typical values are 2.0 to 3.0, equivalent to an efficiency of 200 to ***300*** percent.

EER: Energy efficiency ratio. Used to measure the cooling performance of heat pumps and room air conditioners. The number of Btus of heat removed from the conditioned space per watthour of electricity consumed. Units are Btus per watthour. Typical values for room air conditioners are 8.0 to 12.0 Btus per watthour,

HSPF: Heating seasonal performance factor. Used to measure the seasonal heating efficiency of heat pumps. Incorporates performance under varying outdoor temperatures, losses due to cycling, defrosting, and backup resistance heat. The number of Btus of heat added to the conditioned space per watthour of electricity consumed. Units are Btus per watthour. Typical values are 7.0 to 9.0 Btus per watthour,

SEER: Seasonal energy efficiency ratio. Used to measure the seasonal cooling efficiency of heat pumps. Similar to EER, except it incorporates performance under varying outdoor temperatures and losses due to cycling. The number of Btus of heat removed from the conditioned space per watthour of electricity consumed. Units are Btus per watthour; typical values are 9.0 to 12.0 Btus per watthour.

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[1] At 39.1 degrees F.

Appendix 2-B

Financial Indicators for Energy Efficiency Investments

There are many methods for evaluating the cost-effectiveness of energy efficiency. Here several such methods are illustrated, using an example of a simple efficiency improvement: the addition of insulation to a roof. It is assumed that the insulation costs $1,000 (including labor and materials), and saves about 35 million Btus (MBtus) of natural gas per year, natural gas costs $5.61 /MBtu, the house and insulation last 20 years, fuel prices do not increase over time, and the appropriate discount rate is 5 percent,

Payback is the simplest method for measuring cost-effectiveness. It is simply the number of years required for the savings to equal the upfront costs. For the example here the payback is:

$$\frac{\text{Initial cost}}{\text{Annual savings}} = \frac{\$1{,}000}{35 \text{ MBtus/yr} \times \$5.61 \text{ /MBtu}} = 5.1 \text{ years}$$

Therefore it will take 5.1 years for the savings to equal the initial $1,000, and all savings after that will be profit. Payback is simple to understand and allows easy comparison to other measures, but ignores the time value of money, the value of the savings after the payback period, and the limited life of some measures.

Life-cycle cost is a general term for incorporating all costs associated with the measure over its entire lifetime. One way to measure life-cycle cost is with net present value (NPV), which translates all future costs and savings into their equivalent in today's dollars. For the example here, the savings occur over the next 20 years. If one ignores the time value of money, the total savings are:

$$20 \text{ years} \times 35 \text{ MBtus/yr} \times \$5.61 \text{ /MBtu} = \$3{,}900$$

The net savings, or savings minus costs, are:

$3,900 (total savings) -$1,000 (initial costs) = $2,900

A more realistic calculation would recognize that a dollar received a year from now is less valuable than a dollar received today (because a dollar received today can be put in an interest-earning account, and will grow to $1.05 in 1 year in an account paying 5 percent interest). Future savings can be discounted to reflect the time value of money. The choice of a discount rate will strongly influence the financial attractiveness of an investment and is an area of significant controversy.[1] For this example, an illustrative discount rate of 5 percent is used. Discounting the total savings of $3,900 at 5 percent per year for 20 years yields a net present value equivalent of $2,450:

$2,450 (total savings with discounting) –
$1,000 (initial costs) = $1,450

Therefore this investment is equivalent to $1,450 received today,

A somewhat different but quite useful measure of cost-effectiveness is the cost of conserved energy (CCE), which measures how much one pays for each unit of energy saved. Its advantage is that it is independent of fuel price. The CCE can be compared to the cost of the supplied energy it displaces. The CCE is defined as the initial cost times the capital recovery factor (CRF, which converts an initial investment into an equivalent series of annual payments), divided by the annual energy savings (in energy units).[2] For the example here:

$$\text{CCE} = \frac{\text{Initial cost} \times \text{CRF}}{\text{Annual savings}} = \frac{\$1{,}000 \times 0.08024}{35 \text{ MBtus/yr}} = \$2.30\text{/MBtu}$$

Therefore the insulation can be said to supply energy at less than half the cost of natural gas ($5.61 /MBtu).

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[1] See for example the discussion of discount rates for setting appliance standards in 56 *Federal Register 22261* (May 14, 1991).

[2] The equation for capital recovery factor (CRF) is $i(1+i)^n/((1+i)^n-1)$ where i is the discount rate and n is the number of years. For the example here, the CRF corresponding to a 5 percent discount rate and a 20-year lifetime is 0.08024.

Appendix 2-C

Conversion of Electricity Into Energy Units

Analyses of energy use often require that different forms of energy (natural gas, oil, electricity) be combined into one common measure, typically Btus. The conversion of electricity into Btus is problematic, as there is no one correct conversion method. If one converts 1 kWh of electricity directly into heat, the amount of energy released is 3,412 Btus. This conversion ratio of 3,412 Btus per kWh is known as the 'site' conversion ratio. Site conversion ignores the energy used to produce that 1 kWh of electricity. A typical coal-burning power-plant, for example, requires about 10,240 Btus of energy in the form of coal to produce 1 kWh of electricity.

An alternative to the site conversion ratio is the "primary" conversion ratio of 10,240 Btus per kWh, which includes the energy used to produce the electricity. This ratio better captures the actual energy savings resulting from increased electric efficiency, however it too has its drawbacks. The primary conversion ratio does not account for energy losses occurring during transportation of fuels; however these losses occur for all types of fuel (including those being delivered to the powerplant), suggesting that failure to account for transportation losses may not result in a bias toward any one fuel type. The primary conversion ratio also overstates the energy needed to produce electricity from hydropower; however in the United States less than 10 percent of electricity comes from hydropower,[1] making this issue less of a concern for this report.

This report uses the primary conversion ratio for electricity in most calculations. This allows for a more accurate comparison of the true energy savings resulting from increases in the efficiency of electricity use. Furthermore the price of electricity is comparable to that of other fuels when the primary conversion ratio is used (table 2-C-l), making primary conversions useful for comparing dollar savings as well.

Table 2-C-l-Comparison of Fuel Prices Using Two Electricity Conversion Ratios

Fuel	Price	Units	Site conversion price ($/MBtu)	Primary conversion price ($/MBtu)
Natural gas.	5.61	Dollars per MBtu	$5.61	$5.61
Oil.	1.06	Dollars per gallon	7.08	7.08
Electricity.	7.8	Cents per kWh	*22.86*	*7,62*

NOTE: Prices are 1990 residential. Conversion ratios assumed are oil at 149,700 Btus per gallon, electricity site at 3,412 Btus per kWh, electricity primary at 10,240 Btus per kWh.

SOURCE: U.S. Department of Energy, Energy Information Administration, *Annual Energy Review 1990*, DOE/EIA-0384(90) (Washington, DC: May 1991), pp. 159, 179, 225, 294.

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[1] U.S. Department of Energy, Energy Information Administration, *Annual Energy* Review *1990*, DOE/EIA-0384(90) (Washington DC: May 1991), p. 209.

Chapter 3

If Energy Efficiency Is Such a Good Idea, Why Haven't We Done More of It?

Box 3-A-Chapter Summary

If energy efficiency is technically and economically feasible, why doesn't it happen on its own? Interviews with consumers, builders, and others are used to explore the reasons behind this apparent paradox.

The methods used by consumers to make energy-related decisions often work against energy efficiency. Goals of minimizing first cost, time to make a decision, and risk are often pursued; minimizing life-cycle costs is rarely mentioned. When future savings do enter a decision, they are heavily discounted. There are few incentives for efficiency; for example, repair contracts are often awarded based largely on first cost, which leads to the use of low first-cost, inefficient equipment. Energy costs are about 1 percent of labor costs in a typicaI office building, so management attention and capital are directed elsewhere. Many attributes, such as first cost, familiarity, and convenience, often overshadow energy efficiency. Efficiency is a relatively intangible feature with benefits that are seen as uncertain, and therefore loses out to more tangible, visible attributes. Builders and manufacturers often believe that consumers are relatively unwilling to invest in efficiency, and therefore often offer and emphasize other features.

The net result of these market characteristics is that energy efficiency investments are often neglected.

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Chapter 3

If Energy Efficiency Is Such a Good Idea, Why Haven't We Done More of It?

INTRODUCTION

Many energy efficient technologies offer financial rates of return exceeding those available from other financial investments. Therefore one would expect consumers to take advantage of these efficiency investments. However there are numerous untapped opportunities for cost-effective efficiency improvements, as discussed in chapter 2, suggesting that the issue is more complex than a simple financial analysis would indicate. If energy efficiency is such a good idea, why haven't we done more of it?[1]

Box 3-B—Interview Methodology

The results presented in this chapter are based in part on a series of interviews conducted by OTA in the spring of 1991. These interviews were conducted with building owners, architects, homeowners, engineers, equipment manufacturers, and others whose decisions influence building energy use. The interviews made use of ethnographic interviewing techniques, in which the respondent is allowed to guide much of the discussion. This technique has been used by several researchers to explore perceptions of energy use and energy efficiency.[1] Our intent was to explore the respondent's beliefs and concerns related to energy use; to do so in an unbiased manner we encouraged respondents to raise issues they felt important. For example, rather than asking "do your tenants care about energy costs," we asked "what factors do your tenants seem most concerned with?" Although the number of interviews was relatively small, we believe they captured many of the key issues affecting energy-related decisions.

[1] See, e.g., W. Kempton and L. Montgomery, ''Folk Quantification of Energy,' *Energy,* vol. 7, No. 10, 1982; R. Wilk and H. Wilhite, "Why Don't People Weather-h Their Homes? An Ethnographic Solution," *Energy,* vol. 10, No. 5, 1985; P. Komor and R. Katzev, "Behavioral Determinants of Energy Use in Small Commercial Buildings: Implications for Energy Efficiency,'' *Energy Systems and Policy,* vol. 12, 1988.

This chapter explores why energy efficiency has not been implemented to the level that appears economically justified. Energy use in buildings is determined by decisions about equipment selection and operation, and these decisions are made to satisfy a number of needs and constraints. Implementing greater energy efficiency in buildings will require policies that influence these decisions; these policies will be most effective if they are based on a clear understanding of how and why decisions about equipment selection and operation are made. This chapter provides such an understanding through the use of interviews (box 3-B) and other evidence. The focus is on how these decisions are made, as distinct from how they should be made.

RESIDENTIAL BUILDINGS

Decisions affecting the energy use of residential buildings occur throughout the lifetime of the buildings. Perhaps the most important decisions are made in the initial design and construction, but appliance replacement, shell retrofits, and equipment operation can affect residential energy use as well. This section describes how decisions affecting energy use are made, including those related to design and construction, those made by equipment manufacturers, those related to retrofit and repair, and those of owners and occupants.

The Design and Construction of New Residential Buildings

The energy efficiency of new residences plays a critical role in determining overall residential sector efficiency. It is generally much less expensive to build an energy efficient residence than to retrofit an inefficient one; and some energy saving technologies, such as passive solar design, cannot easily be retrofitted to an existing residence. By 2010 a significant fraction of the total housing stock will

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[1] From D. Morell, "Energy Conservation and Public Policy: If It's Such a Good Idea, Why Don't We Do More of It?" *Journal of Social Issues,* vol. 37, No. 2, 1981, p. 8.

Table 3-l-Construction of New Residential Housing, 1990

Type	Number of units started (thousands)	Percent
Single unit	895	64
2 to 4 units	37	3
5+ units	261	18
Mobile homes	205	15
Total	1,398	100

NOTE: Privately owned units only. Mobile home data are 'placed for use' in 1989.

SOURCE: U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States: 1997* (Washington, DC: 1991), pp. 720, 722.

Table 3-2—The Residential Construction Industry, 1989

Type of firm	Percent of firms	Percent of new units built
Small (1 to 24 units per year)	74	13
Medium (25 to 99 units per year)	16	20
Large (100+ units per year)	9	67
Total	100	100

NOTE: Includes high-rise and multifamily residences. Totals may not add to 100 due to rounding.

SOURCE: National Association of Home Builders (NAHB), *Housing Economics,* June 1990, p. 6.

have been built in the period 1990 to 2010,[2] highlighting the importance of new construction in overall efficiency.

In 1990 the residential construction industry built 1.4 million new residences (table 3-l), at a value of $187 billion.[3] Almost two-thirds of these were single unit residences, the remainder were in multiunit buildings and manufactured (mobile) homes. This industry is usually perceived as a very decentralized business consisting of thousands of very small firms, each building only a few houses each year. This is only partially true: there are about 100,000 residential building firms in the United States, with an average size of about five employees each.[4] These small firms, however, build only 13 percent of new housing units. Larger firms (defined as firms building over 100 units per year) build over two-thirds of new housing units (table 3-2). Larger building firms tend to make greater use of preassembled components and structures (table 3-3), which can reduce construction costs by allowing for standardization of design and economies of scale in assembly.

Large Builders and Developers

Decisions affecting the relative energy efficiency of homes built by large builder/developer companies are driven by several factors. One of the most important factors is the company's perception of what will satisfy the consumer—both to sell the home initially, and to keep the consumer satisfied after moving in. Those in the builder/developer business often believe that consumers are relatively unwilling to invest in energy efficiency. For example, if a builder invests $1,000 in insulation, then most of this investment will be invisible to the prospective purchaser-but the additional cost of the insulation will be extremely visible, in the form of a higher priced house. From the builder's perspective, it may make more sense not to invest the $1,000 and thereby reduce the house price, or alternately to invest the $1,000 in a feature that is more visible to the prospective buyer (e.g., landscaping or more expensive doors).

Photo credit: Paul Komor

Single-family houses account for over two-thirds of new home sales.

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[2] For comparison, in 198940 percent of the total existing housing stock had been built in the preceding 19 years (i.e., in the period 1970 to 1989). U.S. Department of Commerce, Bureau of the Census, *American Housing Survey for the United States in 1989,* H150/89 (Washington DC: U.S. Government Printing Office, July 1991), p. 1.

[3] U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States.' 1991* (Washington, DC: 1991), p. 716.

[4] Ibid., p. 715.

[5] This discussion excludes larger high-rise multistory buildings, because the institutions and decisions affecting energy use in these buildings are similar to those in commercial buildings, which are discussed below.

Table 3-3-New Residential Building Construction in the United States: Definitions and Market Shares

Type	Definition
High-rise	Two or more stories, has an elevator.
Manufactured (mobile) home	Also called a 'HUD-code' home, assembled entirely at the factory and installed on a semi-permanent foundation.
Modular	Approximately 95 percent of assembly occurs at the factory, usually shipped as several pieces and installed on a permanent foundation.
Panelized	Major components, including walls, floors, and ceilings are preassembled at factory; final assembly and finish work done on-site.
Production	Usually uses preassembled roof and floor trusses; remainder of unit built on-site.
Stick-built	Built entirely on-site; no major preassembled components used.

Type	Market share (percent) 1980	1989	Unit sales (thousands) 1989
Manufactured (mobile) home	19	15	202
Modular	5	6	79
Panelized	29	36	487
Production [a]	48	43	573
Total	100	100	1 ,341

[a] Includes Stick-built, which is estimated at less than 5 percent of total (*Automated Builder,* January 1991, P. 15). Percents may not add to 100 due to rounding.

NOTE: Market share and unit sales data apply only to one to four family housing starts.

SOURCE: R. Berg, G. Brown, and R. Kellett, "An Analysis of U.S. Industrialized Housing," Center for Housing Innovation, University of Oregon, October 1990, p. 24. Sales and market share are uncertain, and varying estimates can be found (see NAHB, *Housing Economics,* October 1989 for a discussion).

Builders often market homes as a ''base' home, and then offer a series of upgrades. An upgrade might consist of more expensive bathroom fixtures, wood floors, or a finished basement. Energy efficiency upgrades, however, are rarely offered, as some builders fear that offering such an upgrade will give consumers the impression that their base house is not energy efficient. The energy efficiency of a building can vary widely, but some argue that consumers see energy efficiency as an all or nothing attribute, and that offering an energy efficiency upgrade will lead consumers to think that, without it, the house is not energy efficient.[6]

When selecting space conditioning appliances for new houses, builders often select those brands and models that they have found reliable and easy to work with in the past. There is always competitive pressure to keep first costs low, and investments in energy efficient units, although perhaps cost-effective on a life-cycle basis, may increase the first cost of the house and thereby put the residence at a competitive disadvantage relative to other, lower-priced residences.

Interviews and discussions with larger home-building firms revealed a considerable knowledge and understanding of energy efficient technologies and construction methods. The decisions of these firms to adopt or not adopt innovative energy efficient technologies were not based on ignorance or lack of information but on their perceptions of the economic interests of their company. The director of architecture at one large home building firm, for example, had previously taught passive solar design at an architecture school. However he did not consider solar orientation when designing a new subdivision, because to do so would apparently reduce by 15 percent the number of homes he could fit into the subdivision, which would in turn reduce the firm's revenues.

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[6] A director of marketing for a large home building firm interviewed by OTA indicated that many home-buyers think of energy efficiency as ayes/no feature, similar to a garage or central air conditioning, i.e., the home either has it or doesn't have it.

Small Builders

Most residential construction firms are quite small; about three-fourths of all residential construction firms build less than 25 units per year (table 3-2). Smaller firms typically build more expensive custom homes, while the larger firms typically build less expensive, tract-style homes.

Residential construction is largely a trade learned from experience, rather than through schooling or other formal training, so adoption of new technologies and construction techniques can be quite slow due to a preference for using past practice. The risk associated with innovation is also a barrier, as small firms often cannot carry the financial burden of a house that may not sell due to an innovative characteristic that may prove unpopular.

Moreover, even builders well-versed in energy technologies may not use them. Reported one interviewee, ' 'I'd like to build more energy-efficient homes, I know how to do it, but I can't afford to. " From his perspective, potential home-buyers are often unwilling to pay more for a feature that is largely invisible and whose benefits may be seen as uncertain. Building an efficient home costs more upfront, which puts him at a competitive disadvantage relative to builders offering a home that looks the same but costs less.[7]

Slightly more than one-third of new single-family homes are built for a specific owner, rather than on speculation.[8] The design of these homes is influenced by both the builder and the owner. According to owners and builders interviewed by OTA, owners' interest and concern regarding energy varies. Some owners are interested in payback of energy-related investments such as increased insulation, for example; but many decisions are motivated by other factors. For example, natural gas heat is seen by some as more comfortable than electric heat pumps due to the higher register outlet temperature, and in the opinion of one builder those consumers committed to gas are not interested in paybacks of other technologies, Capital constraints are also an issue; even if an investment offers an attractive payback the owner may not have sufficient capital for the investment (or the source of the capital, typically a bank, may be unwilling to supply it).[9]

Photo credit: Paul Komor

Manufactured (mobile) homes account for about 15 percent of new home sales.

Manufactured Homes

The manufactured home (also called mobile home or HUD-code home, for Department of Housing and Urban Development) industry sold about 202,000 units in 1989 (table 3-3). These units are entirely assembled at the factory and then shipped to retail dealers, who then sell them to consumers. Manufactured homes are typically the least expensive type of new housing. The construction of these units is regulated by the HUD Manufactured Home Construction and Safety Standards (MHCSS), which include energy-related requirements.

Industry decisions as to the energy efficiency level of their new units are bounded at the minimum level set by the HUD code but can exceed the HUD code if there is a demand for greater efficiency. For example, one large manufacturer reported that its basic unit for one climate area has R-14 insulation in the ceiling, but that a utility-sponsored incentive program has resulted in dealer requests for units with R-28 in the ceiling instead.

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[7] It should be recognized that other attributes often accompany efficiency. For example, a well-insulated house may be more comfortable due to smaller temperature fluctuations, as well as more efficient. These attributes, however, suffer from the same problems as efficiency; they are invisible, occur in the future, and are somewhat intangible.

[8] In 1990, about 36 percent of single-family homes were built for a specific owner, 61 percent on speculation and the remaining 3 percent for rental. U.S. Department of Commerce, Bureau of the Census, *Characteristics of New Housing:* 1990, C25-9013 (Washington, DC: June 1991), p. 3.

[9] One policy response t. this problem, the use of mortgages as a source of funds for energy efficiency improvements, is discussed in ch. 5.

Table 3-4—Shipments of Selected New Appliances, 1989

Appliance	Units shipped, 1989 (thousands)
Microwave	10,600
Washer	6,250
Refrigerator	7,100
Room air conditioner	5,090
Dryer	4,570
Dishwasher	3,670
Electric range	3,050
Gas range	2,170
Freezer	1,220
Other	5,010
Total	48,730

SOURCE: Association of Home Appliance Manufacturers (AHAM), *Major Home Appliance Industry* Fact *Book 1990/91* (Chicago, IL), p. 11,

The manufactured home industry markets its units somewhat like the automobile industry. with a basic unit offered at lowest first cost and a number of additional cost packages, which may include energy efficiency features, offered at additional cost. According to a manufacturer, consumers buying the more expensive units are often willing to invest in energy efficient packages, but those looking for less expensive units often cannot afford to upgrade and want the unit with the lowest first cost.

Residential Equipment Manufacturers

Residential equipment manufacturers can be divided into two general types: 1) home appliance manufacturers, who make refrigerators, freezers, clothes washers and dryers, room air conditioners, and other appliances; and 2) heating and cooling equipment manufacturers, who make furnaces, heat pumps, boilers, and central air conditioning systems. Since the manufacturers and market distribution systems differ for these two types, they are discussed separately below. Space heating and cooling equipment is discussed under the Commercial Buildings section.

In 1989 the home appliance industry shipped about 49 million new appliances (table 3-4), worth about $12.4 billion.[10]" Relatively few of these appliances are exported or imported. The industry exported only 6 percent of its production in 1989, and only 16 percent of the appliances bought in the United States in 1989 were imported, two-thirds of which were microwave ovens.[11]

As discussed in the preceding chapter, the energy efficiency of home appliances increased dramatically from about 1970 to the present (see, for example, chapter 2, figure 2-7). The technologies used to achieve these gains were discussed previously as well. It is useful to consider the factors that motivated the manufacturers to make these changes. Several are relevant:

- Technology changes made for reasons other than energy efficiency, such as lower cost, improved reliability, or a simpler manufacturing process, sometimes had the incidental benefit of reduced energy use. For example, the switch from fiberglass to polyurethane foam insulation in refrigerators was done mainly for manufacturing process reasons, but also had the benefit of improved energy efficiency.
- In 1976 California adopted energy efficiency standards for refrigerators and air conditioners, and as California was a significant fraction of the total United States market, these standards influenced national average efficiency levels for these products. Other States followed California's lead, contributing further to the increase.
- Although consumer awareness of energy issues in the 1970s may have motivated manufacturers, OTA interviews with appliance manufacturers suggest that energy efficiency is not seen as a primary consumer product cue; in other words efficiency is not thought to be a primary determinant of consumer purchase decisions. Therefore consumer preference may not have contributed significantly to the historical increase in home appliance energy efficiency.

At present, the requirements of the National Appliance Energy Conservation Act (NAECA, Public Law 100-12, discussed in ch. 4) are driving appliance manufacturers' decisions as to the energy efficiency of their products.

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[10] Products included here are kitchen ranges and cooktops, microwave Ovens, clothes washers and dryers, dishwashers, refrigerators, freezers, room air conditioners, dehumidifiers, disposers, and trash compactors. Association of Home Appliance Manufacturers (AHAM), *Major Home Appliance Industry Fact Book 1990191* (Chicago, IL), pp. 8, 11.

[11] Ibid., pp. 11, 15, 17. This excludes home entertainment equipment, such as televisions and radios. Imports of major home appliances increased from 1970 to 1987 but have dropped since 1987.

Retrofit and Repair

Approximately $57 billion was spent in 1989 to improve, repair, or retrofit existing residences.[12] It is not clear how much of this was spent on energy-related changes, but by one estimate about one-third of all single-family households perform an energy-related retrofit or repair each year.[13] Energy-related retrofits and repairs to many residences are performed by general contractors or specialized tradespeople such as heating and cooling specialists, plumbers, and remodelers. This field is dominated by small businesses, typically with less than 10 employees.[14] These firms are either hired directly by a building owner/manager or as subcontractors.

The contractor typically selects the specific type and model of energy-using equipment to install. Many contractor jobs are awarded based on cost estimates, and therefore there is always pressure to reduce first cost. In the view of many contractors, most homeowners do not want to pay extra for energy efficiency.[15] Contractors also reported other reasons for avoiding the use of new, energy-efficient technologies, including:

- New technologies often require new installation procedures, increasing both the time required for installation and the risk of incorrect installation;
- Their dependability/reliability is unproven;
- There is perceived risk of consumer dissatisfaction due to poor performance and/or mechanical breakdowns;
- Current building standards may make innovation difficult (i.e., changes in equipment may require other design changes, further increasing project cost and complexity);
- The insurance industry often requires that the same materials be used when rebuilding a damaged structure; and
- There is suspicion and distrust of the energy savings claims of new technologies.[16]

Contractors and other home-repair professionals select and install energy-using equipment in existing residences, and these decisions strongly influence the subsequent energy use of these residences. These decisionmakers weigh heavily attributes of first cost, reliability, and familiarity y, and have few incentives to consider energy efficiency.

Owners and Occupants

Building occupants can directly improve the energy use of buildings in several ways: by operating equipment efficiently, by replacing failed equipment with more efficient equipment, and by retrofitting existing buildings with energy efficient technologies and features. In addition, occupants can indirectly influence energy use of new residences by expressing a desire, through purchase behavior, for more efficient technologies and features.

Equipment Operation

Opportunities for building occupants to reduce energy use by improving equipment operation include reducing thermostat settings, turning off lights, taking shorter showers, and other behavioral changes. Although these actions can save significant amounts of energy, they can also reduce comfort and/or convenience. The perception that energy efficiency requires sacrifice is very persistent and acts as a significant barrier to wider use of energy efficient technologies. Survey and interview research has found that a majority of people, when asked what they could do to reduce energy use, typically mentioned turning off lights, reducing thermostat settings, and other behavioral changes involving reduced comfort; improved technology (e.g., a more efficient energy-using device) was rarely mentioned.[17]

Some behavioral changes can save significant amounts of energy with little or no discomfort, such as night setback of thermostats. According to

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[12] U.S. Department of Commerce, Bureau of the census, *Statistical Abstract of the United States: 1991* (Washington, DC: 1991), p. 717.

[13] U.S. Department of Energy, Energy Information Administration, *Housing Characteristics* 1987, DOE/EIA-0314(87) (Washington, DC: May 1989), p. 118.

[14] Employees per establishment for relevant industries. U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States: 1991* (Washington DC: 1991), p. 715.

[15] Participants in a workshop of retrofit contractors estimated that "90 percent of homeowners do not want to pay extra for energy efficiency. " P. Mihlmester, J. Gonos, L. Freeman, M. Brown, *Technology Adoption Strategy for the Existing Buildings Efficiency Research Program, Oak* Ridge National Laboratory, ORNL/CON-286 (Springfield, VA: National Technical Information Service, June 1989), p. 34.

[16] Based on a workshop of contractors. Adapted from ibid., pp. 39-41.

[17] W. Kempton et al., "Do Consumers Know 'What Works' in Energy Conservation?" *Marriage and Family Review, vol. 9, No.* 1/2, fall 1985.

surveys based on self-reports of behavior, 48 percent of U.S. households turn down their heat at night.[18] The energy savings from reducing thermostat settings at night typically range from 6 to 16 percent.[19] Similarly, the use of cold rather than warm rinse in clothes washing machines reduces heated water consumption about 23 percent per wash cycle and is generally agreed to have no adverse effects on washer performance, yet consumers still use warm rinse about 25 percent of the time.[20]

Equipment Selection and Purchase

Consumers can affect energy use through the energy efficiency of new appliances they purchase. Understanding how consumers make appliance selection decisions, and how these decisions are influenced by labels, rebates, and other factors, is needed to design effective programs and policies for encouraging energy efficiency.

Consumer equipment selection decisions can be divided into two types: 1) smaller home appliances (refrigerators, room air conditioners, washing machines, and lights), for which consumers typically make product selection decisions themselves, and 2) larger equipment (furnaces, heat pumps, central air conditioning systems, and water heaters), for which product selection decisions are typically shared with or made by a contractor or other outside agent.

When purchasing a home appliance, consumers try to satisfy many goals. These goals may include spending the least amount of money, spending the least amount of time to make the purchase decision, or buying whatever will fit in the available space. Reducing energy consumption may or may not be a goal, but there is some evidence that energy efficiency must be extremely financially attractive for consumers to invest in it. This can be measured with an ''implied discount rate, ' calculated by comparing the first cost increment to the annual energy savings (table 3-5). The very high implied discount rates shown in table 3-5 suggest that consumers will invest in energy efficiency only if the annual energy savings exceed the additional frost cost within just a few years.

Table 3-5-implied Consumer Discount Rate Estimates for Energy Efficiency Investments

Appliance/action	Discount rate estimate (percent)
Refrigerator	**45 to 300**
Room air conditioner	**5 to 89**
Water heater blanket	**67**
Clock thermostat	**310**
Replacement furnace	**70**

SOURCES: Refrigerator: D. Gately, "Individual Discount Rates and the Purchase and Utilization of Energy-Using Durables: Comment," *The Bell Journal of Economics, vol.* 11, 1980, p. 374. Room air conditioners: J. Hausman, "Individual Discount Rates and the Purchase and Utilization of Energy-Using Durables," *The Bell Journal of Economics, vol.* 10,1979, p. 53. Water heater blanket: P. Komor and L. Wiggins, "Predicting Conservation Choice: Beyond the Cost-Minimization Assumption," *Energy, vol.* 13, No. 8, 1988, p. 641. Clock thermostat and replacement furnace: Cambridge Systematic, Inc., *Implicit Discount Rates in* Residential *Customer Choices,* vol. 1, EPRI EM-5587 (Palo Alto, CA: Electric Power Research Institute, February 1988), p. 4-11.

There are many potential reasons why consumers do not invest in energy efficiency. Consumers often pursue other attributes, such as comfort, convenience, or simplicity, which may take precedence over energy efficiency. They may be unaware of the energy features of an appliance, or unfamiliar with the concept of trading off initial cost and operating cost. They may intend to own the appliance for only a short period of time, making an energy efficiency investment financially unattractive. There may be other undesirable attributes associated with energy efficiency; for example, an energy efficient model of an appliance may be available only with other expensive features that the consumer does not want to purchase.[21] Whatever the reason, the outcome is clear. Consumers often do not invest in energy efficiency unless it offers a fairly short payback—typically less than 2 years for home appliances.

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[18] U.S. Department of Energy, Energy Information Administration, *Housing Characteristics 1987, DOE/EIA-0314(87)* (Washington, *DC: May 1989),* p. 122. There is evidence, however, that self reports of thermostat settings are often lower than actual settings, suggesting that somewhat less than 48 percent of households actually turn down their heat at night. See W. Kempton and S. Krabacher, ''Thermostat Management: Intensive Interviewing Used To Interpret Instrumentation Data,'' in W. Kempton and M. Nieman (eds.), *Energy Efficiency: Perspectives on Individual Behavior* (Washington, DC: American Council for an Energy-Efficient Economy, 1986), p. 261.

[19] Units are heating fuel savings per household. T. Wilson, ''Good News on the Setback Front, ' *Home Energy, vol. 8, No.* 1, Jan./Feb. 1991, p. 12, table 1.

[20] U.S. Department of Energy, *Technical Support Document: Energy Conservation Standards for Consumer Products: Dishwashers, Clothes Washers, and Clothes Dryers,* DOE/CE-0299P (Washington, DC: December 1990), pp. 3-11, 3-12.

[21] For example, as described inch. 2, some very efficient water heaters come with a special finish and a lifetime warranty, and a consumer may not want to pay for these other features.

Investments in larger equipment (furnaces, water heaters, heat pumps, and central air conditioners) are made somewhat differently. Most of these investment decisions are not made solely by the consumer, but by a contractor or other individual hired to fix or replace the equipment. As this equipment supplies essential services (heat, hot water), there is usually a high cost to delaying the purchase; contractors will often install the unit that is easiest to obtain, rather than the most efficient. Consumers may be unaware that they can choose a more efficient unit, or they may want the contractor to put in the cheapest unit that will deliver the needed service. For example, in an OTA interview a homeowner replacing a central air conditioner unit in summer reported that, ''I had three contractors come and give estimates, and then I chose the contractor who gave the lowest estimate. Here again, it is quite easy to see why energy efficient equipment that may be less expensive on a life-cycle cost basis is often not used: consumers usually do not consider life-cycle costs when selecting equipment.

Rental housing is an especially challenging sector for energy efficiency. About 35 percent of U.S. households are rented. In slightly over half of these rented households the tenants pay the energy bill directly, while the remainder pay energy bills through the rent.[22] In Situations where the tenant pays the bills the owners have little incentive to put in energy efficient equipment, because they receive no direct financial benefit from doing so. Conversely, tenants paying for energy through the rent often do not pay for their actual consumption, and therefore have no direct financial incentive for operating equipment efficiently.

Retrofits

The third means for consumers to influence energy use is by retrofitting their homes with energy efficient features. These improvements can range from very simple, low-cost measures (e.g., caulking) to more involved retrofits such as adding wall insulation.

As with other aspects of residential energy use, there is some evidence that retrofits are not made primarily to save money. Survey data have shown that other factors, such as hassle avoidance, frost cost, and perceived effects on comfort, are more important than perceived savings.[23] It has also been argued that the simplified methods of analysis used by consumers in making energy conservation decisions result in lower energy efficiency than would result from the use of economically "rational' methods.[24] For example, using payback as an efficiency investment criterion ignores savings accruing after the payback period regardless of their value. Similarly, high discount rates discourage investment in any option for which the returns accrue in the future, such as energy efficiency. These simplified methods are also used by those with technical energy training,[25] suggesting that information alone is not sufficient to correct these biases.

Extensive market research on how consumers make energy-related decisions has suggested that residential consumers can be divided into distinct groups, based on their values and concerns (table 3-6). For example, ''hassle avoiders' try to limit the time required to make energy-related decisions and are less concerned about cost and other attributes. Utilities use these market segmentation techniques to improve the marketing of their conservation programs. For example, in communities with a large number of 'pleasure seekers' a utility might stress the improved comfort and convenience resulting from a clock thermostat, rather than the energy savings. According to the scheme shown in table 3-6, only 13 percent of the U.S. population is concerned primarily with value when making energy-related decisions. Therefore it is quite clear why cost-effective measures are often not pursued: because much of the population makes decisions based on attributes other than operating cost.

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[22] U.S. Department of Energy, Energy Information Administration, *Housing Characteristics 1987*, DOE/EIA-0314(87) (Washington, DC: May 1989), p. 18.

[23] P. Komor and L. Wiggins, "Predicting Conservation Choice: Beyond the Cost-Minimization Assumption,'' *Energy,* vol. 13, No. 8, 1988, pp. 633-645.

[24] Consumer methods ''are Systematically biased in ways that cause less energy conservation than would be expected by economically rational response to price. " From W. Kempton and L. Montgomery, "Folk Quantification of Energy," *Energy,* vol. 7, No. 10, 1982, p. 826. Specifically, consumers focus on end-uses that are perceptually salient (e.g., electric mixers) but that are not necessarily large energy users, use peak dollars rather than actual energy consumption to measure savings, and do not account for price and weather effects.

[25] Ibid., p. 817.

Table 3-6—Market Segmentation of Residential Energy Users

Type	Description	Percent of market
Pleasure seekers	Interested in comfort, convenience, and personal control.	21.5
Appearance conscious	Most concerned with appearance.	18.4
Lifestyle simplifiers	Less concerned with comfort; pursue simplicity, often rent or low income.	16.9
Resource conserves	Concerned with environment, will pursue conservation for its own sake.	16.7
Hassle avoiders	Minimize hassle (time and effort) in making energy-related purchases, less concerned with cost.	13.4
Value seekers	Most concerned with value, will invest time and effort in making decisions.	13.1

SOURCE: National Analysts, Synergic Resources Corp., QEI, Inc., *Residential/ Customer Preference and Behavior: Market Segmentation Using CIA SSIFY*, EPRI EM-5908 (Palo Alto, CA: Electric Power Research Institute, March 1989), p. 10,

COMMERCIAL BUILDINGS

The energy use of a commercial building is largely determined by the design of the building and the efficiency of the equipment within it, However, occupant decisions in areas such as lighting and thermostat operation also influence energy use. This section describes energy-related decisions as they occur in the lifetime of a typical commercial building-starting with owners/developers, followed by architects/designers and builders, equipment manufacturers, managers/operators, and concluding with tenants/occupants.

Owners and Developers

Commercial building owners include both speculative owners, who lease or sell buildings after construction, and owner-occupants who occupy buildings after construction.[26] Speculative owners' decisions as to energy efficiency are determined in part by first cost and perceived "leasability." Energy efficient designs may require more capable (and therefore more expensive) building designers, more time to construct if builders are unfamiliar with a technology, and more time to work with building inspectors to demonstrate that a design meets health and safety requirements. From the speculative owners' perspective, these are costs that must be compared to the potential benefits. The leasability, or market appeal, of a building is determined by location, appearance, access to transport, lease costs, and other factors. A typical rent (including energy) for a large office or retail building is about $19.70 per square foot per year, while energy costs are only about $1.70 (table 3-7). Therefore a 25 percent drop in energy costs would yield only a 2 percent drop in rent costs—probably not enough to influence significantly a prospective tenant's decision.[27] From the perspective of a speculative owner, the costs of energy efficiency in terms of time and effort are very visible, but there may be little or no financial return.[28]

Many commercial buildings are master-metered, meaning that one meter measures energy consumption for the entire building. This prevents determination of actual energy consumption for an individual tenant occupying part of the building. Many have argued that submetering would reduce consumption by allowing for the billing of actual consumption, thereby providing a financial reward for efficient behavior. This may be difficult in large commercial buildings, however, because much of the energy use is associated with the central heating, ventilating, and air-conditioning (HVAC) unit; furthermore, submetering might also lead to a rate increase as utility rates are often discounted for large users.

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[26] In 1989 about 26 percent of nongovernment-owned commercial space was leased or rented. U.S. Department of Energy, Energy Information Administration, *Commercial Building Characteristics 1989*, DOE/EIA-0246(89) (Washington, DC: June 1991), p. 83.

[27] Some property managers note, however, that in a competitive market a small advantage in operating costs can be enough to influence a prospective tenant. See ' 'Citicorp Managers Call Efficiency Key to Tenant Draw, " *Energy User News*, June 1991, p. 18.

[28] "The goal of the developer is to build a quality building in the least amount of time at the lowest first cost, " reported one interviewee.

Table 3-7—Breakdown of Rental Costs for an Average Large Office/Retail Building in the United States, 1989

Type of expense	Dollars per square foot per year
Energy	1.70
Repair/maintenance	1.30
Cleaning	1.10
Administration/other	0.90
Roads/grounds/security	0.50
Fixed expenses, loan amortization, profit, etc.[a]	14.20
Total	19.70

[a] Calculated as the difference between average rent and variable operating costs shown.

NOTE: Excludes nonbuilding expenses, such as salaries and office equipment.

SOURCE: Adapted from Building Owners and Managers Association International (BOMA), "1990 BOMA Experience Exchange Report," Washington, DC, p. 27.

According to a large building owner/manager interviewed by OTA, tenants prefer fill-service leases that include everything from energy to security to cleaning. This reduces hassle for the tenant as there is only one monthly bill for the space, and simplifies budgeting as this kind of monthly bill does not fluctuate.

Owner-occupied buildings are somewhat more amenable to energy efficient technologies. Owner-occupants are typically more concerned with operating costs, as they are clearly the ones paying these costs. They often work more closely with the building designers, and they may be more willing to invest the time and effort needed to understand and even promote the use of innovative technologies. In fact, many highly energy efficient new buildings are built for clients interested in their high-tech appeal and as a demonstration of environmental awareness—not for their reduced operating costs .29 Reported one architectural/engineering (A/E) firm interviewed by OTA, ''our clients who want energy efficiency seem to be motivated by an ecological ethic or concern, and not by dollar savings.

Commercial Building Architects, Designers, and Builders

About 1.1 billion square feet of commercial buildings were built in 1989 (table 3-8), with a value of about $84 billion.[30] The process by which commercial buildings are planned, designed, and built varies, but typically the owner or developer will hire an architectural/engineering (A/E) firm to design the building and a general contractor to oversee the actual construction. The A/E firm designs and specifies the building design, the building shell, and the energy-using equipment to be installed, and therefore plays perhaps the most important role in determiningg building energy use.

Commercial building architects and engineers interviewed by OTA felt that opportunities for energy efficiency in new commercial buildings are considerable, and that some of these opportunities may *not* require an increase in construction (first) cost (see chapter 2, box 2-D). Building designers interviewed by OTA were confident that energy efficient designs would operate well, and in many cases would have important nonenergy benefits as well. Well-designed lighting, (e.g., making use of daylighting where appropriate) is thought to enhance productivity as well as energy efficiency. Using a cooling system with a larger temperature differential means smaller pumps and smaller pipes-which means lower frost cost, lower energy consumption, and a smaller portion of valuable interior space taken up by the space cooling system.

The implementation of such features, however, is often difficult for several reasons. The lack of incentives for energy efficient design is probably the single most important barrier to greater use of innovative energy technologies by A/E firms. Using a different design, even if it has many advantages, entails some risk. It may not perform as intended, the builders may be unfamiliar with it and install it

Table 3-8—New Commercial Building Construction in the United States, 1989

Type/purpose	Million square feet	Percent of total
Retail and offices	782	69
Educational	138	12
Hospital	71	6
Social/recreational	45	4
Public buildings	36	3
Religious	27	2
Miscellaneous	34	3
Total	1,133	100

NOTE: Percents may not add to 100 due to rounding.

SOURCE: U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States: 1991* (Washington, DC: 1991), p. 718.

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[29] This is similar to the "conservation ethic" often raised as an important motivation for homeowners to invest in energy efficiency.

[30] U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract* @the *United States: 1991* (Washington, DC: 1991), p. 718.

incorrectly, or it may require changes in other building components. The rewards for energy efficient design are usually small. Clients are typically concerned with appearance, comfort, leasability, and other factors and are rarely willing to pay more for energy efficiency, The traditional business relationship between risk and return-that a higher risk choice has a higher return as well-does not appear to hold for energy innovations. It is usually easier for the designer to follow accepted, standard practice, especially if the designer's fee is the same in either case. As one interviewee said, "The path of least resistance does not include energy innovative design.

Commercial Building Equipment Manufacturers

Equipment in commercial buildings consumes energy to provide space conditioning (heating, cooling, and ventilation), lighting, and various other needs, depending on the building. The manufacturers of this equipment vary widely in size. For example, there are about 10 major manufacturers of large air-conditioning systems, while there are many small manufacturers of fluorescent light fixtures. The diversity of the business makes it difficult to generalize about how these firms incorporate energy efficiency into their production and marketing decisions. There are, however, several issues that apply to most of the industry.

The building equipment business is very competitive. Even in the relatively concentrated businesses, such as air conditioning equipment, companies typically compete for contracts. First cost is probably the most important, but certainly not the only, criterion on which manufacturers compete. Other factors raised as important by manufacturers include reliability, performance, features, and energy efficiency.[31]

Equipment manufacturers see energy efficiency as one of several important attributes that could differentiate their product from their competitors and thereby increase their market share. It is not clear how these attributes (first cost, reliability, performance, etc.) are valued or traded off by consumers, but from the manufacturers perspective, energy efficiency is typically of only moderate importance to most consumers. Features that add new functions (e.g., computerized control of an HVAC system to allow free-tuning of temperature in individual offices) are seen as having more marketing appeal than a less visible improvement such as energy efficiency.

The channels through which equipment manufacturers market and distribute their equipment vary. For very large building equipment, such as a large air handling unit, the A/E firm or the mechanical engineering firm subcontracting the HVAC work specifies the equipment, which is then built to order and delivered to the job site. Standardized equipment (such as lighting ballasts) is distributed through a private wholesaler or through a manufacturer-owned distribution system.

Building Managers and Operators

Large commercial buildings and commercial complexes typically have building operators or managers who operate, maintain, and repair the energy-using equipment. Their chief responsibility is to maintain occupant comfort and to respond to complaints. Very large complexes sometimes have energy managers, whose sole responsibility is energy management.

Building managers and operators are often hesitant to use innovative energy efficient equipment and practices, as from their perspective the costs are high and the benefits minimal. As discussed above, an innovation often carries with it an increased risk of poor performance,[32] and typically a change in building operation must go through a period of adjustment and free-tuning. The costs to the operator are in the form of increased complaints, as he or she is expected to fix the problem. The chief benefit, reduced energy costs, typically flows to the institution or owner and not to the operator. In addition, complex systems such as computer-controlled energy management systems are sometimes installed without adequate operator training. Reports a facilities manager for a large commercial building complex, "We simple folk who operate and maintain

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[31] In our interviews we typically asked ''what do your customers look for when selecting equipment?' rather than ''how important is energy efficiency to your customers?' as the former would allow us to see how energy efficiency compares with other attributes.

[32] A survey of commercial customers found "performance of the conservation equipment' ranked as the highest concern when considering efficiency improvements. ''Total amount of money saved and ' 'payback' ranked somewhat lower. Temple, Barker, & Sloane, Inc., Xenergy, Inc., *Market Research on Demand-.Side Management Programs,* EPRI EM-5252 (Palo Alto, CA: Electric Power Research Institute, June 1987), p. 3-4.

systems are given state of the art equipment to operate, and when things don't go well we are frequently told we don't know what we are doing. ' '[33]

Bad experiences with energy efficient equipment, in which the equipment failed prematurely, performed poorly, or was otherwise inadequate, have made operators and managers wary. For example, variable-air-volume (VAV) systems for large commercial buildings are a popular retrofit and are common practice in new construction, due in part to their large efficiency advantage over traditional constant volume systems. One interviewee reported that VAV systems are quite popular with tenants—not for their energy savings, but for their reduced noise. However VAV systems are very design sensitive, and reports one facilities manager, ''I have never seen or known of a fully functional variable air volume system. '[34]

Tenants and Occupants

About one-quarter of commercial building space is leased or rented, rather than owner-occupied. This fraction varies by building use—for example, less than 10 percent of commercial building floor space used for assembly or health services is leased or rented, while 30 percent of office space is leased or rented.[35] In most commercial buildings, opportunities for tenants to influence building energy use are somewhat limited. Control of drapes and blinds, proper use of space heaters, and turning off equipment (e.g., computers and printers) when not needed can all contribute to reducing consumption. However, indoor temperature often cannot be adjusted and lights often are centrally switched, limiting occupant control over energy use.[36] And as energy costs are typically buried in overall rental costs, there is little incentive to reduce energy use. Many larger commercial buildings have multiple tenants but only one energy meter, and energy costs are apportioned according to square footage or other criteria, rather than actual use, thereby reducing further the financial incentive for efficiency.

There are some opportunities for implementing efficiency when the space is initially set up. Those renting commercial space are often responsible for supplying all interior fixtures and equipment, and for retail space this usually includes lighting futures as well. However, turnover in the retail space market is quite rapid, and therefore many renters of retail space have a short time horizon when making lighting equipment choices. Therefore first costs and lighting quality are the chief criteria when making these choices, and operating costs are of less concern.

The relative insignificance of energy costs in comparison to labor costs often results in management attention and interest being directed elsewhere. A typical office building in the United States contains about 270 square feet of floor space per office worker.[37] If one assumes an average cost (salary plus benefits) per employee of $40,000 per year, this works out to about $150 per square foot per year for salaries, which dwarfs the $1.70 per square foot per year spent on energy (table 3-7). In other words, energy costs are on the order of 1 percent of labor costs in a typical office building.

This problem is compounded by the persistent perception that efficiency means discomfort and inconvenience. As noted throughout this report, energy efficiency does not have to reduce comfort—indeed, many technologies enhance both comfort and energy efficiency. However the perception that efficiency means "freezing in the dark" persists, and if an owner believes that a technology may reduce productivity then he or she will not allow its use, because any energy savings would pale next to the perceived productivity loss.[38] A survey of small businesses found that energy efficiency was thought to require turning down heat or turning off lights,

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[33] R.F. Burch, ''Where Have We Failed? Problems in Facilities Operation and Maintenance,'' in F. Payne (cd.), *Strategies for Energy Efficient Plants and Intelligent Buildings* (Lilburn, GA: Fairmont Press, 1987), p. 205.

[34] Ibid., p. 203.

[35] Excludes government-owned buildings. U.S. Department of Energy, Energy Information Administration, *Commercial Building Characteristics 1989,* DOE/EIA-0246(89) (Washington, DC: June 1991), p. 83.

[36] For example, only 35 percent of commercial floor space allows occupant control of heating and/or cooling equipment. U.S. Department of Energy, Energy Information Administration, *Commercial Building Characteristics 1989*, DOE/EIA-0246(89) (Washington DC: June 1991), p. 212.

[37] Building Owners and Managers Association International (BOMA), *1990 BOMA Experience Exchange Report*, Washington, DC, p. 27. There is considerable uncertainty in this number; a separate survey estimates it at 430 square feet per office worker (U.S. Department of Energy, Energy Information Administration, *Commercial Building Characteristics 1989*, DOE/EIA-0246(89) (Washington DC: June 1991), p. 13).

[38] This is especially a concern with lighting retrofits. See ''Lighting the Commercial World, *EPRI Journal*, vol. 14, No. 8, December 1989, p. 9.

and these were not considered acceptable options, because a cold, underlit store would discourage customers.[39]

SUMMARY AND CONCLUSIONS

Understanding how and why energy efficient technologies and practices are often neglected—despite their apparent attractiveness on a life-cycle cost basis—is essential for designing policies to encourage greater use of these technologies.

The methods consumers use to make energy-related decisions often work against energy efficiency. Individuals pursue several goals when making energy-related decisions, such as minimizing first cost, minimizing time to make the decision, or minimizing risk by using the same thing that worked previously. Very few pursue the goal of minimizing life-cycle costs. For example residential building contractors typically select equipment based on first cost, ease of installation, and brand familiarity. And when future savings do enter into a decision, they are heavily discounted. For example implied consumer discount rates in appliance selection can exceed 50 percent.

There are often no incentives, financial or otherwise, for efficiency. A contractor bidding on a job will often win the job if he or she has the low bid—which often requires specifying low first-cost, inefficient equipment. And although energy costs in the aggregate are considerable, they are often low in relation to other costs. In a typical office, for example, energy costs are on the order of 1 percent of labor costs; therefore management and capital are often drawn to other areas. Designing a low-energy commercial building may require the use of innovative designs that might not work as predicted, and unless this greater risk is rewarded it will not be taken.

Over one-third of households, and one-quarter of commercial building floor space, is rented or leased rather than owner-occupied; in these buildings there is a reduced incentive both to invest in efficient equipment and to operate equipment efficiently.

Energy efficiency is just one of many attributes to consider when making complex choices, and its benefits are often seen as relatively intangible and uncertain. For example, a builder faced with the decision of investing $1,000 in insulation or $1,000 in landscaping will probably choose landscaping, as prospective buyers often value visible, tangible objects more highly. When making complex decisions that require the consideration of many attributes, people may focus on a limited number of these attributes-typically the most visible and tangible. For example, one room air conditioner may be small, quiet, and have electronic controls, while another is larger but with more cooling capacity and a different first cost; these features, rather than energy efficiency, often dominate the choice process.[40]

Energy efficiency is often (mis)perceived as conflicting with other goals. For example, small business owners equate efficiency with dark, cold stores, which is bad for business, and as a result show little interest in efficiency.

Many people believe that consumers are relatively unwilling to invest in energy efficiency. Whether or not this is true is difficult to determine; nevertheless the *belief* that it is true influences decisions of builders and manufacturers on what to build, manufacture, and sell.

The result of these factors is that cost-effective and societally beneficial opportunities for increased energy efficiency are often neglected.

This somewhat gloomy list of good reasons for a less than optimal outcome can be seen as an opportunity and a challenge, rather than as an insurmountable barrier. Considerable progress has been made in overcoming technical and economic barriers, as discussed in chapter 2. What remains is to correct some key market imperfections. Chapter 4 discusses past Federal actions to implement energy efficiency in buildings, and chapter 5 offers policy options to overcome these market imperfections and to encourage the use of cost-effective energy efficient technologies in buildings.

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[39] P. Komor and R. Katzev, "Behavioral Determinants of Energy Use in Small Commercial Buildings: Implications for Energy Efficiency," *Energy Systems and Policy*, vol. 12, 1988, p. 237.

[40] In some situations the consideration of other attributes leads to increased energy efficiency. As mentioned above, for example, some commercial building owners invest in very efficient technologies not to reduce operating costs but to demonstrate their environmental ethic.

Chapter 4

A Review of Federal Efforts To Increase Energy Efficiency in Buildings

Box 4-A--Chapter Summary

This chapter reviews past and present Federal programs promoting energy efficiency in buildings. These programs have adopted numerous strategies, including incentives (tax credits, weatherization grants, loan subsidies); Federal leadership (providing public recognition for voluntary energy savings); research, development, and demonstration (RD&D); codes and standards; and information (appliance labels, building energy audits, and technical assistance). A review of these programs suggests that Federal efforts to reduce energy use in buildings often generate significant and cost-effective energy savings, but inappropriate performance measures and a lack of ongoing evaluation have prevented many of them from attaining the full range of cost-effective energy savings available. In fact, the authorizing legislation that establishes building efficiency programs often fails to focus on the promotion of cost-effective energy savings. In addition, many Federal programs were never implemented as planned. Major programs were targeted for elimination, experienced massive budget cuts, suffered delays, or were simply never implemented because of changes in administration priorities in the early 1980s. Specific options for improving the cost-effectiveness of Federal programs are offered.

State, local, and utility programs are reviewed briefly as well. Although this chapter focuses on Federal programs, many State and utility programs surpass Federal efforts in promoting energy efficiency in buildings. The wide variety of nonfederal activity suggests that Federal programs will be most effective if they complement and support, rather than duplicate, these other activities.

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Boxes

Chapter 4

A Review of Federal Efforts To Increase Energy Efficiency in Buildings

INTRODUCTION

The preceding chapters have discussed trends in U.S. building energy use, the technologies available to make that use more efficient, and barriers limiting the adoption of these technologies. This chapter reviews Federal, State, and utility programs designed to promote building energy efficiency, many of which have been designed, at least in part, to spur the wider use of some of the technologies noted earlier.[1] The purpose of this chapter is to indicate the goals of building energy programs, identify the barriers to energy conservation and efficiency they attempt or have attempted to resolve, indicate their results (where known), and highlight key implementation issues associated with each.

A major lesson from this review is that Federal efforts to reduce energy use in buildings have led often to significant and cost-effective energy savings, but inappropriate performance measures and a lack of ongoing evaluation have prevented many of them from attaining the full range of cost-effective energy savings available. In fact, the authorizing legislation that establishes building efficiency programs often fails to focus on the promotion of cost-effective energy savings. To help improve existing programs and policies, this chapter offers options—both general and program-specific-for Congress and the Department of Energy (DOE) to consider. The program-related issues discussed in this chapter are given with the expectation that these programs (and others like them) would be valuable vehicles for achieving significant, cost-effective energy savings available in U.S. buildings, as suggested in chapter 1.

Another major lesson from this review is that many Federal programs were never implemented as planned. Major programs were targeted for elimination, experienced massive budget cuts, suffered delays, or were simply never implemented. Many of these changes stemmed from specific Federal policy changes exerted by the administration in the 1980s. Several Federal programs initiated in the late 1970s and early 1980s had been in operation only a few years before they were scaled back (or eliminated) by shifts in Federal political priorities.

The first part of this chapter is organized by the several types of building energy efficiency and conservation programs directed by the Federal Government: incentives (tax credits, weatherization grants, loan subsidies); Federal leadership in promoting voluntary energy savings through public recognition; research, development, and demonstration (RD&D); codes and standards; and information (appliance labels, building energy audits, and technical assistance). Many programs apply several of these approaches, but they are organized here according to their primary focus. The enabling legislation authorizing the major Federal programs discussed in this chapter is listed in box 4-B. Major building conservation and efficiency programs administered by the Federal Government in the last two decades are described briefly in box 4-C. As used in this chapter, a program is an effort designed specifically to reduce energy use in buildings or building-related equipment.

REVIEW OF FEDERAL PROGRAMS

Incentive Programs

As suggested in chapter 3, financial incentives can encourage consumer investments in energy efficiency. The Federal Government has offered several incentive programs to reduce energy use in buildings, including tax credits, weatherization grants, and loan subsidies.

Tax Credits

The Energy Tax Act of 1978 (Public Law 95-618; ETA), as amended by the Crude Oil Windfall Profit

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[1] A variety of other programs have had and will have important effects on building energy use, but they are not discussed in this report, because their primary focus lies beyond building energy use. The Clean Air Act Amendments of 1990 (Public Law 101-549), for example, allow utilities to earn pollution reduction credits for reducing the energy demands of their consumers, but the focus of that program is emissions reductions, not building energy conservation per se.

Box 4-B—Major Legislation Authorizing Federal Energy Programs for Buildings

The statutes listed below generally covered multiple energy policy issues and programs, but only those elements concerning building energy use are mentioned below. Most of these statutes have been amended since their original passage but, for simplicity, only the initial legislation is given below. The statutes are listed in chronological order, and the dates in parentheses indicate when the measures were signed into law.

Energy Policy and Conservation Act (Public Law 94-163; December 22, 1975)-Directed the Federal Trade Commission to develop and promulgate labels listing energy use for new appliances; directed the Federal Energy Administration and later the Department of Energy (DOE) to develop voluntary appliance efficiency standards; and established the State Energy Conservation Program to provide technical assistance for energy conservation efforts at the State and local level.

Energy Conservation and Production Act (Public Law 94-385; August 14, 1976)_Required the development of national mandatory Building Energy Performance Standards for all new U.S. buildings; these standards were later made voluntary for all nonfederal buildings (public Law 97-35); and created the Weatherization Assistance Program to fund energy saving retrofits for low-income households.

National Energy Extension Service Act (Public Law 95-39; June 3, 1977)-Established the Energy Extension Service, a State-administered energy information, education, training, and demonstration program overseen and funded by DOE.

Energy Tax Act (Public Law 95-618; November 9, 1978+Granted residential energy conservation and renewable energy tax credits for income tax years 1978 to 1985.

National Energy Conservation Policy Act (Public Law 95-619; November 9, 1978)-Established the Residential Conservation Service, which required large electric and natural gas utilities to provide residential energy audits to their customers; created the Institutional Conservation Program, a matching grant program providing monies for energy audits and energy saving retrofits in nonprofit institutional buildings (colleges, schools, and hospitals); required the voluntary appliance efficiency targets being developed under the Energy Policy and Conservation Act to become mandatory standards; and required the national mortgage associations to encourage lending institutions to offer extended mortgage credit for the purchase of energy efficient homes.

Energy Security Act (Public Law 96-294; June 30, 1980)-Established the Commercial and Apartment Conservation Service, which required large electric and natural gas utilities to offer energy audits for commercial and multifamily buildings; and created the Solar Energy and Energy Conservation Bank at the Department of Housing and Urban Development to provide grants and loan subsidies for energy conservation and solar energy retrofits in low- and moderate-income households and in commercial and agricultural buildings with nonprofit owners or tenants.

Low-Income Home Energy Assistance Act (Public Law 97-35; August 13, 1981)-Established the low-Income Home Energy Assistance Program (LIHEAP), a block grant program administered by the Department of Health and Human Services that provides funds to low-income households for heating and cooling expenditures. As amended, this legislation allows states to allocate 15 percent of their L IHEAP monies to weatherization; upon request, HHS may raise this amount to 25 percent.

National Appliance Energy Conservation Act (Public Law 100-12; March 17, 1987)-As amended (Public Law 100-357), this statute established energy standards for the 13 categories of new appliances covered under the Energy Policy and Conservation Act as amended. The NAECA requires DOE to review and update these standards to keep pace with technological improvements.

Tax Act of 1980 (Public Law 96-223), revised the Internal Revenue Code of 1954 to encourage *inter alia* residential energy conservation and renewable energy investments. The residential credits applied to income taxes and were available for investments made between April 20, 1977 and December 31, 1985. The discussion here is focused on the conservation credits.

The ETA income tax credits for residential conservation investments were limited to 15 percent of the first $2,000 expended for a maximum potential credit of $300. Conservation expenditures were limited to residential units in the United States that were substantially complete by April 20, 1977 and that were the principal residences of occupants claiming the credit. Conservation expenditures eligi-

Box 4-C—Major Federal Programs Designed To Reduce Energy Use in Buildings

The Arab oil embargo of 1973-74, several major domestic natural gas shortages, and other events fueled national concerns about U.S. energy security in the 1970s. In response, the U.S. Congress established a variety of national programs aimed at reducing energy use in all sectors. The major programs designed to reduce energy use in buildings are described below. Several of these programs no longer exist.

Department of Energy

Appliance energy standards were initially devised as voluntary energy efficiency targets that the Federal Energy Administration, predecessor agency to the Department of Energy (DOE), was directed to promulgate under the Energy Policy and Conservation Act. These targets were to represent energy savings of at least 20 percent for the covered products, as measured by expected 1980 energy use levels relative to known 1972 levels. Under the National Energy Conservation Policy Act of 1978 (Public Law 95-619), however, the targets were changed to mandatory standards. In January 1981, after DOE had announced that promulgation of the standards was imminent, a series of internal Department policy changes made by the newly arrived Reagan administration delayed their issuance. After 6 years, two major legal actions by environmental and consumer groups, and a pocket-vetoed bill that restated Congress' intent to have mandatory national appliance efficiency standards, the National Appliance Energy Conservation Act (Public Law 100-12; NAECA) became law on March 17, 1987.

The NAECA, as amended, designates minimum efficiency or maximum energy consumption levels for 13 categories of covered products and requires DOE to update and strengthen these standards on a regular basis in order to keep pace with technological improvements. Thus far, the Department has revised standards for refrigerator-freezers, freezers, small gas furnaces, dishwashers, clothes washers, and clothes dryers--all at levels more stringent than the original NAECA requirements.

Building Energy Performance Standards (BEPS) were originally the responsibility of the Department of Housing and Urban Development (HUD). The BEPS were originally intended to be mandatory national energy performance standards for all newly constructed buildings, as required by Title III of Public Law 94-385. Later amendments to this statute transferred these responsibilities to DOE (Public Law 95-91; 1977), directed the issuance of interim standards for new Federal buildings by August 1981 (Public Law 96-399; 1980), and made the standards voluntary for all nonfederal buildings (Public Law 97-35; 1981). At present, DOE has issued mandatory interim standards for all Federal residential buildings and voluntary standards for all commercial and multifamily high-rise buildings. Voluntary interim standards for nonfederal residential buildings are still pending (as of January 1992).

Institutional Conservation Program (ICP) is a Federal institutional grant program administered by the States through DOE regional offices. Program grants fund energy audits and energy conservation measures in nonprofit schools (primary and secondary), colleges and universities, and hospitals. Originally, only buildings constructed before April 20, 1977 were eligible for ICP grants, but recent legislation extended that cutoff date to buildings constructed before May 1, 1989 (Public Law 101-440; 1990). The purpose of this program is to provide conservation retrofit funds for institutions with limited capital resources, hence the exclusive participation of nonprofit organizations. A recent national evaluation of ICP energy savings determined that program costs through 1988 totaled almost $1.4 billion (1987 dollars) and resulted in an estimated 1987 cumulative energy savings of 0.3 quadrillion Btus (317 trillion Btus) worth an estimated $1.9 billion (1987 dollars). The total cost figure includes both DOE grant outlays and the matching funds required of participating institutions. By this simple measure, ICP has exceeded its break-even payback costs by $500 million. In addition, DOE estimates that ICP-funded measures completed by 1988 will save an extra $400 million per year over their remaining lifetimes.[1]

Residential Conservation Service (RCS) required large electric and natural gas utilities to offer residential energy conservation audits to their consumers. The operating assumption of the program was that residential consumers would invest in energy saving retrofits if they had adequate information about the energy and financial savings potential of their homes. This assumption proved optimistic. However, State and utility programs that included financial incentives in their programs enjoyed the highest audit request rates, and the highest retrofit activity, in the Nation. By law, the RCS expired in 1989.

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[1] U.S. Department of Energy, Assistant Secretary, Conservation and Renewable Energy, An *Estimate of Aggregate Energy Savings Due to the ICP Program,* DOE/SF/00098-H2 (Washington DC: March 1988), pp. vi, 33.

(Continued on next page)

Box 4-C—Major Federal Programs Designed To Reduce Energy Use in Buildings--Continued

State Energy Conservation Program (SECP) requires States to develop and implement energy conservation programs as a condition to receive Federal monies for a variety of State and local financial and technical assistance programs designed to save energy. All 50 States, the District of Columbia, and six U.S. territories participate in this program, which offers professional and consumer energy education programs and materials, demonstration programs, and technical assistance for conservation efforts in all sectors. As an effort to enhance existing State and local energy conservation efforts, SECP is administered with another DOE program, the Energy Extension Service (EES); both channel Federal resources and expertise to participating States.

Weatherization Assistance Program (WAP) was authorized in 1976 to provide grant monies for the weatherization of low-income households in order to reduce their fuel expenses. Funds are used for retrofits, related repairs, and consumer education. WAP funds are disbursed by DOE through State and local agencies to community organizations that are responsible for client selection, weatherization installation and repairs, financing, and consumer education. Roughly 1,200 local organizations participate in WAP, most with staffs of only 5 to 10 people.[2] Using DOE and other Federal weatherization funds, these groups reach about 250,000 households annually.[3]

Department of Housing and Urban Development

Manufactured Home Construction and Safety Standards are Federal standards with minimum quality requirements that apply to manufactured housing. These standards provide a means to administer Federal energy efficiency guidelines to this specialized portion of the new housing market.

Minimum Property Standards (MPS) are residential construction requirements that apply to federally financed housing, and they include provisions for energy efficiency. New homes are required to meet MPS standards to qualify for Federal Housing Administration and Veterans Administration loans.[4]

Solar Energy and Energy Conservation Bank was authorized to provide financial assistance for conservation and solar measures to low- and moderate-income households, as well as commercial and agricultural buildings with nonprofit owners or tenants. The Bank suffered early uncertainties over resources-Congress rescinded virtually all program funding in fiscal year 1981-but the program appeared to make very promising progress in later years. According to HUD estimates, conservation investments made during the last year of the program (1987) achieved average simple paybacks of 4.4 years.[5]

Department of Health and Human Services

Low-Income Home Energy Assistance Program (LIHEAP) is a block grant program that provides financial assistance to low-income households for their energy expenses. Up to 25 percent of LIHEAP monies may be used for weatherization, but States spend on average only about 9 percent for that purpose. In fiscal year 1990, LIHEAP serviced roughly 6 million households, but only 148,000 homes received weatherization assistance.[6]

Federal Trade Commission

Appliance efficiency labeling is required under Title V of the Energy Policy and Conservation Act of 1975 (Public Law 94-163), as amended. Administered by the Federal Trade Commission, the labeling program became effective in May 1980 and covers 13 categories of appliances and equipment. As required, the labels indicate estimated annual energy costs and list the range of estimated costs for similar products to provide consumers comparative information.

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[2] M. Schweitzer, "Energy Conservation for Low-Income Households: A Study of the Organization and outcomes Of Weatherization Assistance Programs," *Energy Systems and Policy*, vol. 12, No. 2, 1988, pp. 102, 105.

[3] U.S. Department of Energy, Office of the Assistant Secretary for Conservation and Renewable Energy, "Report on the Present Weatherization Grant Program," prepared for the U.S. Senate, Committee on Appropriations, Aug. 29, 1989, p. 5.

[4] E. Hirst, J. Clinton, H. Geller, W. Kroner, and F.M. O'Ham (cd.), *Energy Efficiency in Buildings: Progress & Promise* (Washington, DC: American Council for an Energy-Efficient Economy, 1986), p. 167.

[5] U.S. Department of Housing and Urban Development, Solar Energy and Energy Conservation Bank, *Solar Energy and Energy Conservation Bank: FY 1987 Annual Report to the Congress* (Washington DC: 1987), pp. 3,6.

[6] U.S. Department of Health and Human Services, Division of Energy Assistance, *Low Income Home Energy Assistance Program: Report to Congress for Fiscal Year 1990* (Washington, DC: September 1991), p. vii.

other Federal Programs

Green Lights is a voluntary commercial lighting retrofit program formally initiated by the Environmental Protection Agency (EPA) in January 1991. The program encourages major corporations to perform cost-effective lighting retrofits at all their U.S. facilities to lower electricity use and thereby reduce the pollution associated with its generation. In exchange for technical assistance and Federal Government recognition, Green Lights participants agree to conduct lighting retrofits in at least 90 percent of the total square footage of their U.S. facilities within 5 years of signing an agreement with EPA. Program participants are expected to implement only those lighting retrofits that will be cost-effective and that will not compromise lighting quality. As of December 1991, roughly 150 companies had enrolled in the program.

Residential energy conservation and renewable energy tax credits were available for income tax years 1978 to 1985. Conservation expenditures were limited to residential units located in the United States that were substantially complete by April 20, 1977 and that were the principal residences of occupants claiming the credit. Allowable conservation expenditures included insulation, exterior storm windows, exterior storm doors, automatic setback thermostats, caulking, weatherstripping, and all associated installation costs. The residential conservation credits were limited to 15 percent of the first $2,000 invested for a maximum potential credit of $300. For a variety of reasons, participation in the program was low.

ble for the ETA credits included insulation, exterior storm windows and doors, automatic setback thermostats, caulking, and weatherstripping.[2] To be eligible for the credit, conservation expenditures had to originate with the taxpayer and remain in operation at least 3 years. Credits applied to both materials and installation costs.[3]

There are no reliable determinations of the economic costs and benefits of the ETA residential conservation credits. A variety of policy and market changes were working simultaneously to motivate conservation investments in the residential sector.[4] As a result, determining the *incremental* effect of the Federal tax credits on residential energy investments has been elusive.[5] By reducing consumer first costs for conservation and renewable investments, the credits clearly created social benefits but at undetermined social costs.

As these comments suggest, studies analyzing the effectiveness of the Federal residential tax credits as inducements to energy conservation and renewable energy investments have been inconclusive.[6] One of these studies suggested that the increasing price of energy relative to other goods and services was the principal factor behind the decline in residential energy consumption at the time the tax credits were available.[7] Average U.S. household energy costs rose sharply (nominally by about $400) from 1978 to 1984.[8] And a decline in real income in the early

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[2] Public Law 95-618, 92 Stat. 3175.77, sec. 101(a). Other conservation expenditures eligible for the residential tax credit were energy saving furnace replacement burners, flue adjustment devices, electrical or mechanical furnace ignition systems that replaced gas pilot lights, exterior thermal windows, exterior thermal doors, and meters displaying energy costs. Public Law 95-618, 92 Stat. 3177, sec. 101(a).

[3] Public Law 95-618, 92 Stat. 3176-77, sec. 101(a).

[4] Namely, Federal, State, and utility energy conservation programs were encouraging consumers to save energy through information and other incentives, the 1979 Iranian revolution pushed oil prices up for several years, and public commitment to energy conservation generally increased during this period.

[5] E. Hirst, R. Goeltz, and H. Manning, *Household Retrofit Expenditures and the Federal Residential Energy Conservation Tax Credit*, ORNL/CON-95 *(Oak* Ridge, TN: Oak Ridge National Laboratory, July 1982), pp. 5,37.

[6] See, for example, references cited in footnotes 5, 7, 14, and 17.

[7] US. Library of Congress, Congressional Research Service, *An Economic Evaluation of Federal Tax Credits for Residential Energy Conservation*, Report No. 82-204E (Washington, DC: December 1982), pp. 7-10, 41-61. An OTA analysis completed shortly after the tax credits became available suggested the same. See U.S. Congress, Office of Technology Assessment, *Residential Energy Conservation*, *OTA-E-9* (Washington, DC:* U.S. Government Printing Office, July 1979), vol. 1, pp. 6, 20-22.

[8] Specifically, the nominal increase in household energy costs was from $724 (1978) to $1,123 (1984). (These figures refer only to site energy use and exclude household transportation costs.) See U.S. Department of Energy, Energy Information Administration, *Residential Energy Consumption Survey: Trends in Consumption and Expenditures, 1978-1984*, DOE/EIA-0482 (Washington DC: June 1987), p. 19.

Table 4-l—Use of the Residential Energy Conservation Tax Credits by Income (1983)

	Family income less than $10,000	$10,000 $14,999	$15,000 $19,999	$20,000 $2&99	$30,000 and higher	Total
Percent of homes that claimed a tax credit on their 1983 return	9	11	17	21	26	17
Percent of homes that claimed a tax credit on their 1983 return that would have made all the same improvements if the tax credit had not been available	100	89	93	84	88	88
Percent of homes that made at least one conservation improvement in 1983 but did not claim a tax credit, for the following major reasons[a]:						
Unaware of the credit.	38	37	30	20	19	26
Expenditure too small to claim[b]. . .	18	16	22	22	28	23
Did not file the long form[c].	34	28	28	19	12	21
Total with at least one reason	86	87	83	81	86	85

[a] Although respondents could list more than one reason, percentages are below 100, because not all reasons are listed here. The other reasons given for not claiming the credits were minor, were not reported by the Energy Information Administration due to large statistical variance, or both; those reasons included reluctance to file tax forms, use of the maximum credit in previous years, ineligible home, and no taxes filed in 1983.

[b] The Energy Tax Act of 1978 (public Law 95-618) disallowed residential conservation credits less than $10 (sec. 101 a). As the credits amounted to 15 percent of the f first $2,000 expended, this meant that the minimum expenditure eligible for the credit was just over $66,

[c] Filing the IRS long form was required to claim the tax credit.

SOURCE: U.S. Department of Energy, Energy Information Administration, *Residential Energy Consumption Survey: Housing Characteristics 1984,* DOE/EIA-0314(84) (Washington, DC: October 1986), p. 27.

1980s may also have contributed to the drop in residential energy use during the period the credits were available.[9]

From 1978 to 1985, there were about 30 million claims for the residential conservation credits, amounting to nearly $5 billion (nominal dollars) in lost revenues to the U.S. Treasury. The largest number of annual claims for the conservation credits came in the first year-about 6 million. For the next 5 years (1979-83), the total number of returns declined steadily (to 2.4 million in 1983), but climbed again the last 2 years (2.7 million in 1985).[10]

A 1983 household survey conducted as part of the DOE Energy Information Administration's (EIA) Residential Energy Consumption Survey (RECS) suggests why national use of the conservation credit waned. The survey determined that 85 percent of U.S. households that had conducted conservation retrofits in 1983 bypassed the conservation tax credits entirely. The nonclaimants in the survey explained that they were unaware of the credits, they did not use the Internal Revenue Service (IRS) long form (required to claim the credit), or the amount of their investment was too small to claim a credit. Other, less common reasons given for foregoing the credit included the difficulty in filling out the tax credit forms and ineligibility (table 4- 1).[11]

Actual claims for the conservation credits correlated directly with income; the highest level of participation (26 percent) was in the highest income category ($30,000 and up), and the lowest levels of participation (9 to 11 percent) were in the lowest income categories (less than $15,000). Perhaps the most interesting finding in the 1984 RECS study was that most respondents claimed they would have made the same conservation investment without the credit. Eighty-eight (88) percent of respondents who

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[9] U.S. Library of Congress, Congressional Research Service, *An* Economic. *Evaluation Of Federal Tax* Credits for *Residential* Energy *Conservation,* Report No. 82-204E (Washington DC: December 1982), pp. 9,58.

[10] These are summary figures compiled by OTA from unpublished IRS data. John Kozielec, Internal Revenue Service, personal communication, June 24, 1991.

[11] U.S. Department of Energy, Energy Information Administration, Residential Energy *Consumption Survey: Housing Characteristics 1984,* DOE/EIA-03 *14(84)* (Wasington, DC: October 1986), p. 27.

had claimed the conservation credit asserted they would have made the same expenditures without the tax credits.[12] This suggests that the incremental value of the credits as inducements to perform retrofits may have been negligible, and the credits may have created a windfall for many energy investors who would have made the same conservation investments anyway.[13]

The IRS required claimants to indicate the nature of their expenditures. From 1978 to 1981, about 85 percent of credited conservation expenditures were for insulation, storm windows, and storm doors; caulking and other conservation retrofits comprised the small remainder of expenditures in this category. Though more homes in this period made insulation investments, the total cost of storm doors and windows for program participants was slightly higher.[14] Experience in other Federal programs, however, suggests that many of the credited retrofits (particularly storm doors and windows) were among the least cost-effective.[15] In addition, the program did not establish incentives or guidelines to promote *cost-effective* retrofits; the principal goal was to encourage retrofits that consumers judged worthwhile (by whatever criteria they chose).

The rental housing market was minimally affected by the residential energy tax credits.[16] Under the principal residence requirement necessary to obtain the credits, landlords were generally ineligible, while renters generally had little financial incentive to retrofit their units (especially if they did not pay their energy bills directly). This lost market was important because, at the time the credits were available, one-third of the 80 million housing units in the United States were rented.[17]

In sum, the conservation credits established under the Energy Tax Act appear to have been bypassed by most consumers that performed retrofits. Apparently, other factors motivated retrofits more strongly. This suggests that the tax incentives were a windfall for most claimants. There are several explanations (given below) for this general disregard of the conservation credits, which Congress should be aware of if it considers re-enacting such credits in the future.

- The conservation credits were poorly advertised and were restricted to claimants using the IRS long forms. The 1984 RECS study determined that these were the two most common reasons for not claiming the credits. First, the study revealed that a significant portion of consumers were unaware of the credits (between 19 and 38 percent, depending on income). In fact, awareness decreased with decreasing income, suggesting that the relative need to advertise incentive programs to low-income groups is greater than for higher income groups. Second, low-income households and renters may have been discouraged or prevented from claiming the credits, because many of them generally do not file long forms.
- The rate of the conservation credits (15 percent) was probably too low to motivate widespread retrofitting. This was a major reason given for all income groups in the 1984 RECS study. Interestingly, Congress considered extending and increasing the conservation credits to 25 percent for tax years 1985 to 1988 for households earning less than $30,000,[18] but no measure was enacted.

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[12] U.S. Department of Energy, Energy Information Administration, *Residential Energy Consumption Survey: Housing Characteristics 1984,* DOE/EIA-0314(84) (Washington, DC: October 1986), p. 27.

[13] Yet the survey had at least two drawbacks. First, respondents were questioned well after they made their investments; they were not asked the extent to which the availability of the credits motivated them to undertake the investments in the first place, or whether learning about the Federal credits was connected to their seeking energy improvements in their principal residences. Also, the survey did not determine the potential effects of a ***larger*** credit.

[14] U.S. Department of Energy, Energy Information Administration, *An Economic Evaluation of Energy Conservation and Renewable Energy Tax Credits,* DOE/NBM—6000728 (Washington, DC: October 1985), Service Report, p. 12.

[15] See, e.g., J. Schlegel, J. McBride, S. Thomas, and P. Berkowitz, ''The State-of-the-Art of Low-Income Weatherization: Past, present, and Future, ' *Proceedings of the ACEEE 1990 Summer Study on Energy Efficiency in Buildings* (Washington DC: American Council for an Energy-Efficient Economy, 1990), vol. 7, p. 7.212.

[16] J. Clinton, H. Geller, and E. Hirst, ' 'Review of Government and Utility Energy Conservation Programs,' *Annual Review of Energy 1986* (Palo Alto, CA: Annual Reviews, Inc., 1986), vol. 11, p. 109.

[17] U.S. Department of Energy, Energy Information Administration, *Residential Energy Consumption Survey: Trends in Consumption and Expenditures, 1978-1984,* DOE/EIA-0482 (Washington, DC: June 1987), p. 118. See also P. McDevitt and R. Peterson, ''Residential Energy Conservation: An Investigation of the Post Tax Credit Era in the U.S., " ***Journal*** *of Public Policy & Marketing,* vol. 4, 1985, p. 45.

[18] U.S. Department of Energy, Energy Information Administration, *An Economic Evaluation of Energy Conservation and Renewable Energy Tax Credits,* DOE/NBM—6000728 **(Washington,** DC: October 1985), Service Report, p. v.

- The principal residence requirement under the ETA prevented landlords (and those owning two or more homes) from using the credits. If landlords had been able to use the conservation credits, a larger portion of the sizable rental market, which comprised from 26 to 31 million units between 1978 and 1984,[19] probably would have received retrofits.
- Other economic changes (notably the rise **in** household energy costs and the drop in personal income) during the late 1970s and early 1980s were probably more significant inducements to perform retrofits than were the energy tax credits. A change in energy prices, depending on the relative level, may exert a stronger influence on conservation investments than tax credits.
- The lag time between financing retrofits and enjoying the tax credits (from several months to a year or more) probably diminished the value of the credits as a financial incentive for many consumers. This issue was not addressed in the 1984 RECS, but the more distant the enjoyment of financial incentives, the less likely that consumers will pursue them.

Therefore, U.S. experience with residential energy conservation tax credits reveals uncertainty about their merits as financial incentives. Although nearly 30 million credit claims were made, their ultimate economic benefits have not been reliably determined. Greater efforts to target low-income groups and renters, to encourage the adoption of cost-effective measures, to advertise the program and, perhaps, to increase the allowable credit limits could have increased participation in the program and maybe improved its benefit-cost ratio, which is still undetermined.

Weatherization Grants

The Federal Government currently offers two major weatherization assistance programs for low-income households.[20] Based on historical budget allocations, low-income weatherization is the major focus of Federal efforts to conserve energy in U.S. buildings. The combined budgets of these two programs have consistently been higher (about $330 million in 1991) than any other Federal program aimed at energy conservation in buildings. (For example, the 1991 DOE buildings conservation research and development (R&D) budget was about $43 million.) The DOE Weatherization Assistance Program (WAP), the older of the two, is authorized under Title IV of the Energy Conservation and Production Act (Public Law 94-385), as amended.

The WAP funds weatherization measures for low-income households to reduce their energy use. The other program, the Low-Income Home Energy Assistance Program (LIHEAP) authorized under Title XXVI of Low-Income Home Energy Assistance Act (Public Law 97-35) as amended, primarily subsidizes energy bills for low-income households. However, States may use 15 percent of their LIHEAP funds for low-income weatherization (up to 25 percent with an approved waiver application).

The weatherization components of these programs are intended to reduce residential energy costs for low-income families, which typically spend larger fractions of their incomes on energy relative to higher income households. For example, families earning less than $5,000 per year spend on average 25 percent of their household income on energy, while higher income families (earning $15,000 or more) spend 5 percent or less of their income on energy.[21] And families earning less than $5,000 Per year consume on average 68 percent more energy to heat a square foot of living space than those earning $15,000 or more.[22] Low-income residences are often older and in greater disrepair than those of higher income groups. According to DOE, energy savings of 25 percent or more are possible for a substantial number of low-income homes eligible for Federal weatherization monies .[23]

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[19] U.S. Department of Energy, Energy Information Administration, *Residential Energy Consumption Survey: Trends in Consumption and Expenditures, 1978-1984,* DOE/EIA-0482 (Washington, DC: June 1987), p. 118.

[20] In this context, weatherization refers t. measures designed to save heating and cooling energy by shell, equipment, and behavioral changes applied to existing homes.

[21] U.S. Department of Energy, Energy Information Administration, Household *Energy Consumption and Expenditures 1987, Part 1: National Data,* DOE/EIA-0321/1(87) (Washington, DC: October 1989), p. 50.

[22] Based on natural gas heating expenditures and adjusted for climate. This difference across the income groups is somewhat smaller for electrically heated households (about 52 percent). These OTA calculations are based on data in ibid., pp. 101, 104.

[23] U.S. Department of Energy, Office of the Assistant Secretary for Conservation and Renewable Energy, ‘‘Report on the Present Weatherization Grant Program,” prepared for the U.S. Senate, Committee on Appropriations, Aug. 29, 1989, pp. v, 35.

The other major Federal weatherization grant program in operation is the Institutional Conservation Program (ICP). This program provides match monies to nonprofit schools and hospitals for energy audits and retrofits and is discussed after the low-income programs,

Weatherization Assistance Program--Administered by the Weatherization Assistance Program (WAP) Division, which is within the Office of Technical and Financial Assistance (formerly the Office of State and Local Assistance Programs) at DOE, WAP funds energy conservation measures for low-income households at no charge to the residents. With its creation by the Energy Conservation and Production Act (ECPA) in 1976, WAP supplemented an existing Federal weatherization program overseen by the Community Services Administration (CSA). The CSA authorized its local grantees in 1974 to assist low-income households burdened with rapidly rising fuel prices caused by the Arab oil embargo of 1973. The CSA program was the first of its kind but was eliminated in 1981, leaving WAP as the sole Federal program designed exclusively to weatherize low-income households.[24]

State requirements vary, but households with incomes less than 150 percent of the Federal poverty line, incomes less than 60 percent of their State's median income level, or receiving welfare are generally eligible for WAP funds. State expenditures were limited to an average of $1,600 per household, which includes apartments, but recent legislation allows that amount to adjust annually with inflation or by 3 percent, whichever is smaller,[25] These funds are available for materials and labor (installation and related repairs), and priority is given to households having elderly or handicapped residents.

Until recently, at least 40 percent of WAP funds were required to cover materials costs, but recent legislation allows States to bypass this requirement if they apply energy audits to client households to determine optimal retrofit needs and if they establish weatherization criteria that ensure cost-effective retrofits-not merely energy saving ones.[26] No more than 10 percent of WAP monies may be used for administrative costs.[27]

As with the former CSA program, a WAP priority is to use nonprofit, nongovernmental community action programs (CAPS) to manage weatherization services locally. Local agencies, whether CAPS or others, install the conservation measures for participating households. Roughly 1,200 such groups participate in WAP, with average staff sizes of only 5 to 10 people.[28] As a result, the program is highly decentralized, and most major efforts-client selection, weatherization installation, and financing-are provided by these generally small, local groups.

The WAP has changed considerably in its 15-year history. Initially, 90 percent of grant funds were restricted to materials costs; all labor was provided by trainees working under the Comprehensive Employment and Training Act (CETA); priority was given to households with elderly or handicapped residents; and rental units could be weatherized if the resultant benefits accrued mostly to tenants rather than their landlords. (ECPA disallowed landlords to raise rents on the basis of weatherization improvements.[29]) Subsequent statutory and rules changes, however, have altered the program.

In recent years, DOE regulations have allowed WAP to fund furnace repairs and adjustments, raised the program eligibility limit twice (currently at 150 percent of the poverty level, up from 100 percent in 1979), granted States additional discretion to admin-

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[24] J. Schelegel, J. McBride, S. Thomas, and P. Berkowitz, "The State-of-the-Art of Low-Income Weatherization: Past, Present, and Future," *Proceedings of the ACEEE 1990 Summer Study on Energy Efficiency in Buildings* (Washington, DC: American Council for an Energy-Efficient Economy, 1990), vol. 7, p. 7.206.

[25] State Energy Efficiency Programs Improvement Act of 1990, Public Law 101-440, 104 Stat. 1013, sec. 7(e)(2).

[26] Ibid., sec. 7(d)(3).

[27] This requirement was identified as a major program impediment in a national survey of local programs. See M. Schweitzer, ' 'Energy Conservation for Low-Income Households: A Study of the Organization and Outcomes of Weatherization Assistance Programs, " *Energy Systems and Policy, vol. 12, No. 2, 1988,* p. 111. However, recent legislation partially corrects this problem, because agencies receiving less than $350,000 per year may use an additional 5 percent for administrative costs. See State Energy Efficiency Programs Improvement Act of 1990, Public Law 101-440, 104 stat. 1013, sec. 7(d)(2).

[28] Ibid., pp. 102, 105.

[29] J. Schelegel, J. McBride, S. Thomas, and P. Berkowitz, ''The State-of-the-Art of Low-Income Weatherization: Past, Present, and Future, " *Proceedings of the ACEEE 1990 Summer Study on Energy Efficiency in Buildings* (Washington, DC: American Council for an Energy-Efficient Economy, 1990), vol. 7, p. 7.206.

ister their WAP programs, established a maximum *average* spending cap of $1,600 per household, and provided the option to spend as little as 40 percent of program costs on materials.[30] The minimum materials costs were lowered in response to growing evidence that more emphasis on labor, especially for related repairs, could result in important energy savings.[31] In addition, household cooling efficiency retrofits are now eligible for WAP funds.[32]

The only national WAP evaluation was completed in 1984 and represented program results through 1981. The study determined that average annual household energy savings were roughly 10 percent.[33] The numerous statutory and rule changes to the program since 1981, however, render this early national assessment of the program obsolete. Although DOE recently initiated the second national evaluation of the program, the final report will not be available until the end of 1993.[34]

Until the second national evaluation is finished, it is encouraging to consider that WAP has evolved from a largely volunteer, inexperienced labor force (under CETA) into a skilled force using more sophisticated diagnostic technologies in weatherization assessments. Moreover, the goal of achieving cost-effective energy savings has become increasingly common in State and local planning. Seemingly obvious in retrospect, the notion of cost-effective weatherization—that is, funding retrofit options for which the energy savings, discounted appropriately, exceed the initial investment-is not required by the legislation that authorizes WAP. That now obvious oversight is being addressed somewhat on the State and local levels, but no Federal legislation has yet required all WAP projects to be cost-effective.

OTA has identified several major issues for Congress to consider regarding WAP.

- Though WAP pursues a variety of goals in selecting clients for weatherization (e.g., targeting the handicapped and the elderly), stressing or even requiring cost-effective weatherization (with paybacks generally ranging, for example, no longer than 5 to 8 years) would better ensure that program monies are spent more carefully.
- The State allotment scheme for the disbursement of Federal WAP funds could be reassessed. Federal regulations require DOE to determine State WAP allotments based on several criteria: climate, the relative number of low-income households, and the share of residential energy consumption for each State. This WAP disbursement scheme, however, has apparently allowed colder States to receive a higher proportion of WAP funds than other States with relatively larger low-income populations or relatively greater low-income energy expenditures. One proposed alternative is to adjust WAP funding according to the size of a State's low-income population and on the State's household energy expenditures. This, apparently, would result in a different flow of WAP funds to the States.[35] Recent legislation requires DOE to update annually the data used to determine WAP allotments but does not direct the agency to revise its scheme accordingly.[36]
- Delays (both State and Federal) in reimbursing local weatherization programs have been identified as a major impediment to WAP success, affecting long-range planning, sol-

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[30] Ibid,

[31] Ibid.

[32] These include replacement air conditioners, ventilation equipment, window films, and shading devices. See State Energy Efficiency Programs Improvement Act of 1990, Public Law 101-440, 104 Stat. 1012, sec. 7(a).

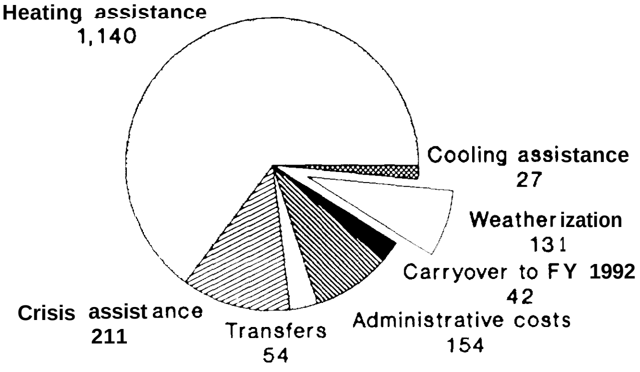
[33] G.E. Peabody, U.S. Department of Energy, Energy Information Administration *Weatherization Program Evaluation* SR-EEUD-84-1 (Washington DC: August 1984), Service Report, pp. 1, 18.

[34] D.A. Beschen and M.A. Brown, U.S. Department of Energy, ''Evaluation Plan for the Weatherization Assistance program,' October 1990, figure A-1 .

[35] The LIHEAP has a different allocation scheme that partially corrects this same problem. In particular, the second of two allocation formulas used in LIHEAP resolves this presumed inequity. The selection of a formula in a given year depends on the amount of appropriations in that year. When appropriations are below $1.975 billion, which has been the case for several years, the first formula is applied. That formula favors colder States, because it stresses climate and total State heating costs, When appropriations exceed $1,975 billion, though, the second formula is used, which bases State LIHEAP allocations according to each State's actual share of heating costs for low-income households—not the climate nor the total State heating costs. See M.F. Smith and J. Richardson, U.S. Library of Congress, Congressional Research Service, '' Weatherization Assistance Programs of the Departments of Energy and Health and Human Services, 90-285 EPW, June 1990, p. 7.

[36] State Energy Efficiency Programs Improvement Act of 1990, Public Law 101-440, 104 Stat. 1013, sec. 7(c)(2).

Figure 4-1—Use of Funds in the Low-Income Home Energy Assistance Program, Fiscal Year 1991 (in millions of current dollars)



SOURCE: Unpublished data from U.S. Department of Health and Human Services, Office of Energy Assistance, July 1991. These 1991 data are based on estimates from a 1991 LIHEAP telephone survey.

vency, and local performance. A recent review of local performance indicated that the average time to reimburse local agencies was roughly 30 days. About 25 percent of the agencies participating in the same review, however, had to wait an average of at least 38 days or longer to receive funds for performed work,[37]

Resolving these critical WAP issues is likely to improve the timeliness, quality, and cost-effectiveness of the program. Regarding timeliness, combined WAP/LIHEAP weatherization efforts reach about 250,000 households annually, which suggests that reaching the 15 to 18 million households that have not yet participated in the program (by DOE estimates)[38] would require an additional 60 to 70 years. Addressing the issues discussed above, leveraging more State and utility resources for low-income weatherization and, perhaps, allowing a greater percentage of LIHEAP funds to apply to low-income weatherization could substantially shorten this projected period.

Low-Income Home Energy Assistance Program—Since 1982, the WAP has been supplemented by the Low-Income Home Energy Assistance Program, which is administered by the Department of Health and Human Services (HHS). The LIHEAP is an outgrowth of Crisis Intervention, a program initiated in 1974 under the auspices of the now defunct Community Services Administration low-income energy assistance program.[39] Enacted by Title XXVI of the Low-Income Home Energy Assistance Act of 1981 (Public Law 97-35), LIHEAP disburses funds to States to assist with heating and cooling bills for their eligible low-income households.

At their discretion, States may use up to 15 percent of their LIHEAP funds for low-income weatherization; with HHS approval, that maximum can increase to 25 percent. The uses of LIHEAP funds in 1991 are given in figure 4-1. In recent years, WAP and LIHEAP together have weatherized more than 250,000 households a year at a Federal cost of about $300 million annually.[40]

As figure 4-2 illustrates, States expend on average between 7 and 10 percent of their LIHEAP funds on weatherization. If more LIHEAP funds were directed to weatherization, the need to assist many low-income households with their energy bills in outlying years could diminish, but then the Federal Government may not be able to reach as many households in a given year. For example, LIHEAP heating assistance payments have averaged around $200 per household,[41] far less than the average amount allowed for weatherization in WAP (about $1,600 per household). By this simple comparison, directing all current LIHEAP monies to weatheriza-

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[37] M. Schweitzer, "Energy Conservation for Low-Income Households: A Study of the Organization and Outcomes of Weatherization Assistance Programs, ' *Energy Systems* and *Policy, vol.* 12, No. 2, 1988, p. 110. This source indicated that most States further restrict local agency administrative expenses to about 5 percent.

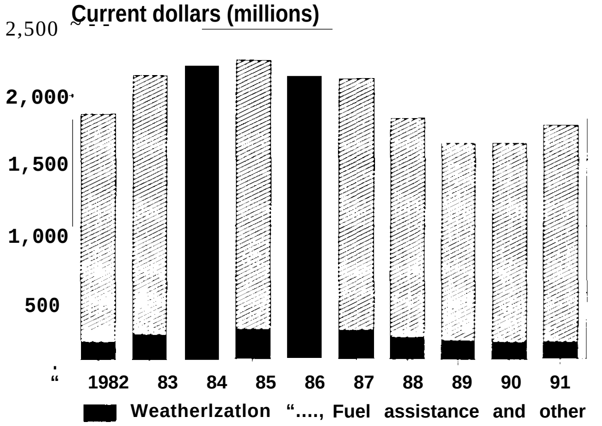
[38] U.S. Department of Energy, office of the Assistant Secretary for Conservation and Renewable Energy, "Report on The Present Weatherization Grant Program, ' prepared for the U.S. Senate, Committee on Appropriations, Aug. 29, 1989, p. 41. These estimates of nonparticipating households do not exclude those previously weatherized in separate State and utility programs. The actual number of nonparticipants, therefore, is overstated to some degree.

[39] J. Schlegel, J. McBride, S. Thomas, and P. Berkowitz, ' 'The State-of-the-Art of Low-Income Weatherization: Past, Present, and Future," *Proceedings of the ACEEE 1990 Summer Study on Energy Efficiency in Buildings* (Washington, DC: American Council for an Energy-Efficient Economy, 1990), vol. 7, pp. 7.206-7.207.

[40] M.F. Smith and J. Richardson, U.S. Library of *Congress,* Congressional Research Service, "Weatherization Assistance Programs of the Departments of Energy and Health and Human Services, ' 90-285 EPW, June 1990, p. 4.

[41] Unpublished data provided by U.S. Department of Health and Human Services, Office of Energy Assistance, to OTA, July 31, 1991.

Figure 4-2--Weatherization Funding in the Low-Income Home Energy Assistance Program, Fiscal Years 1982-91



SOURCE: Unpublished data from U.S. Department of Health and Human Services, Office of Energy Assistance, July 1991, The 1991 data are based on estimates from a 1991 LIHEAP telephone survey, and the remaining data are historical.

tion would reduce the number of households serviced annually by a factor of about eight, but placing greater emphasis on weatherization could reduce the ultimate energy requirements of eligible households over time.

Although LIHEAP is principally an energy assistance program, there are several important issues worth considering about its weatherization efforts:

- The cost-effectiveness of weatherization measures funded by LIHEAP is not being assessed, nor are there clear program policies or measures that encourage cost-effective weatherization.
- Federal requirements or policies to leverage LIHEAP weatherization monies with State and utility resources are appropriate to consider. The private U.S. utility industry benefits secondarily but substantially from Federal LIHEAP outlays, because these funds are used to assist low-income households that might not otherwise pay their energy bills as quickly or at all. By providing energy assistance, LIHEAP offsets utility arrearages from delayed or missed payments by low-income households. (Utility arrearages from delayed residential payments amount to hundreds of millions of dollar-s annually.)42 As a result, Congress could determine whether private utilities should provide greater assistance to a Federal effort from which these firms benefit.

Institutional Conservation Program—The ICP is a Federal institutional grant program administered by States through DOE regional offices. Since 1980, ICP grants have funded energy audits and the application of energy conservation measures to over 20,000 schools (primary and secondary), colleges, universities, and hospitals.[43] The program is designed to assist the financing of energy audits and retrofits in the nonprofit institutional sector, where resources are generally limited.

Until 1990, ICP eligibility was limited to nonprofit institutional buildings constructed before April 20, 1977. Recent legislation, however, shifted the eligibility to such buildings constructed before May 1, 1989.[44] By 1988, ICP spending totaled almost $1.4 billion and resulted in an estimated cumulative energy savings of 0.3 quads (317 trillion Btus) worth an estimated $1.9 billion.[45] This spending figure includes both DOE grant outlays and the matching funds required of participating institutions. By this measure alone, the ICP has exceeded its break-even payback costs by $500 million.[ti]

There are two kinds of ICP grants. Technical analysis (TA) grants fund energy audits to determine appropriate energy conservation measures (ECMS) for participating institutions. ECM grants fired the design, acquisition, and installation of energy conservation measures for participating institutions. Except in cases of demonstrated hardship, ICP grants are limited to 50 percent of participant costs. Where hardship has been demonstrated, ICP will fund up to 90 percent of the TA or ECM. By the end of 1987, ECM grants resulted in an average

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[42] P. Rodgers, M. Foley, and R. Tucker, *Survey of Electric and Natural Gas Utility Uncollectable Accounts and* Service Disconnections *for 1984* (.Washington, DC: National Association of Regulatory Utility Commissioners, October 1985), pp. 41-48.

[43] N.E. Collins, R.C. Kammerud, and P.H. Kier, *Energy Conservation* in *Hospitals, Colleges and Universities, and Public* School Districts: Results *of a National Evacuation* (Argonne, IL: Argonne National"Laboratory, May 1988), p. 30.

[44] State Energy Efficienc, Programs Improvement Act of 1990, Public Law 101-44O, 104 Stat. 1011, sec. 6(b)(l).

[45] U.S. Department of Energy, Office of Conservation and Renewable Energy, *An Estimate of Aggregate* Energy Savings *Due to the ICP program,* DOE/SF/00098-H2 (Washington, DC: March 1988), p. vi. Figures in this section are expressed in 1987 dollars.

[46] ICP-funded measures completed b, 1988 are expected to save an additional $400 million per year over their remaining lifetimes. Ibid., p. 33.

energy savings of 12 percent for participating educational facilities and 8 percent for participating hospitals.[47]

As of 1988, approximately 115,000 schools, colleges, and hospitals comprised the institutional sector. Ninety percent of these institutions were schools, but they accounted for only 35 percent of the total institutional energy use. This suggests that the energy intensity (energy use per square foot of floor space) of schools is far lower than colleges or hospitals.[48] Given the large number but low energy intensity of schools, a separate Federal effort could target colleges and hospitals, because they are relatively less numerous but more energy intensive. As of 1988, however, 80 percent of ICP grants were awarded to schools.[49]

Summary figures confirm the point that ICP program monies are reaching the less energy-intensive buildings eligible for assistance: ICP grants have reached 29 percent of the eligible institutional floor space but that space consumes only 27 percent of the total energy in the eligible portion of the institutional subsector.[50] Nevertheless, paybacks are favorable for all subsectors, averaging 3.6 years. The cost of conserved energy has been estimated at just over $2 per million Btu.[51] If this figure accurately reflects true ICP savings, this program is probably the most cost-effective Federal energy grant program in operation, and the use of energy audits invariably contributes to this success.

Loan Subsidies

Solar Energy and Energy Conservation Bank—The SEECB (or the "Bank") was authorized by the Energy Security Act of 1980 (Public Law 96-294) to subsidize the purchase and installation of conservation and renewable energy measures in households (one to four families), multifamily buildings (more than four families), and nonprofit commercial and agricultural buildings with low- and moderate-income owners and tenants. The goal of the program, which was administered by the Department of Housing and Urban Development (HUD), was to encourage energy conservation and the use of renewable energy sources (solar, wind, and wood) in buildings to reduce national dependence on foreign energy supplies.[52] Although later extended 6 months, the original statutory sunset date for the Bank was September 30, 1987.[53]

Bank monies were disbursed through cooperative agreements executed with States, all of which participated in the program at least 1 year.[54] The original funding authorization for the Bank was unprecedented for a Federal conservation and renewable energy incentive program designed for low-income groups-over $3 billion for fiscal years 1981 through 1984.[55] Before the program was implemented, however, the newly arrived Reagan administration proposed cutting the 1981 Bank budget from $300 million to $250,000, which Congress did.[56] The revised 1981 budget was intended to cover only administrative expenses; funding authorized for 1982 to 1984 reactivated the

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[47] Ibid., p. vi.

[48] In fact, measured in thousands of Btus per square foot per year (kBTU/sq ft/yr), median energy intensities for ICP-eligible buildings are the following: schools 130, colleges 240, and hospitals 420. N.E. Collins, R.C. Kammerud, and P.H. Kier, *Energy Conservation in Hospitals, Colleges and Universities, and Public School Districts: Results of a National Evaluation* (Argonne, IL: Argonne National Laboratory, May 1988), pp. 14-15.

[49] Ibid., p. 43.

[50] Ibid., p. 44.

[51] Ibid., p. 43. For comparison, the average cost of electricity in 1987 (the year represented in the ICP energy savings estimates) for the residential and commercial sectors has been estimated at $21.18 per million Btu and natural gas at $5.12 per million Btu the same year. See U.S. Department of Energy, Energy Information Administration, *Annual Energy Review 1990*, DOE/'EIA-0384(90) (Washington DC: May 1991), p. 69.

[52] Energy Security Act of 1980, Public Law 96-294, 94 Stat. 719, sec. 503.

[53] Energy Security Act of 1980, Public Law 96-294, 94 Stat. 722, sec. 505(a). House Joint Resolution 395 (December 21, 1987) extended SEECB authorization to March 15, 1988. Congress officially withdrew all unspent monies in 1990, although Bank activities had essentially ceased by mid-1988. Public Law 101-507, 104 Stat. 1364.

[54] U S Department of Housing and Urban Development, Solar Energy and Energy Conservation Bank, *Solar Energy and Energy Conservation Bank: FY* 1987 *Annual Report to the Congress* (Washington, DC: 1987), p. 7.

[55] The $3.025 billion originally authorized for the Bank were designated primarily for conservation measures ($2.5 billion for fiscal years 1981 to 1984), with the remainder designated for renewable measures ($525 million for fiscal years 1981 to 1983). Public Law 96-294,94 Stat. 737, sec. 522(a)-(b).

[56] Omnibus Budget Reconciliation Act of 1981, Public Law 97-35. See associated Senate Report (Budget Committee) No. 97-139, June 17, 1981, p. 384,

program, but at substantially reduced levels.[57] By the time the Bank effectively expired in September 1987, program expenditures totaled only $76 million and assisted about 98,000 projects.[58] All administration requests for the Bank budget after 1981 were zero.[59]

The virtual elimination of the Bank budget in 1981 contributed to the delay in program implementation. Interim rules establishing program requirements were not promulgated until May 1983,[60] and final rules were not issued until March 1984.[61] Given the 1987 sunset date, program planners could expect only 3 1/2 years of operation. In fact, Congress enacted no new budget authority for the Bank after 1985; budget authority for fiscal years 1986 and 1987 was zero, although $1.7 million of recaptured 1985 funds were reappropriated for 1988.[62]

Bank funds subsidized loans (either the principal or interest portions) for energy conservation and renewable energy measures installed in newly constructed or existing (pre-1980) buildings; grants for energy conservation measures were also available under the program. Any Bank funds allocated to States but not expended within prescribed periods were recaptured and redistributed; this was intended to encourage the timely use of Bank funds and to prevent States from hoarding program resources. Also, the Energy Security Act prevented Bank participants from claiming energy conservation or renewable energy credits available under the Energy Tax Act (Public Law 95-618).[63]

The Energy Security Act directed the Bank to decrease assistance with increasing income according to enacted guidelines to ensure that the lowest income groups would receive the greatest assistance.[64] As a result, by the end of 1987, 65 percent of program funds had been disbursed to the lowest income group defined in the statute. In 1987, the last year of major program activity, average loan subsidies were $1,053 and average matching grants were $720.[65] Ninety percent of total program funds were allocated to conservation measures.[66]

The Energy Security Act directed HUD to analyze annually the cost-effectiveness of the Bank program, by comparing total expenditures against total energy savings,[67] but the statute did not impose limits on program assistance according to any measure of cost-effectiveness. Nonetheless, HUD proposed in the 1983 interim rule that energy conservation and passive solar measures should achieve a 7-year simple payback, as determined by an energy audit, to receive Bank assistance.[68] Although this payback test was based on DOE guidance issued for the Residential Conservation Service (RCS), there were objections to the HUD proposal, and later that year Congress prohibited any limits on Bank assistance that were based on projected energy savings.[69]

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[57] The Omnibus Budget Reconciliation Act of 1981 (Public Law 97-35) sec. 1071 reduced the Bank budget to $150 million for fiscal years 1982 to 1984. Subsequent legislation reduced this funding even further, to $135 million. Public Law 98-181, 97 Stat. 1235, sec. 463(f)(l).

[58] U.S. Department of Housing and Urban Development, Solar Energy and Energy Conservation Bank, *Solar Energy and Energy Conservation Bunk: FY 1987 Annual Report to the Congress* (Washington, DC: 1987), p. 2.

[59] Walter Preysnar, U.S. Department of Housing and Urban Development, former Program Director, SEECB, personal communication, Nov. 25, 1991.

[60] 48 *Federal Register 24254* (May 31, 1983).

[61] 49 Federal *Register 9865* (Mar. 16, 1984).

[62] U.S. Department of Housing and Urban Development, Solar Energy and Energy Conservation Bank, Solar Energy *and Energy Conservation Bank: FY 1987 Annual Report to the Congress* (Washington, DC: 1987), p. 12.

[63] Public Law 96-294, 94 Stat. 723, sec. 506(f). The residential credits under the Energy Tax Act were available for tax years 1978 to 1985. In addition, the Energy Security Act prevented Bank assistance from being counted as income for any individual participating in the program. Public Law 96-294, 94 Stat. 726, sec. 509(c).

[64] Public Law 96-294, 94 Stat. 726-729, sec. 511-512 For example, owners or tenants of single family residences earning less than 80 percent Of their median area income (MAI), the lowest income group in the program, were eligible for $1,250 of assistance, while those earning between 80 and 100 percent of their MAI, the second lowest income group, were eligible for only $875 of assistance. See 48 *Federal Register 24265 (May 31, 1983).*

[65] U.S. Department of Housing and Urban Development, Solar Energy and Energy Conservation Bank, *Solar Energy and Energy Conservation Bank: FY 1987 Annual Report to the Congress* (Washington, DC: 1987), p. 4.

[66] Ibid., p. 9.

[67] Public Law 96-294, 94 Stat. 736, sec. 519(a)(3).

[68] 48 *Federal* Register 24262, 24265 (May 31, 1983).

[69] Housing and Urban-Rural Recovery Act of 1983, Public Law 98-181, sec. 463(c)(2). According to the former SEECB program manager, this prohibition was imposed to prevent further delays in program implementation. U.S. Department of Housing and Urban Development, former Program Director, SEECB, personal communication, Nov. 25, 1991.

Despite HUD objections to this prohibition,[70] the Bank appears to have conducted an extremely cost-effective program. According to HUD estimates, SEECB conservation investments made in 1987 achieved average simple paybacks of 4.4 years.[71] As with RCS, however, these estimates were based on State reports that summarized audit estimates of energy savings potential; no Federal effort was made to test the reliability of these estimates or the actual effect of the retrofits by using fuel use data, surveys, or other methods.[72]

The implementation lessons applicable to the Bank and worthy of attention by Congress are the following:

- Encouraging or requiring energy audits prior to the disbursement of Federal funds for building retrofits may be appropriate. Energy audits inform consumers about economical retrofit options, which will encourage them to spend their (and Federal) monies as effectively as possible. Of course, performing audits requires resources that could be used for retrofits, but audit costs are relatively minor compared to major retrofits, and they can indicate the most cost-effective retrofit opportunities.
- The use of mandatory cost-effectiveness requirements for Federally subsidized residential retrofit assistance has not been tested. The Bank was never able to test this option, but it is likely that such Federal requirements would improve the cost-effectiveness of residential retrofit programs.

Federal Leadership

Providing Public Recognition for Voluntary Energy Savings

Green Lights Program-Green Lights is a voluntary, cooperative corporate program formally initiated by the Environmental Protection Agency (EPA) in January 1991. The program is intended to reduce commercial building energy use by encouraging companies to conduct voluntarily all possible cost-effective lighting retrofits at their U.S. facilities. To participate in the program, companies sign nonbinding agreements to survey lighting at all their U.S. facilities and to perform retrofits in at least 90 percent of their total floor space. Retrofits are required only where they would be cost-effective and where they would not compromise lighting quality. By reducing lighting energy use, the program aims to reduce the air and other pollution associated with extracting and burning fossil fuels for electricity generation.

The Green Lights program operates on the assumption that a variety of highly efficient lighting technologies have been developed but insufficiently implemented in the last decade.[73] To address all of the relevant barriers to energy efficiency, ranging from inadequate information to financing, the Green Lights program consists of several distinct arms.

The first program arm is the Decision Support System designed to assist companies with lighting surveys, the identification of retrofit options, and the final selection of a retrofit option that maximizes energy savings without compromising lighting quality. A separate Green Lights effort, the National Lighting Product Information Program, is designed to provide reliable information about lighting technologies and options to interested companies that may question product claims or potential employee response to lighting changes. Beyond such information about technical performance, the Green Lights program also offers a support project to inform participants about retrofit financing options, including assistance offered by utilities, government, energy service companies, and other more conventional lending institutions such as banks.

The Green Lights program distinguishes several participant groups: corporate partners, manufacturer allies, electric utility allies, and lighting management company allies. To join the program, each group must sign a nonbinding memorandum of understanding with EPA that describes the responsibilities of EPA and the participant. As of December

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[70] "In the opinion of the Bank . . .the new legislation [Public Law 98-181] has impaired the Bank's ability to focus appropriately on the most cost-effective expenditures. ' 49 *Federal Register 9867* (Mar. 16, 1984).

[71] U.S. Department of Housing and Urban Development, Solar Energy and Energy Conservation Bank, *Solar Energy and Energy Conservation Bank: FY 1987 Annual Report to the Congress* (Washington, DC: 1987), pp. 3, 6.

[72] Walter Preysnar U.S. Department of Housing and Urban Development, former Program Director, SEECB, personal communication, Nov. 25, 1991.

[73] See EPA pamphlet, "Green Lights: A Bright Investment in the Environment, " July 1991.

1991, roughly 150 companies had enrolled in the program.

Although few actual measured energy savings data are available at present, the Green Lights offers an innovative approach to saving energy in the private sector that is worth duplicating, because it stresses cooperation, public recognition, cost-effective energy savings, and voluntary participation.

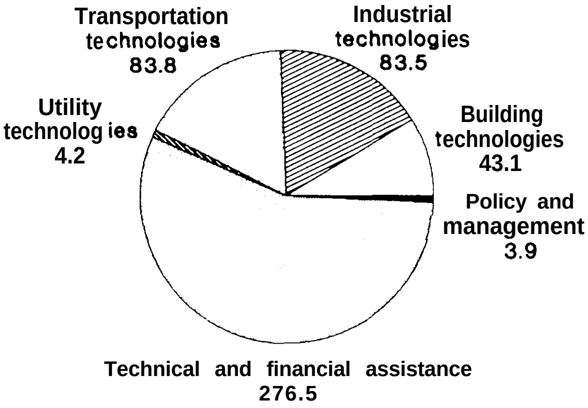
Research, Development, and Demonstration Programs

This section reviews the budgets and several major accomplishments of the DOE energy conservation research and development (R&D) program for buildings. This DOE program is administered by the Deputy Assistant Secretary for the Office of Building Technologies, who is under the Assistant Secretary for Conservation and Renewable Energy. The other Conservation and Renewable Energy offices at the level of Deputy Assistant Secretary are Industrial Technologies, Transportation Technologies, Utility Technologies, and the Office of Technical and Financial Assistance. This organizational scheme was adopted in April 1990 to consolidate better the office's efforts by end-use sector. The fiscal year 1991 Office of Conservation and Renewable Energy budgets by office are shown in figure 4-3.

With few exceptions, the most successful DOE conservation R&D projects related to buildings were initiated, and some completed, before the Department's conservation budget was severely cut in the early 1980s (box 4-D). Solid-state fluorescent light ballasts, for example, were developed through DOE-funded work between 1976 and 1980, accounting for a total Federal R&D investment of about $3 million. These efficient ballasts represent a 20 to 25 percent energy efficiency improvement over conventional magnetic ballasts, and their use is expected to save billions of dollars in lighting energy costs over the next several decades.[74]

However, not all conservation R&D funding results in major successes nor should this be expected. One goal of conservation R&D is to explore the potential for improving the efficiency of energy use; much of that exploration requires trial and error. Indeed, even when technology is improved in the laboratory, high costs, inadequate marketing, or poor consumer response often limit or prevent its adoption. For example, commercially available heat pump water heaters consume about one-half the energy used by conventional electric resistance water heaters, but high first costs have slowed their market penetration.[75]

Figure 4-3--U.S. Department of Energy Conservation Research and Development Budget by End-use Sector, Fiscal Year 1991 (in millions of current dollars)



SOURCE: U.S. Department of Energy, *United States Department of Energy Fiscal Year 1992 Congressional Budget Request*, DOE/CR-0001 (Washington, DC: February 1991), vol. 4, p. 273.

The low penetration of several important energy efficient technologies indicates that Federal research cannot be limited strictly to technical improvements—there should be a commensurate Federal effort to demonstrate and market these technologies once they are developed. Such marketing requires ongoing evaluations of consumer, builder, and manufacturer preferences, as well as a detailed understanding of the barriers that prevent the wider adoption of these technologies. To assist the marketing effort, there could be more aggressive implementation of newer, efficient technologies in the building retrofit programs administered by DOE.

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[74] H. Geller, J.P. Harris, M.D. Levine, and A.H. Rosenfeld, "The Role of Federal Research and Development in Advancing Energy Efficiency: A $50 Billion Contribution [o the US Economy," *Annual Review of Energy* 1987 (Palo Alto, CA: Annual Reviews, Inc., 1987), vol. 12, pp. 381-382.

[75] M.A. Brown, L.G. Berry, and R.K. Goel, *Commercializing Government-Sponsored Innovations: Twelve Successful Buildings Case Studies*, ORNL/CON-275 *(Oak* Ridge, TN: Oak Ridge National Laboratory, January 1989), pp. 70-81.

Box 4-D—DOE Conservation Research and Development for Buildings: Four Successful Projects

A variety of energy conservation technologies associated with buildings has emerged from DOE-funded R&D projects. Many of the most important successes resulted from work initiated prior to the drastic cuts in the DOE conservation R&D budget that occurred in fiscal year 1982. A brief history of the development of four of these DOE-sponsored technology projects is given below: high-efficiency refrigerator compressors, high-efficiency refrigerator-freezers, solid-state fluorescent ballasts, and low-emissivity window coatings. This history is a limited but useful indication of the Federal R&D contribution to advancing building energy conservation.

High-efficiency refrigerator compressor—Using DOE funds, the Oak Ridge National Laboratory (ORNL) funded the development of a prototype high-efficiency refrigerator compressor from 1977 to 1981. This work was conducted by the Kelvinator Co., a major appliance manufacturer. Refrigerators and freezers account for about 10 percent of primary energy use in the residential sector, and compressors use between 70 and 85 percent of that energy. Through design changes in the refrigerator motor and suction muffler, Kelvinator achieved an improvement in compressor efficiency of 44 percent. By one estimate, this improvement will save $1,1 billion in consumer energy costs annually by 2005. According to the same source, DOE involvement in this project hastened commercialization by 2 years.[1]

High efficiency refrigerator-freezer—From 1977 to 1983, ORNL funded a project conducted by Amana Refrigeration, Inc. in cooperation with Arthur D. Little, Inc. to improve overall refrigerator-freezer efficiency. Six design changes were selected for the prototype model, including thicker cabinet insulation, relocation of the fan motor outside the freezer, improved door gaskets, and separate evaporators for the freezing and refrigerating sections. The resulting energy savings were 60 Percent.[2]

Although these refrigerators were not widely marketed, the success of this research contributed to the development of the 1990 and 1993 refrigerator standards under the National Appliance Energy Conservation Act (Public Law 100-12). In brief, the successful design changes in the prototype model compelled DOE to consider them in its refrigerator efficiency rulemaking under the National Energy Conservation Policy Act (Public Law 95-619; NECPA) in the early 1980s. Although the Department never promulgated real legally binding standards under NECPA, the California Energy Commission (CEC) set its 1992 refrigerator standard based on the DOE analysis behind this NECPA effort, which indicated the feasibility and cost-effectiveness of adopting the technologies incorporated in the DOE prototype. Subsequently, the 1992 CEC standard was used to develop the 1990 and 1993 NAECA refrigerator standards. Thus, DOE-funded research was instrumental in demonstrating technologies that were eventually used to guide the development of Federal appliance efficiency standards.[3]

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[1] H. Geller, J.P. Harris, M.D. Levine, and A.H. Rosenfeld, "The Role of Federal Research and Development in Advancing Energy Efficiency: A $50 Billion Contribution to the US Economy," *Annual Review of Energy 1987* (Palo Alto, CA: Annual Reviews, Inc., 1987), vol. 12, pp. 360-361, 391,

[2] Ibid., p. 391.

[3] David B. Goldstein, Natural Resources Defense Council, written communication to OTA, Oct. 11, 1991.

(Continued on next page)

Despite major successes in building and other energy technology R&D in the late 1970s and early 1980s, the DOE conservation R&D budget was severely cut in the 1980s (figure 4-4). These cuts stemmed from a major Federal R&D policy change introduced by the Reagan administration, which advocated a shift toward private sector funded R&D. As a result, DOE conservation R&D budget requests were lower than the actual budgets authorized by Congress from fiscal years 1983 through 1990. In fiscal year 1983, the administration's conservation R&D budget request for buildings, industrial, and transportation activities was zero.[76] Congress continued funding these conservation programs but at levels far below the 1979 to 1981 fiscal years.

The sharpest drop in the overall DOE conservation R&D budget was experienced in fiscal year

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[76] U.S. Congress, General Accounting Office, *Energy R&D: DOE's Allocation of Funds for Basic and Applied Research and Development*, GAO/RCED-90-148BR (Gaithersburg, MD: May 1990), p. 24.

Box 4-D—DOE Conservation Research and Development for Buildings: Four Successful Projects-Continued

Solid-state fluorescent ballast-In 1977, researchers at Lawrence Berkeley Laboratory (LBL), another DOE-funded national energy lab, began work on solid-state fluorescent ballasts, a technology that had promising theoretical potential at the time but had not yet been developed. With DOE funding, LBL began working with two small contractors to develop these ballasts; none of the major ballast manufacturers decided to participate in this effort. DOE was involved in this effort until 1980, shortly after the efficacy of the new ballasts was demonstrated in several test projects, including one at a Veterans Administration medical facility in Long Beach, California. These ballasts allow about a 25 percent reduction in fluorescent lighting energy use without losses in illumination. By one estimate, DOE involvement hastened commercialization of this technology by 5 years.[4] At present, solid-state ballasts are installed only in 3 percent of fluorescent fixtures in the United States.[5] However, their penetration in the new ballast market reached 10 percent in the first 6 months of 1991,[6] and future sales are projected to increase.[7]

Low-E **window** coating--Low-emissivity (low-e) coatings are designed to reduce heat loss or gain through windows. Similar to other DOE projects begun in the late 1970s and early 1980s, initial industry interest in researching and developing this technology was low. Windows account for significant heat transfers in buildings; as noted in chapter 2, the R-value (or resistance to heat transfer) of atypical wall in the United States is 15, whereas a single-pane window has an R-value of just 1. Low-e coatings increase window R-values. As noted in chapter 2, low-e double-pane windows presently on the market have R-values ranging from 2.5 to 3.2, an improvement over the uncoated double-pane R-value of 2. As with solid-state ballasts, DOE funded this project through LBL. The initial DOE interest and financial backing in the low-e project contributed to its early progress, which prompted window manufacturers to invest $150 million of their own funds in this effort by the mid-1980s. Commercialization of the first low-e window coatings, despite a few early setbacks, occurred in 1983, an estimated 5 years sooner than it would have without DOE support.[8] Today, large window manufacturers offer low-e glass as an option for almost all of their products.[9]

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[4] H. Geller, J.P. Harris, M.D. Levine, and A.H. Rosenfeld, "The Role of Federal Research and Development in Advancing Energy Efficiency: A $50 Billion Contribution to the US Economy," *Annual Review of Energy 1987 (Palo* Alto, CA: Annual Reviews, Inc., 1987), vol. 12, pp. 360,379-383.

[5] U.S. Department of Energy, Office of Conservation and Renewable Energy, *A Compendium of Energy Conservation Success Stories 90, DOIZKH1OO93-83* (Washington, *DC: December* 1990), p. 19.

[6] Figure refers t. sales for the first two quarters of 1991. U.S. Department of Commerce, Bureau of the Census, *Current Industrial Reports: Fluorescent Lamp Ballasts, Second* Quarter 1991 (Washington, DC: September 1991), p. 1.

[7] Arthur D. Little, Inc., *Supply and Demand of Compact Fluorescent Lamps and Electronic Ballasts* (Cambridge, MA: January 1991), p. 17.

[8] H. Geller, J.P. Harris, M.D. Levine, and A.H. Rosenfeld, "The Role of Federal Research and Development in Advancing Energy Efficiency: A $50 Billion Contribution to the US Economy," *Annual Review of Energy 1987 (Palo Alto,* CA: Annual Reviews, Inc., 1987), vol. 12, pp. 360,383-390.

[9] J. Trombly, "Window Company Standardizes Low-E Glass," *Home Energy,* May/June 1990, pp. 6-7.

1982, when funding dropped 71 percent from $300.1 million to *$87.2* million (current dollars). While the total DOE conservation R&D budget has been increasing modestly since 1982, the 1991 budget in current dollars was only 62 percent of the 1980 budget. The 1991 DOE buildings conservation R&D budget in current dollars was only 44 percent of the 1980 budget.[77] This is not to suggest that the 1980 funding level was optimal, but it serves as a benchmark for other fiscal years, because it was the largest conservation R&D budget in DOE history.

While funding is critical, the Federal commitment to energy conservation R&D cannot be measured solely by budget size. Other important measures of Federal commitment to energy conservation R&D include the actual division of overall funding between basic and applied research, the mix of R&D

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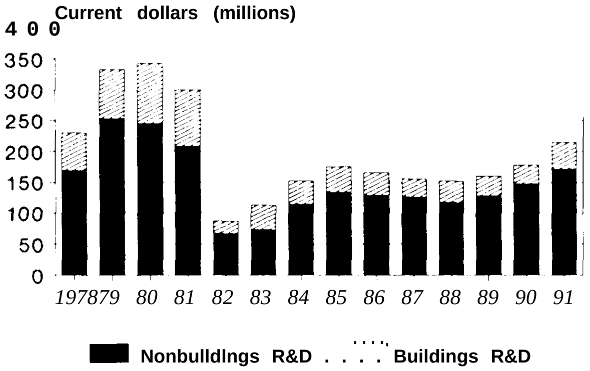
[77] In current dollars, the total DOE conservation R&D budget was $343.7 million in 1980 and $214.7 million in 1991. The DOE building conservation R&D budget in current dollars was $98,3 million in 1980 and $43.1 million in 1991. The 1980-82 data are from F.J. Sissine, U.S. Library of Congress, Congressional Research Service, IB85 130, *Energy Conservation: Technical Efficiency and Program Effectiveness,* CRS Issue Brief, April 1991. The 1991 data are from U.S. Department of Energy, *United States Department of Energy Fiscal Year 1992 Congressional Budget Request,* DOE/CR-0001 (Washington DC: February 1991), vol. 4, p. 273.

Figure 4-4--U.S. Department of Energy Conservation Research and Development Budgets, Buildings Versus Nonbuildings Funding, Fiscal Years 1978-91



SOURCE: Fiscal years 1978 to 1989 from F.J. Sissine, U.S. Library of Congress, Congressional Research Service, *Energy Conservation: Technical Efficiency and Program Effectiveness*, CRS Issue Brief 85130 (Washington, DC: Congressional Research Service, April 1991); fiscal years 1990 and 1991 from U.S. Department of Energy, *United States Department of Energy Fiscal Year 1992 Congressional Budget Request*, DOEfCR-0001 (Washington, DC: February 1991), vol. 4, p, 273.

funding divided between end-use sectors and fuel types, the degree to which technology demonstration and transfer play a role in R&D, and the level of private sector involvement and cost sharing. Thus, simply raising the DOE conservation R&D budget will not by itself ensure program success. At least as important, for example, will be a well-defined R&D plan along with a steady level of funding, at whatever level, particularly if Congress hopes to maximize private sector cooperation in DOE R&D efforts.

Building Codes and Appliance Standards

Building codes are legally binding requirements that apply to structures and their occupancy to ensure public health, safety, and welfare. Although the traditional focus of code efforts has been health and safety (e.g., sanitation and fire protection), energy efficiency has assumed greater prominence in building code development in the last two decades. While codes are adopted and enforced locally, few municipalities develop their own codes; instead, four major organizations develop and publish model building codes for State and local use: the Building Officials & Code Administrators International, the International Conference of Building Officials, the Southern Building Code Congress International, and the Council of American Building Officials, which is a federation of the first three organizations.[78]

Appliance efficiency standards are legally binding requirements designed to ensure minimum efficiency levels in new products. As discussed below, Federal programs in the last 20 years have been involved in building codes and standards, as well as appliance efficiency standards.

Building Codes and Standards

Two Federal agencies, the Departments of Energy and Housing and Urban Development, have been active in the development of model or actual building energy codes and standards. Although the number of buildings constructed annually for Federal Government use is limited, the government directly finances about 27 percent of new home mortgages through the Federal Housing Administration, the Veterans Administration, and the Farmers Home Administration.[79] Eligibility requirements for Federal financing can directly influence building design and construction.

Building Energy Performance Standards (BEPS)—Under authority of the Energy Conservation and Production Act (Public Law 94-385), DOE first issued draft building energy performance standards (BEPS) in 1979 for new commercial and residential buildings. The BEPS compliance approach was highly innovative, and DOE considered it to be a ''radical departure from standard practices of the building community.''[80] Yet BEPS offered no

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[78] National Association of Home Builders, *Understanding Building Codes and Standards in the United States*, rev. ed. (Washington, DC: 1989), pp. 7-8.

[79] This figure represents the portion of total mortgages applying to new, privately owned one-family houses sold in 1990. See U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States: 1991*, 111th ed. (Washington, DC: U.S. Government Printing Office, 1991), p. 721.

[80] 52 *Federal Register* 17053 (May 6, 1987). The most significant aspect of the proposal was the introduction of the ' 'whole building energy budget. ' The standards set a maximum energy consumption level for a type of building in a given climate, In all, DOE approved 21 types of buildings and 78 climate zones; each commercial building type had an assigned energy budget for each climate zone. The proposed standard required the use of computer simulation to demonstrate that a proposed building design met the prescribed energy level. The residential proposal included prescriptive packages, but the standard was unclear about whether compliance with the prescriptive package also met the energy budget requirements.

guidance on how to comply with defined energy budgets. Although the performance approach had been available in the prevailing building standard issued by ASHRAE,[81] builders rarely used it. Given this unfamiliarity with performance criteria, therefore, most of the 1,800 comments DOE received on the initial proposed rule claimed that BEPS was unsuitable for a mandatory building standard. Many comments stressed the difficulty of calculating energy performance formulas and the likely costs of computer analysis necessary to demonstrate compliance.

More than 1,000 comments maintained that the ASHRAE standard would be a preferable substitute.[82] Many States had already adopted the ASHRAE standard, which contained the traditional criteria familiar to the building community. The following year, Congress restricted mandatory building energy standards to the Federal sector, making BEPS voluntary for all other sectors.[83] DOE was also required to project the impact of the standard on construction costs, design, and expected energy savings; the impacts of the residential standards on the ability of low- and moderate-income persons to purchase or rent buildings had to be assessed as well.[84] In addition, Federal building standards were required to meet the life-cycle cost criteria detailed in the Code of Federal Regulations.[85]

DOE has established three separate standards to comply with its revised mandate. The frost, the interim mandatory standards for new Federal residential buildings, was proposed in 1986.[86] The crux of the standard is the Conservation Optimization Standard for Savings in Federal Residences (COSTSAFR) program, a computerized calculation procedure designed to select the most cost-effective measures available for the building on a life-cycle basis. The program assigns values to the measures, allowing builders to decide whether to meet or exceed the energy consumption goal for the building type, A DOE economic analysis of these energy standards concluded that life-cycle cost savings would average about $760 per unit.[87]

The second, voluntary standards for new commercial and multifamily high-rise residential buildings, were published in 1989.[88] DOE planned to publish the third standard, voluntary nonfederal residential guidelines (VOLRES), in June 1991.[89]

Minimum Property Standards—Through a variety of legislation, Congress has directed HUD to issue an energy standard for housing programs within the agency and for manufactured homes. The Federal Government first issued the Minimum Property Standards (MPS) in the 1950s to establish energy criteria for homes using federally financed mortgages.[90] The standard limited the level of household utility expenses and reduced the rate of default on home mortgage loans. The latest MPS is the 1984 version developed by HUD. In November of 1990, HUD issued a proposed rule for adopting an updated energy standard. The rule proposes that ‘all detached one and two family dwellings and one family townhouses not more than three stories in height shall comply with CABO Model Energy Code, 1989 Edition, including 1990 supple-

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[81] ASHRAE is the American Society of Heating, Refrigerating and Air-Conditioning Engineers. ASHRAE standards are commonly used in building design.

[82] 52 *Federal Register 17054* (May 6, 1987).

[83] Housing and Community Development Act of 1980, Public Law 96-399, sec. 326; and Omnibus Budget Reconciliation Act of 1981, Public Law 97-35, Title X, Subtitle D.

[84] 42 U.S.C. 6833(a)(1)-(2).

[85] 10 CFR Part 436, Subpart A. Life. cycle cost (LCC) is a method of economic evaluation that estimates the costs and savings Over the life Of the item in question. Federal agencies are required to use the method when evaluating new building designs.

[86] 51 *Federal Register 29754* (Aug. 20, 1986). This proposal became a final interim rule in 1988. A final rulemaking cannot be promulgated until DOE conducts a demonstration of the final interim standards and reports the results to Congress. See 53 *Federal Register 32536* (Aug. 25, 1988).

[87] U.S. Department of Energy, Office of Building and Community Systems, Economic Analysis in *Support of Interim Energy Conservation Standards for New Federal Residential Buildings*, DOE/CE-0223 (Washington, DC: June 1988), vol. 4, pp. vi, 3.8.

[88] 54 *Federal Register* 4538 (Jan. 30, 1989). See 10 CFR Part 435.

[89] B. Reid Detchon, Principal Deputy Assistant Secretary, office of Conservation and Renewable Energy, U.S. Department of Energy, testimony at hearings before the Senate Subcommittee on Energy Regulation and Conservation, Committee on Energy and Natural Resources, Mar. 19, 1991, p. 2. As of December 1991, these standards had not been issued.

[90] The National Housing Act, 12 U.S.C. 1702 authorizes the Secretary of Housing and Urban Development to prescribe standards for determining the acceptability of dwellings for families and care-type facilities. The standards are to ‘‘establish the acceptability of. . properties for mortgage insurance. . .’ 12 U.S.C. 17151(f).

Table 4-2—Federal Energy Standards for New Buildings

Code	Application	Status
HUD Minimum Property Standards (1950s)	Residential buildings receiving Federal mortgages	To be replaced with Council of American Building Officials 'Model Energy Code' (1989 edition)
National Manufactured Housing Construction and Safety Standards (1974)	All manufactured housing	Active
DOE Building Energy Performance Standards (1979)	All new construction	Never implemented; supplanted by performance standards listed below
DOE Mandatory Performance Standards for New Federal Residential Buildings (1989)	Federal residential construction (95 percent is military housing)	Active
DOE Energy Performance Standards for New Commercial Buildings (1990)	Mandatory for Federal commercial buildings. Voluntary for private sector commercial buildings.	Active
DOE voluntary guidelines for nonfederal residential buildings	Voluntary standards for nonfederal residential buildings	Under development; issuance pending

SOURCE: Office of Technology Assessment, 1992.

ments. . ."[91] An interim rule has been drafted and is awaiting approval by the Office of Management and Budget (as of December 1991).

Manufactured Home Construction and Safety Standards—The National Manufactured Housing Construction and Safety Standards Act of 1974 (Public Law 93-383) sought to reduce the number of accidents in manufactured homes and assure their quality and durability .[92] The construction standard that emerged from the act also contained provisions for building shells and heating and cooling systems. In 1990, Congress passed legislation directing HUD to assess current Federal standards on manufactured homes.[93]

Table 4-2 lists Federal standards bearing on building energy efficiency.

Appliance Standards

National Appliance Energy Conservation Act—This legislation was passed nearly 12 years after Congress first became concerned about appliance energy use (box 4-E). The statute and its amendments establish minimum efficiency or maximum energy use standards for appliances listed as covered products under the Energy Policy and Conservation Act (Public Law 94-163) as amended. The current group of covered products is listed in table 4-3. The NAECA standards apply to these covered products.

The NAECA established numerical standards for most (7 of 13) of the appliance categories (e.g., refrigerators, room air-conditioners, central air-conditioners, furnaces, and fluorescent lamp ballasts); other covered products were given design standards. As required by law, subsequent DOE rulemakings have strengthened the energy requirements

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[91] 55 *Federal Register* 46637 (Nov. 5, 1990).

[92] 42 U.S.C. 5401-5425.

[93] Public Law 101.625, 104 Stat. 4414, sec. 943(d) HUD recently proposed amendments to these standards. 57 *Federal Register 6420* (Feb. 24, 1992).

Box 4-E—A Brief History of the National Appliance Energy Conservation Act of 1987

In 1975, Congress passed the Energy Policy and Conservation Act (EPCA), requiring the Federal Energy Administration (FEA), later succeeded by the Department of Energy (DOE), to develop voluntary appliance efficiency targets. These targets were required to represent reductions in energy use of new appliances of at least 20 percent by 1980 compared to their known 1972 levels.

By the end of 1978, the new Federal DOE had been established, assuming the duties of the now defunct FEA, and had been directed to develop mandatory appliance efficiency standards for 13 categories of new products under the National Energy Conservation Policy Act (NECPA); the statute identified nine of these covered products as priorities for standard setting. On January 2, 1979, DOE published an advance notice of proposed rulemaking for the nine priority products.[1] As required by NECPA, this required DOE to promulgate final standards by January 2, 1981.[2]

DOE proposed standards for 8 of the 13 covered products in June 1980.[3] The following January, DOE notified Congress that the new appliance standards were essentially complete.[4] Later that month, however, the newly arrived Reagan administration requested that Congress repeal the DOE appliance standards program on the grounds that it represented inappropriate regulatory policy. The next month, after Congress had not acted on the administration proposal, DOE announced that a new review of the economic analysis underlying the standards was necessary before the Department could promulgate them.[5] In October, a citizen suit was brought against DOE to compel promulgation of the standards, which by then were delinquent 10 months.[6] The suit was settled in 1982, after DOE published a notice of proposed rulemaking for eight of the nine priority covered products; the notice proposed that "no standards" standards be adopted.[7]

Arguing that standards were neither economically justitified nor likely to result in significant energy savings, DOE actually promulgated the proposed "no standards" standards through rulemakings for eight of the covered products in late 1982 and 1983.[8] This prompted the filing of a second citizen suit in late 1983 in the U.S. Court of Appeals for the District of Columbia Circuit. The suit challenged the "no standards" standards as contrary to law. Agreeing with the petitioners, the Court voided the DOE rules in July 1985 as arbitrary and capricious interpretations of the EPCA as amended and directed DOE to initiate a new rulemaking.[9]

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[1] 44 *Federal Register* 49.

[2] "A rule prescribing an energy efficiency standard for a type (or class) of covered products. . .shall be published. . .in no event later than 2 years after publication of the advance notice." Public Law 95-619,92 Stat. 3262, sec. 422.

[3] 45 *Federal Register* 43976 (June 30, 1980).

[4] R. Alta Charo, L.R. Stearns, and M. Case, "Overview of Legal Issues Arising in the Development of Federal and State Appliance Efficiency Standards," *Columbia Journal of Environmental Law, vol.* 11, No. 2, 1986, p. 322.

[5] Ibid., p. 322.

[6] *Natural Resources Defense Council v. Edwards*, Civ. No. 80-2546 (D.D.C.).

[7] 47 *Federal Register* 14424 (Apr. 2, 1982).

[8] See 47 *Federal Register* 57198 (Dec. 22, 1982) and 48 *Federal Register 39376* (Aug. 30, 1983).

[9] *Natural Resources Defense Council v. Herrington*, 768 F.2d 1355 (D.C. Cir. 1985).

mandated by NAECA. The covered products and their corresponding energy use, efficiency level, or design requirements under NAECA are listed in table 4-4.

As there are multiple NAECA standards for most of the product categories, table 4-4 lists for simplicity only one standard based on a generally representative size and design.[94] As table 4-4 indicates, there is often a large difference between the energy use or efficiency of appliances meeting the NAECA standards and the same for the best models that are listed as commercially available. However, these products are not always comparable. For example, the criteria used to determine what constitutes commercial availability can vary considerably; some commercially available products may be more expensive,

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[94] For example, there are seven separate NAECA numerical standards for refrigerator-freezers, based on varying sizes and designs (e.g., with or without through-the-door ice service), but the standard shown in table 4-4 applies to units having designs that account for approximately 73 percent of new refrigerator and refrigerator-freezer sales. See 54 *Federal Register 47935 (Nov. 17, 1989).*

During the 1970s and 1980s, California and a few other States had established their own appliance efficiency standards. The emerging mix of State standards, in fact, motivated the appliance manufacturing industry to seek uniform national standards. As a result, the major appliance manufacturer organizations began negotiations in early 1986 with the Natural Resources Defense Council to develop national standards. An agreement was reached in July 1986, which was subsequently written as proposed legislation and was based on previously enacted State standards. This legislation was introduced in August 1986 in both Houses of Congress (H.R. 5465, S. 2781). After waiting nearly 7 years for standards, Congress passed H.R. 5465 on October 15, 1986. Unlike previous legislation, H.R. 5465 proposed actual minimum standards to be established by statute for the EPCA covered products. However, President Ronald Reagan pocket-vetoed the measure on November 1, 1986 on the argument that appliance efficiency standards were not consonant with the administration's policy of minimal Federal regulatory involvement in the marketplace.[10]

The next year, however, Congress passed an essentially identical bill (S. 83, or the National Appliance Energy Conservation Act) on March 3, and President Reagan signed it on March 17,1987. Amendments to NAECA, passed in 1988 (Public Law 100-357), added fluorescent lamp ballasts to the list of EPCA covered products and established minimum efficiency levels for them. As discussed in the text, DOE has already upgraded many of these standards, as required by law.

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[10] The official Memorandum of Disapproval maintained that" [t]he bill intrudes unduly on the free market, limits the freedom of choice available to consumers who would be denied the opportunity to purchase lower-cost appliances, and constitutes a substantial intrusion into traditional state responsibilities and prerogatives." Senate Report No. 100-6, Jan. 30, 1987, p. 4. See U.S. Code Congressional and Administrative News, 100th Congress-First Session, 1987, vol. 2, p. 55.

may serve only niche markets, or may not provide identical or comparable services as their more widely sold counterparts. The intended point of the table is that there is often a large efficiency gap between the average product sold and the best commercially available one. Chapter 5 offers options to encourage greater use of cost-effective energy efficient appliances.

Energy savings—Researchers at the Lawrence Berkeley Laboratory (LBL) examined the effect of the NAECA appliance standards before DOE began updating the original statutory targets. The study determined that NAECA would yield a total estimated electricity savings of 822 terawatthours (TWh), or roughly 2.8 quadrillion Btus (quad) of end-use energy, for appliances purchased between 1990 and 2015. This energy savings translates to net dollar savings estimated at $24.5 billion.[95]

A major strength of the LBL study was that it measured the energy and economic impacts separately by each DOE region, finding that net social benefits of NAECA will be positive for all regions.[96] The study estimated that national electricity savings will be 2.5 percent, while the savings for all fuels will be less, about 0.8 percent.[97]

Table 4-3—Covered Products Under the Energy Policy and Conservation Act, as Amended

1. **Refrigerators, refrigerator-freezers, freezers**
2. **Room air conditioners**
3. **Central air conditioners (CACs) and CAC heat pumps**
4. **Water heaters**
5. **Furnaces**
6. **Dishwashers**
7. **Clothes washers**
8. **Clothes dryers**
9. **Direct heating equipment**
10. **Kitchen ranges and ovens**
11. **Pool heaters**
12. **Television sets**
13. **Fluorescent lamp ballasts**

SOURCE: 42 U.S.C. 6292(a). Under certain conditions, EPCA authorizes the Secretary of Energy to add appliances to the list of covered products. 42 U.S.C. 6292(b).

The effective dates for the NAECA standards are 1988, 1990, 1992, and 1993, depending on the appliance. DOE is required to review (and update

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[95] Expressed as 1987 dollars and based on a 5-percent real discount rate. This figure represents the sum of electricity savings ($30.7 billion) and fuel savings ($8.2 billion) less incremental appliance costs ($14.5 billion). The LBL researchers estimated the lifetime energy savings of NAECA appliances purchased between 1990 and 2015, These estimates, therefore, include energy savings beyond 2015. J.H. Eto, J.E. McMahon, J.G. Koomey, P.T. Chan, and M.D. Levine, *The Regional Energy and Economic Impacts of The National Appliance Energy Conservation Act of 1987, LBL-25471* (Berkeley, CA: Lawrence Berkeley Laboratory, June 1988), pp. 11, 13.

[96] Ibid., p. 19.

[97] Ibid., p. 11.

Table 4-4-National Appliance Energy Standards and Efficiencies

Covered product	NAECA standard	Average shipped	Best available
Refrigerator-freezers [a].	960 kWh/yr(l 990) 688 kWh/yr (1 993)	884 kWh/yr (1 990)	840 kWh/yr (1 989)
Freezers [b].	706 kWh/yr (1 990) 533 kWh/yr (1 993)	679 kWh/yr (1 990)	585 KWh/yr (1 989)
Room air conditioners[c].	9.0 EER (1990)	8.7 EER (1990)	12.0 EER (1990)
Heat Pumps[d].	10.0 SEER (1992) 6.8 HSPF (1 992)	9.1 SEER (1988) 6.9 HSPF (1988)	16.4 SEER (1 989) 9.2 HSPF (1989)
Water heaters[e]:			
Electric.	88.4% EF (1990)	—	98.0% EF (1 990)
Natural gas.	52.50/’ EF (1990)		74.0% EF (1990)
Furnaces [f].	78.00/’ AFUE (1 992)	750/0 AFUE (1988)	97.30/0 AFUE (1989)
Dishwashers.	Shall have option to dry without heat (1988) Energy factor 0.46 (1994)	Energy factor 0.37 (1990)	·
Clothes washers[h].	Shall have option to rinse without heat (1 988) Energy factor 1.18 (1994)	Energy factor 0.99 (1990)	—
Clothes dryers[i].	Gas operating machines shall not be equipped with constant burning pilots (1988) Energy factor 3.01 (1994)	N/A	N/A
Direct heating equipment.	See 42 U.S.C. 6295(e)(3)	N/A	N/A
Kitchen ranges and ovens. . . .	Gas operating machines having an electrical supply cord shall not be equipped with constant burning pilots (1990)	N/A	N/A
Pool heaters.	Thermal efficiency of at least 78%(1 990)	—	—
Television sets.	Reserved by NAECA; DOE may prescribe rule no sooner than 1992[j]	N/A	N/A
Fluorescent lamp ballasts. . . .	See 42 U.S.C. 6295(g)(5)-(6).	—	—

[a] NAECA refrigerator-freezer standards shown here are for automatic defrost units with top-mounted freezers, no through-thedoor ice, and with adjusted volumes of 20.8 cubic feet. Data for 1990 average shipped products from Robert M. Gants, Association of Home Appliance Manufacturers, written communication to OTA, Oct. 18, 1991. Data for 1989 best available products refer to automatic defrost units with top-mounted freezers having unadjusted volumes of 18.0 cubic feet. See American Council for an Energy-Efficient Economy,*The Most Energy-Efficient Appliances -1989-90 Edition*(Washington, DC: 1989), p. 5.

[b] NAECA freezer standards shown here apply to upright, manual defrost units with an adjusted volume of 26.1 cubic feet. Data for 1890 average shipped products from Robert M. Gants, Association of Home Appliance Manufacturers, written communication to OTA, Oct. 18,1991. Data for 1989 best available product refers to an upright, manual defrost unit with an unadjusted volume of 15.8 cubic feet. See American Council for an Energy-Efficient Economy, *The Most Energy-Efficient Appliances -1989-90 Edition* (Washington, DC: 1989), p. 8. *Note:* Using DOE methods for adjusting freezer volumes, this best available unit has an adjusted volume of 27.3 cubic feet. See 10 CFR Part 430, Subpart B, Appendices Al and B1.

[c] NAECA room air conditioner standard shown here applies to units without reversecycle, with louverd sides, and with capacities ranging from 8,000 to 13,999 Btus. Data for 1990 average shipped products from Robert M. Gants, Association of Home Appliance Manufacturers, written communication to OTA, Oct. 18, 1991. Data for 1990 best available product from Association of Home Appliance Manufacturers, 1991 *Directory of Certified Room Air Conditioners,* Edition No. 1 (Chicago, IL: October 1990).

[d] NAECA heat pump standards shown here apply to split (rather than single package) systems. The NAECA SEER standards appiy to central air conditioning systems as well. Data for average shipped from “Integrated Heat Pump System,” *EPRIJournal, vol. 15, No. 2,* March 1990, p. 41. Data for best available from American Council for an Energy-Efficient Economy, *The Most Energy Efficient New Appliances -1989-90 Edition* (Washington, DC: 1989), p. 18.

[e] NAECA water heater standards are adjusted in inverse proportion to heater volume; i.e., the standards are eased with increasing size. The standards shown here apply to 50 gallon units. Data for best available from Gas Appliance Manufacturer’s Association, *Consumer’s Directory of Certified Efficiency Ratings* (Arlington, VA: October 1989), pp. 134, 163.

[f] Data for average shipped and best available gas furnaces from American Council for an Energy-Efficient Economy, The *Most Energy Efficierrt New Appliances 1989-90 Edition* (Washington, DC: 1989), pp. 21-22.

[g] Energy factor refers to cycles per kWh. Standard shown here refers to standard size dishwashers (exterior width of 22 inches or greater), 1994 standard for compact dishwashers (exterior width less than 22 inches) is energy factor 0,62. See 56*federal Register 22279.* By DOE estimates, this standard level will correspond to an average annual energy consumption of 498 kWh for new dishwashers. See U.S. Department of Energy, *Technical Support Document: Energy Conservation Standards for Consumer Products: Dishwashers, Clothes Washers, and Clothes Dryers, DOE/CE-0299P* (Washington, DC: December 1990), p. 5-2.

[h] Energy factor refers to Cubic feet per kilowatts per year, Standard shown here applies to top loading standard models (capacities of 1.6 cubic feet or greater). Revised NAECA standard for top loading compact units (capacities less than 1.6 cubic feet) is an energy factor of 0.90. See 56 *Federal Register 22279.* The 1988 standard for top loading semiautomatic, front-loading, and suds-saving clothes washers were unchanged by this rulemaking.

[i] Energy factor refers to pounds per kilowatts, Standard shown here refers to standard size (capacities of 4.4 cubic feet or greater) electric clothes dryers. There are three additional standards for clothes dryers (two for compact electric units and one for natural gas units). See 56 *Federal Register 22279.* Average and best available energy factors for clothes dryers are not readily available, because the FTC exempts these appliances from its energy labeling program. See U.S. Department of Energy, Office of Codes and Standards, *Technical Support Document: Energy Conservation Standards for Consumer Products: Dishwashers, Clofhes Washers, and Clofhes Dryers,* DOE/CE-0299P (Washington, DC: December 1990), p. 4-5.

[j] See 42 U.S.C. 6295(i)(3).

KEY: kWh/yr - kilowatthours per year; EER - energy efficiency ratio; SEER - seasonal energy efficiency ratio; HSPF - heating seasonal performance factor; EF = efficiency factor; AFUE - annual fuel use (or utilization) efficiency; N/A = not readily available. Appliance energy information for these products is not readily available, because FTC rules exempt these appliances from Federal labeling requirements.

NOTE: The figures for average sold and best available products are preliminary and are subject to change.

where necessary) all of these standards within 3 to 10 years, depending on the appliance. New or amended standards are required to achieve the maximum improvement in energy efficiency (or the maximum reduction in energy use) that is both technologically feasible and economically justified.[98] In no case may DOE revisions to NAECA standards allow a decrease in the efficiency, nor an increase in the energy use, of covered products. Table 4-5 lists DOE statutory deadlines for revising NAECA standards,

As table 4-5 indicates, DOE has issued two final rulemakings that update the original NAECA statutory standards: refrigerators, refrigerator-freezers, freezers, and small gas furnaces (November 1989) and dishwashers, clothes washers, and clothes dryers (May 1991). LBL researchers have estimated that the two revised rulemakings will generate *additional* savings (beyond the original, unrevised standards) of about 7.5 quads primary energy for appliances purchased from 1993 through 2015. These savings are worth an estimated net present value of about $11.4 billion.[99]

Information Programs

Appliance Labels

The Energy Policy and Conservation Act (Public Law 94-163; EPCA), as amended, requires the Federal Trade Commission (FTC, or the Commission) to develop and promulgate appliance energy labels for 13 covered products, *m The FTC is directed to label only those covered products for which DOE has prescribed test procedures that measure either the efficiency or energy use of a given appliance. An underlying principle of this program is that lack of information about comparative product efficiencies and operating costs prevents consumers from identifying and purchasing more efficient appliances. As a result, EPCA requires appliance labels to list estimated annual operating costs for each product, as well as the range of operating costs for other commercially available products in the same appliance class. The estimates of annual operating costs are provided in the belief that consumers can make more informed appliance purchase decisions when they possess reliable information about comparative product efficiencies.[101]

The Commission promulgated the first labeling rule in November 1979, establishing label formats for 7 of the 13 covered products: refrigerators and refrigerator-freezers, freezers, dishwashers, water heaters, clothes washers, room air conditioners, and furnaces,[102] The remaining covered products were exempted, because the Commission determined that labeling them would not be economically feasible, would not assist consumers in making purchase decisions, or both. In many cases, the estimated added costs of product labeling resulted in a labeling exemption on economic grounds.[103]

The Commission's decision to exempt the five covered products from labeling were based on DOE estimates of energy use and appliance industry analyses of labeling costs. In most cases, the FTC appliance labeling exemptions appear to have been

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[98] 42 U.S.C. 6295(l)(2)(A).

[99] Expressed as 1987 dollars using a real discount rate of 7 percent. (These summary figures include savings from small gas furnaces purchased from 1992 through 2015.) Estimated savings for the November 1989 rulemaking are given in U.S. Department of Energy, Office of Conservation and Renewable Energy, Building Equipment Division, *Technical Support Document: Energy Conservation Standards for Consumer Products: Refrigerators and Furnaces, DOE/CE-0277* ('Washington DC: November 1989), pp. 5-7 to 5-15. Estimated savings for the May 1991 rulemaking are given in U.S. Department of Energy, Office of Conservation and Renewable Energy, Office of Codes and Standards, *Technical Support Document: Energy Conservation Standards for Consumer Products: Dishwashers, Clothes Washers, and Clothes Dryers,* DOE/CE-0299P (Washington, DC: December 1990), pp. 5-3 to 5-14.

[100] As originally passed, EPCA covered products were the following: 1) refrigerators and refrigerator-freezers, 2) freezers, 3) dishwashers, 4) clothes dryers, 5) water beaters, 6) room air conditioners, 7) home heating equipment (not including furnaces), 8) television sets, 9) kitchen ranges and ovens, 10) clothes washers, 11) humidifiers and dehumidifiers, 12) central air conditioners, 13) furnaces, and 14) any other type of consumer product defined by the Administrator of the Federal Energy Agency as covered. These duties were assumed by the Secretary of Energy when that Department formed in 1977, In addition, the National Appliance Energy Conservation Act of 1987 (Public Law 100- 12; NAECA) and its 1988 amendments (Public Law 100-3S7) added pool heaters and fluorescent lamp ballasts to this list (42 U.S.C. 6292). These statutes also extended the labeling requirements to the two new covered products (42 U.S.C. 6294). For a complete list of current EPCA covered products see the discussion in this chapter on appliance efficiency standards and table 4-3.

[101] R.F. Dyer, ''A Longitudinal Analysis of the Impact of the Appliance Energy Labeling Program--Final Report, ' November 1986, prepared for the Federal Trade Commission, Office of Impact Evaluation, p. 2.

[102] The decision t. label heat Preps and central air conditioners was postponed, because DOE had not completed test procedures 'or these two products. Label requirements for these covered products were promulgated in a later rulemaking. See 52 *Federal Register 46888 (Dec.* 10, 1987).

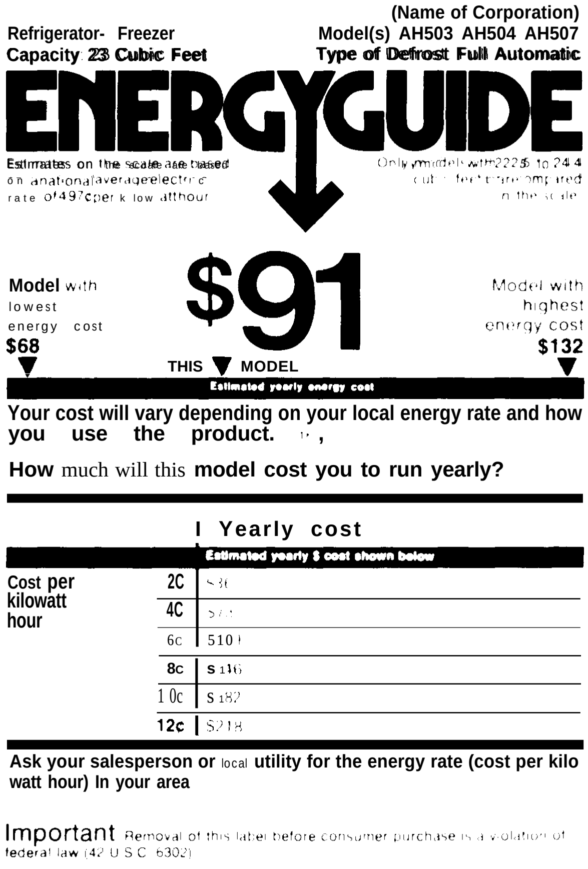
[103] The appliances exempted from labeling were clothes dryers, home heating equipment other than furnaces, television sets, kitchen ranges and ovens, and humidifiers and dehumidifiers. 44 *Federal Register 66466 (Nov.* 19, 1979).

Table 4-5—DOE Schedule for Revising the NAECA Standards

Covered product	**Final** rule date
Round I	
Refrigerators, refrigerator-freezers, freezers, and small gas furnaces	**November 17, 1989a**
Dishwashers, clothes washers, and clothes dryers	**May 14, 1991[b]**
Room air conditioners, water heaters, pool heaters, direct heating equipment, fluorescent lamp ballasts, furnaces, clothes washers,[c] television sets, and kitchen ranges and ovens	**January 1, 1992**
Central air conditioners and central air conditioning heat pumps	**January 1, 1994**
Round II	
Furnaces	**January 1, 1994**
Refrigerators, clothes dryers, and dishwashers	**January 1, 1995**
Kitchen ranges and ovens, and room air conditioners	**January 1, 1997**
Water heaters, pool heaters, and direct heating equipment , , ...	**January 1, 2000**
Central air conditioners and central air conditioning heat pumps	**January 1, 2001**
Round III	
Furnaces	**January 1, 2007**

[a] 54 Federal Register 47916. See 10 CFR Part 430. This revised rule was due July 1, 1989.42 U.S.C. 6295.
[b] 56 Federal Register 22250. See 10 CFR Part 430. This revised rule was due January 1, 1990.42 U.S.C. 6295.
[c] DOE is reevaluating the NAECA standards for clothes washers so soon after revising the original standard, because horizontal axis technology was not considered in the May 1991 rulemaking from lack of public interest during the comment period. Because they require considerably less water than conventional vertical axis machines, horizontal axis products, which are common in Europe, consume far less energy.

SOURCE: Adapted from U.S. Department of Energy testimony in hearings before the House Subcommittee on the Department of the Interior and Related Agencies, Committee on Appropriations, Apr. 30, 1991. See *Department of the Interior and Related Agencies Appropriations for 1992* (Washington, DC: U.S. Government Printing Office, 1991), part 11, p. 1438.



(Name of Corporation)
Refrigerator- Freezer
Model(s) AH503 AH504 AH507
Capacity: 23 Cubic Feet
Type of Defrost: Full Automatic

ENERGYGUIDE

Estimates on the scale are based on a national average electric rate of 4.97¢ per kilowatt hour

Only models with 22.5 to 24.4 cubic feet are compared in the scale

Model with lowest energy cost **$68**

$91

Model with highest energy cost **$132**

THIS ▼ MODEL

Estimated yearly energy cost

Your cost will vary depending on your local energy rate and how you use the product.

How much will this **model cost you to run yearly?**

		Yearly cost
		Estimated yearly $ cost shown below
Cost per kilowatt hour	**2C**	$36
	4C	$73
	6c	$109
	8c	$146
	10c	$182
	12c	$218

Ask your salesperson or local **utility for the energy rate (cost per kilo watt hour) In your area**

Important Removal of this label before consumer purchase is a violation of federal law (42 U S C 6302)

Photo credit: Federal Trade Commission

The Federal Trade Commission requires many new appliances to display labels that indicate the units' expected energy use or efficiency.

well considered. For example, the Commission found that all humidifiers operate at the maximum possible efficiency (exceeding 95 percent) and their operating costs are all basically equal, the difference between the lowest and highest energy users amounting to less than $1 per year. As a result, the Commission reasoned that the additional costs of labeling humidifiers were not warranted and that such labeling would not assist consumers in making their purchase decisions. And television sets and some kitchen ranges and ovens were exempted, because their annual operating costs were extremely low, suggesting again that labels would not assist consumers in making their purchase decisions.[104]

However, the FTC exempted clothes dryers and heating equipment other than furnaces based on narrow ranges of appliance efficiencies and operating costs that existed in 1979. The rulemaking failed to evaluate (or at least indicate) opportunities for future improvements in either efficiency or operating costs. Electric clothes dryers, for example, showed a narrow range of operating costs in 1979 ($39 to $45 per year), but these total costs were not small. For some products, therefore, the FTC criteria

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[104] 44 *Federal Register 66468-66469* (Nov.19,1979).

for determining the merits of labeling may be inadequate, because they fail to assess potential product improvements. And energy labels may spur improvement by encouraging manufacturers to increase product efficiencies, lower operating costs, or both when technical opportunities exist. Of course, the degree of that potential must be evaluated in relation to the costs of labeling.

The Commission has performed one evaluation of appliance label effectiveness in the 11-year history of the program. Completed in 1986, the study determined that roughly one-third of clothes washer buyers and nearly half of refrigerator buyers who were aware of the labels claimed that the information affected their purchase decisions.[105] In addition, the evaluation suggested that appliance labels served an increasingly important role in purchase decisions as the program progressed. The portion of consumers noting energy efficiency as an important attribute for refrigerators, for example, increased during the study period from nearly 12 percent in 1979 to about 21 percent in 1983. Questions about important appliance attributes were unaided and preceded any mention of energy use in the questionnaire. The actual role of the FTC labels in that change of consumer preference, however, was not assessed.[106]

Aside from this early and limited evaluation, the Commission has not performed any formal assessments of appliance energy labeling, even though new appliance efficiencies and operating costs have changed in the 12 years since the original rulemaking. At present, the Commission has no plans to conduct another labeling evaluation. Current efforts are focused on the completion of a rulemaking process begun in 1988, Dubbed the "cleanup rulemaking," because it will refine current labels, the Commission is considering several policy questions for this effort, such as whether the new NAECA standards will raise product efficiencies enough to render labels relatively unimportant. Also, the Commission is considering whether the required labels could be limited to display models—rather than every salable appliance-as a way to save costs,[107]

After 12 years, U.S. experience with appliance labeling is fairly extensive, but the value and impact of that experience remain poorly understood, primarily from a lack of regular program evaluation. The FTC appliance labeling program, however, reveals several interesting points for Congress to consider.

- Although consumers may consider energy information when making their appliance purchases, the actual value to consumers of the current FTC labels remains unclear. Regular evaluations covering more products would provide data on the merits of the appliance labels, whether and how to improve them, and the potential effects of limiting labels to display models. More regular evaluations would suggest whether consumers use the information on current labels and the kind of information that would best assist their appliance purchase decisions. Furthermore, if the FTC performs additional labeling evaluations, it should reassess the products currently exempted from the program.

The 1986 FTC evaluation confirmed that consumers use the information on appliance labels but did not determine if the labels could be improved. Also, program costs might decrease if labels were limited to display models, but consumers may be less likely to notice the labels as well. In fact, stores do not always display all of their appliance models. As a result, potential cost savings would have to be considered in relation to the primary program goal of providing information meant to assist consumer purchase decisions.

- Providing information about life-cycle costs might improve the value of current appliance energy labels, but determining such

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[105] R.F. Dyer, ''A Longitudinal Analysis of the Impact of the Appliance Energy Labeling Program-Final Report,'' November 1986, prepared for the Federal Trade Commission, Office of Impact Evaluation, p. 7. However, the telephone questionnaire used in the surveys quizzed consumers about energy prior to the question about purchase decisions, suggesting that respondents may have been inadvertently cued ('‘aided”) for the question about purchase decisions.

[106] Ibid,, p. 5. In nominal terms, U.S. residential electricity prices rose almost 55 percent in the study period (1979-83). This rise was equivalent to a real price increase of 17 percent (1982 dollars). See U.S. Department of Energy, Energy Information Administration, *Annual Energy Review 1989,* DOE/EIA-0384(89) (Washington, DC: May 1990), p. 217. Thus, rising prices may have been far more important than labels in motivating consumers to consider appliance efficiencies in their purchase decisions, but the FTC labels at least allowed consumers to make informed decisions about energy use if they were so interested.

[107] James Mills, Attorney, Division of Enforcement, FTC, personal communication, Mar. 25, 1991. The notice for the proposed 'cleanup rulemaking'' is at 53 *Federal Register 22106* (June 13, 1988).

costs may be difficult. Life-cycle costs are the sum of purchase and operating costs discounted over the life of a product. At present, this information is not included on appliance energy labels, but it could influence consumer purchase decisions and drive the market to produce more efficient goods. Life-cycle cost information would impart more complete information about comparative appliance costs, but making allowances for retail price shifts and determining appropriate discount rates could complicate such an effort.

- Where labeling is not economically feasible or is not likely to assist consumers in making purchase decisions, other policy actions to improve energy efficiency, such as standards or incentives, may be more appropriate. For example, FTC furnace labels convey only information on how to use them efficiently; they are not designed for purchasers, because many furnace purchasers (builders, landlords) are generally not their users, effectively excluding users from purchasing decisions. As a result, standards or incentives may override critical market barriers to efficiency that exist when appliance purchasers are not users.

In addition, FTC appliance labels may increase the probability that consumers will be informed about comparative product efficiencies in their purchase decisions, but such information is not necessarily a critical determinant in those decisions. Concerns about first cost, reliability, warranty coverage, color and design, and special features (e.g., refrigerators offering through-the-door ice) may be more important to the majority of consumers. As a result, labels can be expected to inform consumers interested in appliance efficiency but not necessarily to inspire that interest.[108]

- The likelihood that the National Appliance Energy Conservation Act will compress the range of comparative efficiencies in new appliances suggests a need to reassess the value of the FTC labels as an information tool. The NAECA, passed in 1987, sets energy standards for new appliances. If this statute has the effect of compressing the efficiencies of new appliances, the costs and benefits of the FTC labels need to be reevaluated. The continued use of appliance energy labels could exert a market pressure that might spur appliance efficiency improvements even greater than will be realized under NAECA; alternatively, their continued use could represent an unwarranted administrative cost in a market that may become relatively uniform in terms of efficiency.[109]
- The information on the FTC labels is often used by utilities to determine rebates in their appliance efficiency programs. Utility programs offering rebates for the purchase of efficient appliances are becoming increasingly common,[110] and the FTC labels provide an accepted benchmark by which U.S. utilities can determine and advertise the efficiency of individual products.

Through regular evaluation and possible improvements or expansions, the FTC appliance labeling program could better fulfill the original rationale for its creation: to help consumers make more informed purchase decisions regarding appliance energy efficiency. The costs of such changes as well as their likely effects on consumer purchase decisions, however, need to be assessed before final determinations of their desirability can be made, especially given the new NAECA standards.

Building Energy Audits

There have been two major Federal programs designed to provide building owners and occupants with building-specific information about energy use

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[108] Other policy approaches—such as rebates, higher energy prices, or standards-maybe better tools to achieve efficiency, but they introduce their own costs as well. The tradeoffs (including estimations of cost-benefits) of using any policy tool need to be understood, but information programs generally exert effects, especially in relation to energy efficiency, that are difficult to measure.

[109] Experience with appliance standards in California prior to the development of Federal standards suggests that such programs only temporarily compress the range of new product efficiencies. As noted by a staff member of the California Energy Commission, “data taken from manufacturer’s [sic] directories before and after the adoption of [the California] standards indicate that the range of efficiencies available narrows only slightly in the frost year and expands to its pre standards range in the course of 2 to 3 years, ” See M. Messenger, ‘‘An Overview of California’s Appliance Efficiency Programs, ” *Proceedings From the ACEEE 1986 Summer Study on Energy Efficiency in Buildings* (Washington DC: American Council for an Energy-Efficient Economy, August 1986), vol. 6, p. 6.52.

[110] For example, a survey of utility demand-side management efforts identified 91 appliance efficiency programs offered by 75 electric utilities and determined that rebates were the most common incentive used to promote these programs. See Battelle, *1988* Survey *of Residential-Sector Demand-Side Management Programs,* EPRI CU-6546 (Palo Alto, CA: Electric Power Research Institute, October 1989), pp. 4-1,4-10.

and potential savings through utility-sponsored audits. Neither exists today, because participating utilities lacked sufficient incentives to conduct the programs, State regulatory efforts have encouraged many utilities to develop their own conservation programs, and the administrative requirements for conducting the Federal programs were often onerous.

The two programs were the Residential Conservation Service (RCS), which expired in 1989, and the Commercial and Apartment Conservation Service (CACS), which was repealed in 1986. Though both of these programs have been terminated, at least one (RCS) offers clues about some of the key barriers and implementation problems confronted by Federal programs aimed at reducing energy use in buildings. In particular, national experience with the Residential Conservation Service illustrates that utilities can play a vital role in implementing building energy conservation programs, especially when they are given adequate incentives for participation.

In addition, the RCS experience suggests the need to incorporate flexibility in the administration of national programs to allow States and utilities to tailor their programs according to their regional circumstances. Lessons from the RCS could assist Congress and Federal agencies working on similar demand management programs today, such as the DOE Weatherization Assistance program (discussed earlier).

Residential Conservation Service—The RCS was created with the expectation that residential consumers would invest in energy saving retrofits if they were given adequate information on how to reduce energy use in their homes. As with appliance labels, there was a general belief that lack of information was the decisive barrier preventing investments in residential energy efficiency. The expectation, however, proved optimistic, failing to recognize that other important barriers prevent investments in energy conservation, even when consumers are aware of the potential value of such investments. And even after retrofits have been completed, changes in occupant behavior (' 'rebound effect' or poor quality materials or workmanship can diminish actual savings. As designed, the Federal RCS program did not address either the availability and costs of financing conservation retrofits nor the varying regional availability of conservation supply and installation services. In addition, and perhaps most importantly, the program did not address the strong disincentives investor-owned, profit-driven utilities confront in attempting to encourage conservation, an activity that can lower their revenues when successful.

The focus of the RCS program was the 'Class A' audit, which involved an on-site inspection by a trained professional, typically assisted by computer analysis, to determine potential energy savings. Required by the National Energy Conservation Policy Act (Public Law 95-619; NECPA), the on-site audits represented the major cost of the RCS program. Each audit typically lasted several hours and cost an estimated $130 in 1983. Although DOE rule changes relaxed some program requirements, the national average audit cost was only $30 lower 6 years later (table 4-6).[111]

Utility audit offers were typically conveyed by mail. During the program, the nearly 74 million eligible RCS customers received more than 296 million audit offers; in other words, an average of four audit offers each during the IO-year operation of the program (1980-89). On a yearly basis, the ratio of audits requested to those offered was low, ranging from 1,9 to 4.3 percent (figure 4-5). By the end of the program in 1989, 11 percent of the eligible population had participated in the program.[112] This was at the low end of the initial DOE participation goal of 7.5 to 35 percent expected by 1985.[113] The cumulative national participation rate, however, was actually above the level (4 to 7 percent) at which DOE estimated the program would be cost-effective.[114]

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[111] Figures here are expressed in 1984 dollars. See table 4-6. The DOE rule changes allowed at least one State (California) to cut its average audit time in half, which reduced its program costs by one-third. See J.A. Walker, T.N. Rauh, and K. Griffin, ''A Review of the Residential Conservation Service program, " *Annual Review of Energy 1985* (Palo Alto, CA: Annual Reviews, Inc., 1985), vol. 10, pp. 302-303.

[112] U S Department of Energy, Office of State and Local Assistance programs, *Summary and Highlight of RCS Annual Reports: 1982 'o 1989, '@' 1990*, p. 6. *Note: The* DOE RCS participation figures may not be adjusted for multiple audit requests from single households, suggesting that there may be some double counting of audit requests.

[113] U.S. Congress, General Accounting Office, *Federal Home Energy Audit* Program Has *Not Achieved Expectan'ens,* GAO/RCED-87-38 (Gaithersburg, MD: December 1986), p. 3.

[114] 47 *Federal Register* 27771 (June 25, 1982).

Table 4-6-Residential Conservation Service: Average Program Expenditures Per Audit 1983-89 in Constant 1984 Dollars

	1983	1984	1985	1986	1987	1988	1989
Utilities	128.00	129.00	100.00	110.00	115.00	92.00	99.00
States	1.76	1.56	1.21	2.50	2.36	1.63	1.25
Federal (DOE) ... ,	0.69	2.19	0.56	0.43	0.13	0.15	0.20
Total.	130.45	132.75	101.77	112.93	117.49	93.78	100.45

SOURCE: U.S. Department of Energy, Office of State and Local Assistance Programs, *Summary and Highlights of RCS Annual Reports: 1982 to 1989,* April 1990, p.10.

The cost-effectiveness of the early RCS program appears to have been marginal. A 1984 program evaluation concluded that participants performed less cost-effective retrofits than nonparticipants; the evaluation suggested that actual savings were lower than estimated savings due to previous retrofits, imperfect engineering estimates, and customer rebound effects.[115] A subsequent evaluation suggested that program cost-effectiveness improved in later years, where measured benefit-cost ratios for RCS participants ranged from 0.9 to 2.1. (Benefit-cost ratios greater than 1 indicate that benefits exceed Costs.)[116]

It is important to note that NECPA did not require utilities to conduct a cost-effective RCS audit program-perhaps because utilities were intended to pay for the bulk of program costs, and it was assumed they would minimize these costs. Moreover, by stressing primarily the on-site audits rather than follow-up retrofits, NECPA created a program far too narrow in scope. The RCS would likely have enjoyed better success if utilities were directed or encouraged to conduct cost-effective programs, if the performance of conservation retrofits subsequent to audits had been stressed more strongly, and if program administrators had monitored whether the retrofits suggested by the auditors as most economical were those actually installed by consumers.

Although the ultimate cost-effectiveness of RCS is uncertain, the program created an important precedent for many State and utility residential conservation efforts by providing experience in program implementation, suggesting the value of providing incentives for consumer participation, and highlighting the need to develop better tools for determining the effectiveness of residential conservation programs. Today, State and utility conservation programs typically encourage household energy audits and retrofits, suggesting that the lessons from this defunct national program have current value for the Federal Government as well. In particular, if Congress decides in the future to mandate a national audit program similar to the RCS--or if it wishes merely to assist related Federal, State, or utility programs-it would be well served to consider the factors behind low RCS participation rates and how to correct them to ensure more cost-effective energy savings in conservation programs.

- Consumers and utilities lacked sufficient incentives to participate in the program. Although many consumers were aware of the RCS, providing financial incentives for them to participate would almost certainly have improved program success.[117] One of the major barriers to conservation investments is high first cost (i.e., purchase cost), even when such investments pay back relatively quickly. Not

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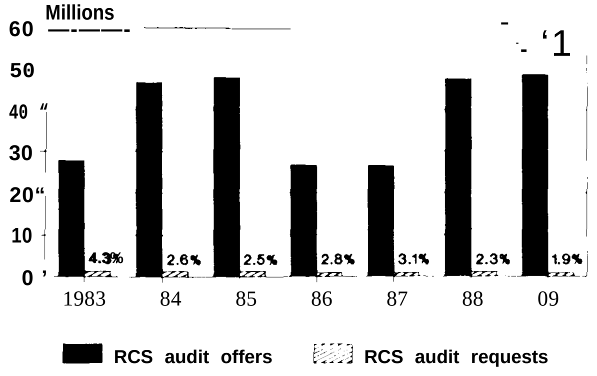
[115] M.L. Frankel and J.A. Duberg, “Energy Audits as an Investment: The Residential Conservation Service Program Analyzed,’ *Public Utilities Fortnightly,* Apr. 12, 1984, pp. 21-22. In this context, a ‘‘rebound effect’ refers to changes in consumer behavior that diminish the savings expected from a conservation retrofit.

[116] U.S. Department of Energy, *Update of the Evaluation of the Residential Conservation Service program,* DOE/CS/10097—T1 (Washington, DC: September 1986), vol. I, p. ES-2. This range of estimated benefit-cost ratios was based on evaluations of eight utility programs from several regions and was calculated assuming a 5-percent discount rate, Many analyses of RCS program cost-effectiveness are unreliable, because they are based on inconsistent State or household reports that used varying methods of calculating RCS energy savings, but the 1986 DOE study is an exception. That analysis considered only programs that provided actual residential fuel use data—not household or other estimates of energy savings—which made it far more reliable.

[117] As discussed earlier, Federal income tax credits were available for residential conservation investments made in tax years 1978 to 1985 but were probably too small and not advertised well enough to have much effect on consumer behavior. In fact, as discussed earlier, a DOE survey found that most households conducting retrofits in 1983 neglected to claim any of the tax credits.

Figure 4-5—Residential Conservation Service Audit Offers and Requests, 1983-89



SOURCE: U.S. Department of Energy, Office of State and Local Assistance Programs, *Summary and Highlights* of *RCS Annual Reports.' 1982 to 1989,* April 1990, p. 6.

surprisingly, States offering special consumer incentives—such as no- or low-cost loans for retrofits--consistently showed higher participation rates in the RCS program. For example, Massachusetts, Rhode Island, and Connecticut offered consumers financial or other incentives, and their participation rates were among the highest in the Nation—between 16 and 20 percent, well above the national total of 11 percent. Moreover, the 10 utilities with the highest participation rates all offered financial or other incentives for participation. These 10 utilities experienced participation rates ranging from 17 to 53 percent, roughly one-and-a-half to almost five times the national average.[118]

Utilities generally lacked incentives to participate in the RCS program as well. The large electric and natural gas utility industry in the United States is largely investor-owned and profit-driven. As a result, successful conservation programs have, from the perspective of many utilities, the perverse effect of reducing their revenues, especially under the prevailing State utility regulatory structure of the late 1970s and early 1980s, which generally prevented utilities from profiting directly from consumer energy savings. Though many States are revising their utility regulatory programs to allow these companies to profit from conserving energy, some investor-owned utilities still have few incentives to promote consumer energy savings. For utility-oriented conservation programs to achieve optimal results under an investor-owned system, utilities in the future will have to be able to enjoy profits from both providing *and* saving energy.

- Utilities and States were burdened with complex RCS program requirements not directly related to promoting cost-effective energy savings. As enacted, the RCS placed large administrative burdens on utilities: the program required them to announce and provide audits, compile lists of retrofit contractors for their customers, arrange for customer retrofit financing, and establish procedures for resolving customer/contractor disputes. These requirements placed utilities in the undesirable position of acting as liaisons between customers and contractors without ensuring the utilities any economic return for their efforts. Among other things, these controversial program requirements prevented most States from participating in the RCS program until 1982 or 1983. As late as 1983, about 10 States had not initiated any RCS program.[119]
- The availability of retrofit installation services may have been limited in many areas. At the time the RCS was created, the Edison Electric Institute estimated that accomplishing the program's ambitious goals would require 320,000 auditors and 2.5 million insulation installers,[120] a growth in this service industry that appeared unlikely given the original 5-year life of the program. Any future national effort to promote residential energy conservation retrofits through audit or other programs should first ensure that the growth of the accompanying service industry occur gradually over a longer period—to allow for sufficient time to develop auditor and installation personnel and expertise.
- Insufficient program marketing to low-income households and renters. Significant energy savings opportunities are common in low-income and rented households. These units

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[118] These figures represent participation through the 1987 reporting period. See U.S. Department of Energy, Office of State and Local Programs, *1987 General and Summary Reports to Congress on the Residential Conservation Service Program* (Washington, DC: December 1987), pp. 18-21.

[119] J.A. Walker, T.N. Rauh, and K. Griffin, "A Review of the Residential Conservation Service Program," *Annual Review of Energy 1985* (Palo Alto, CA: Annual Reviews, Inc., 1985), vol. 10, pp. 290291.

[120] Ibid., p. 288.

are often older, needing repair, and thus less energy efficient, yet they were not specially targeted in most States. Department of Energy surveys for the RCS program confirmed the low participation of these groups.[121]

- Many consumers had performed retrofits before the Federal program was initiated. Several States had conducted their own residential conservation programs prior to the creation of the RCS. Also, natural gas shortages in the winter of 1977 and rising oil and electricity prices in the late 1970s motivated many consumers to conduct retrofits before the RCS program was even initiated. In fact, many utilities reported that energy savings in their own conservation programs were greater than those from the Federal RCS,[122] and many may have promoted their own energy conservation programs more aggressively than the DOE effort.
- The uncertain future of the RCS program after 1985 coupled with energy price drops in the late 1980s probably contributed to dwindling participation rates at the end of the program. Moves to repeal the RCS before its apparent sunset date of January 1, 1985 left program planners uncertain of its future; in fact, the program was largely in limbo during 1985 and 1986, when there were disputes about whether it needed reauthorization.[123] It was not until the passage of the Conservation Service Reform Act (Public Law 99-412) in August 1986 that DOE, State, and utility program administrators were fully certain that the program would continue. In those 2 years, however, audit offers dropped nearly 50 percent. At the same time, the real price of energy had been falling, making its largest drop in 1986. These events suggest why annual RCS participation rates (measured as the annual fraction of audits requested to those offered) were the lowest in the last 2 years of the program-2.3 percent (1988) and 1.9 percent (1989). See figure 4-5.

Commercial and Apartment Conservation Service—The impetus behind the CACS program was similar to the RCS: to provide information through energy audits to induce building owners and occupants to conserve energy through retrofits and operational changes. The CACS required large electric and natural gas utilities to offer energy audits to small commercial buildings and centrally heated or cooled multifamily apartment buildings with five or more units.[124] Unlike the RCS program, however, only a few States submitted implementation plans, and only one State (Michigan) initiated a program.

In the event that any States did not submit CACS implementation plans, the Energy Security Act directed DOE to implement a Federal Standby Plan, which the Department issued in September 1985.[125] Though the Standby Plan became effective 1 month later, Congress repealed the program the next year (Public Law 99-412). According to a DOE official in the office that administered the program, State disinterest in the CACS stifled the program from the outset, funds appropriated to the program were always low, and no final report or final evaluation of the program was completed.[126]

Technical Assistance

DOE administers two major programs that offer education, technical assistance, and demonstration services to nonfederal organizations such as State and local governments, commercial businesses, academic institutions, and other, generally small-

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[121] U.S. Department of Energy, Office of State and Local programs, 1987 *General and Summary Reports to Congress on the Residential conservation Service Program* (Washington, DC: December 1987), p. 4.

[122] U.S. Congress, General Accounting Office, *Federal Home Energy Audit Program Has Not Achieved Expectations,* GAO/RCED-87-38 (Gaithersburg, MD: December 1986), p. 4.

[123] The dispute centered on the meaning of the expiration date for requiring RCS program announcements, as allowed in the National Energy Conservation Policy Act (Public Law 95-619). The DOE interpreted that date (January 1, 1985) as the implied termination date for the entire program. Others, such as the General Accounting Office, disagreed with that position, arguing that utilities had a continuing obligation to conduct their other RCS program activities. See Harry R. Van Cleve, U.S. General Accounting Office, testimony at hearings before the House Subcommittee on Energy Conservation and Power, Committee on Energy and Commerce, Sept. 5, 1985.

[124] The Energy Security Act of 1980 (Public Law 96-294) defined small commercial buildings as those consuming less than 4,000 kWh per month, 1,000 therms of natural gas per month, or 100 million Btus of any other fuel. In addition, Title V of the Act expanded the RCS program to include as of January 1, 1982 all multifamily apartment buildings with five or more units that *lacked* central heating or cooling systems.

[125] so *Federal Register* 37818 (Sept. 17, 1985).

[126] Andre Van Rest, U.S. Department of Energy, office of Conservation and Renewable Energy, former DOE manager of the Commercial and Apartment Conservation Service, personal communication, Mar. 27, 1991 and Feb. 4, 1992.

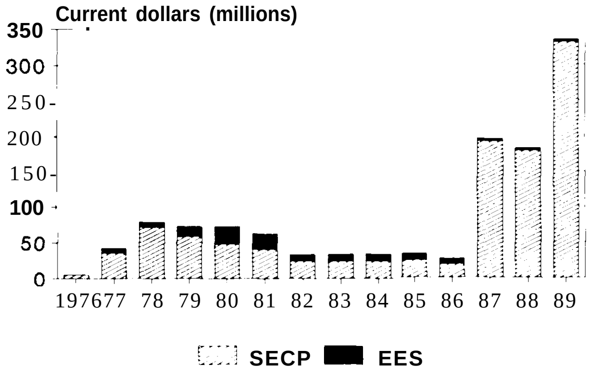
scale energy users. These are the State Energy Conservation Program (SECP) and the Energy Extension Service (EES), Their combined budget history is given in figure 4-6. All 50 States, the District of Columbia, and six Territories participate in both programs, each of which requires a 20 percent finding match.[127]

State Energy Conservation Program—Under the Energy Policy and Conservation Act (Public Law 94-163), States are required to develop and implement conservation plans through the State Energy Conservation Program (SECP).[128] The 1975 statute directed the Federal Government to oversee and assist States in the development and implementation of their own conservation programs, which were required to reduce the energy demand in each State by at least 5 percent of its anticipated 1980 consumption level. To be eligible for financial assistance under the Act, each State had to submit a conservation plan indicating how the statutory conservation goal would be reached.

State plans were required to contain five basic elements, two of which related to building energy efficiency: mandatory lighting efficiency standards for public buildings (except those owned or leased by the Federal Government) and mandatory thermal efficiency standards and insulation requirements for new and renovated buildings (except those owned or leased by the Federal Government).[129] All States have implemented programs that meet the five EPCA requirements, and most States have developed additional conservation programs that supplement the SECP. These programs include energy education, energy technology demonstration, and technical assistance.[130] Examples of several SECP-related buildings efforts convey a sense of the program (box 4-F).

SECP appropriations have decreased since 1979, but monies transferred from Petroleum Violation Escrow funds (from Exxon and Stripper Well judicial rulings stemming from oil overcharge suits) since 1987 have expanded program resources in recent years far beyond original funding levels (figure 4-6).

Figure 4-6-Combined Funding for the State Energy Conservation Program and the Energy Extension Service, 1976-89



NOTE: The sharp increase in SECP funding since 1987 stems entirely from newly available oil overcharge funds. In current dollars, actual SECP appropriations have been decreasing since 1979. In recent years, administration requests for SEC P/EES funding have sought only these overcharge funds.

SOURCE: U.S. Department of Energy, Office of Technical and Financial Assistance, *Eleventh Annual Report to Congress and the Secretary of Energy on the Nationwide Energy Extension Service Program,* DOE/CE-0291 P (Washington, DC: July 1990), p. 6; Office of State and Local Assistance Programs, Annual *Report* to *the President and the Congress on the State Energy Conservation Program for Calender* Year *1989,* DOE/CE-O296P (Washington, DC: December 1990), p. 3.

DOE does not estimate the cost-benefits of SECP energy savings, because there are great uncertainties in calculating savings from such a diversity of relatively small-scale activities; measuring the incremental energy savings that have resulted from past SECP efforts would be difficult and almost certainly unreliable.[131] On the other hand, program funding has increased dramatically in recent years with the availability of petroleum violation monies, and Congress and DOE may wish to determine if

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[127] U.S. Department of Energy, *United States Department of Energy Fiscal Year 1992 Congressional Budget Request*, DOE/CR-0001 (Washington, DC: February 1991), vol. 4, p. 470.

[128] A State is any State, the District of Columbia, Puerto Rico, and the territories and possessions of the United States.

[129] 42 U.S.C. 6322(c).

[130] U.S. Department of Energy, *Annual Report to the* President *and the Congress on* the *State Energy Conservation program for Calender year* 1989, DOE/CE-0296P (Washington, DC: December 1990), pp. 1-2.

[131] One review of the SECP suggested that typical residential energy savings stemming from the program have been small, perhaps 5 percent, but the review suggested that savings could reach 10 percent if feedback on personal energy use was provided. Yet published estimates of SECP energy savings are often unreliable, because they are commonly based on household reports of energy savings rather than actual fuel-use *information. See* J. Clinton, H. Geller, and E. Hirst, ' 'Review of Government and Utility Energy Conservation Programs, '' *Annual Review of Energy 1986* (Palo Alto, CA: Annual Reviews, Inc., 1986), vol. 11, p. 104.

Box 4-F—Examples of State Energy Conservation Program Projects[1]

- ***Cultural* Heritage Center (Pierre, South** Dakota): This demonstration project was conducted under the auspices of the gubernatorial Office of Energy Policy and the State Historical Society and involved the installation of passive solar, efficient lighting, and automated control designs and technologies at the center. Eight separate efficiency measures, ranging from earth sheltering to heat recovery ventilation, are now demonstrated to the Center's 25,000 annual visitors.
- Cabell Couny Courthouse Demonstration ***Project (Huntington,*** West Virginia): This project involved the installation of a commercially available, but seldom used, natural gas pulse boiler and heat distribution system in the Courthouse to demonstrate the applicability of this technology as an alternative to larger, centralized boilers. Typical of the 55 courthouses in the State, the Cabell County building is a brick and stone structure that had proven difficult to heat. This project is expected to save 53 percent of previous energy use in the Courthouse.
- ***Community Energy Management Program*** (Oklahoma Department of Commerce): The CEMP is a community-oriented, technical assistance effort designed to implement cost-effective energy efficiency and conservation options for local governments in the State. Trained Local Energy Officers operate the program and receive input from local groups and interested individuals.

[1] Us. Department of Energy, *Annual Report to the President and the Congress on the* State *Energy Conservation Program for Calender Year 1988,* DOE/CE/0293P ('ashington, DC: October 1989), p. 5; U.S. Department of Energy, *Annual Report to the President and the* Congress *on the State Energy Conservation Program for Calendar Year 1989,* DOE/CE-0296P (Washington, DC: December 1990), pp. S-6.

more rigorous evaluations of program effectiveness (including cost-benefits) should become integral to SECP planning and evaluation.[132]

Energy Extension Service--EES provides basic information, education, and training-such as audits and self-help workshops—to homeowners, farmers, small businesses, local governments, and other, small-scale public institutions. The purpose of the program, which is administered with the SECP, is to maintain a decentralized system of information to serve the local needs of small-scale energy users; technical assistance and demonstration projects are offered as well. EES programs are State designed, and DOE disburses funds through grants to State energy offices or other State entities designated by their governors to administer the program. States distribute these funds according to DOE-approved plans. Several examples of EES efforts convey a sense of the program (box 4-G).

A review of a State energy official survey suggested that on-site workshops, auditor training, and well-targeted information programs are the most effective part of the EES program. The study viewed general information dissemination as the least effective program function.[133] Reliable calculations of SECP and EES energy savings are extremely difficult to make on a national level given the diversity, small-scale, and decentralized nature of projects in both these programs.

Despite the lack of reliable data on energy savings, however, both programs are important networks for conveying Federal monies and expertise to the State and local level, and both programs are connected to small-scale energy users that could help DOE demonstrate technologies emerging from its energy conservation research and development projects. In addition, the auditor and other training offered by these programs help establish and sustain local expertise and markets for weatherization and other conservation services. Finally, SECP and EES efforts could complement other Federal programs (such as the Weatherization Assistance Program and the Institutional Conservation Program, both discussed above) that are designed to operate on the local level.

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[132] This was one of a series of recommendations in a 1982 General Accounting Office (GAO) report, and it is still pertinent today. In their report, GAO made a variety of recommendations for improving the SECP after States missed the 1980 national goal of reducing their energy use at least 5 percent. See U.S. Congress, General Accounting Office, *State Energy Conservation Program Needs Reassessing, EMD-82-39* (Gaithersburg, MD: April 1982).

[133] J. Clinton, H. Geller, and E. Hirst, "Review of Government and Utility Energy Conservation Programs,'' *Annual Review of Energy 1986* (Palo Alto, CA: Annual Reviews, Inc., 1986), vol. 11, p. 104.

Box 4-G-Examples of Energy Extension Service Projects[1]

- *School Lighting* (Washington): The Washington Energy Extension Service in cooperation with its State Energy Office has provided training to school districts on how to reduce energy use through lighting changes in classrooms, gymnasiums, and other school areas.
- *Cogeneration Demonstration* (Taos, New Mexico): With the assistance of Federal funds partially matched by the State's Energy, Minerals, and Natural Resources Department, the Taos Coronado Center, a local community meeting and business place, has installed a cogeneration system expected to save over $10,000 in energy costs annually.
- *State Government Lighting (Rhode* Island): A combined State, utility, and nonprofit group effort has leveraged Federal EES funds to upgrade lighting systems in State buildings, which are expected to reduce total State government electricity costs by 20 percent.
- *Seniors' Weatherization and Training* (Kentucky): The SWAT program is a combined effort, joining the State EES with seven local nonprofit groups. The nonprofits recruit and train volunteers to weatherize residences of the elderly. With materials donated by a major corporation, the SWAT team in 1989 offered information and weatherization services to over 850 homes in the State.

[1] U.S. Department of Energy, *Tenth Annual Report to Congress and the Secretary of Energy on the Nationwide Energy Extension Service Program,* DOE/CE-0266 (Washington, DC: March 1989), p. 10; U.S. Department of Energy, *Eleventh Annual Report to Congress and the Secretary of Energy on the Nationwide Energy Extension Service Program, DOE/CE-O291P* (Washington, DC: July 1990), pp. 8-10.

NONFEDERAL PROGRAMS TO PROMOTE ENERGY EFFICIENCY IN BUILDINGS

Efforts to promote energy efficiency in U.S. buildings have by no means been restricted to Federal initiatives; State, local, private sector, and utility programs have in many instances been seminal in promoting energy efficiency in U.S. buildings. This section reviews briefly some of these programs. The intent is not to provide a comprehensive list of all such programs but rather to provide some indication of the level of nonfederal activity. This will allow for a better determination of how Federal programs can best complement the existing network of other programs.

States and utilities have been leaders in implementing energy efficiency. State efforts include those by State energy offices, State-level R&D organizations and, perhaps most importantly, State regulatory agencies. In some States, utility regulators have aggressively promoted efficiency by requiring the development of utility conservation programs or by providing financial incentives for utilities to develop such programs.

State Programs

State efforts to promote energy efficiency in buildings vary greatly. Some States—notably California, New York, Wisconsin, and Massachusetts—have been very aggressive in pursuing building energy efficiency. State-level organizations implementing these programs vary as well, but in many States the lead organization is the State utility regulatory body, commonly the public utility commission. In some States the public utility commissions, via the utilities they regulate, have been strong proponents of energy efficiency. Utility programs are reviewed below.[134]

State-level efforts to promote efficiency are not limited to utility regulatory programs. Many States have State energy offices, which often administer Federal funds such as those from the DOE weatherization assistance program and from oil-overcharge funds.[135] State energy offices use a variety of programs to promote efficiency, including audits, loans, grants, and general information efforts. For example, the Washington State Energy Office operates an information clearinghouse with a staff of technical experts that responds to public inquiries

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[134] A detailed discussion of the role of utilities in implementing energy efficiency will be provided in OTA, "Utilities and Energy Efficiency," forthcoming,

[135] From 1973 t. 1981011 companies in the United States were subject to price controls on their crude oil and refined petroleum products. Investigations by the DOE's Economic Regulatory Administration uncovered a number of violations of these controls by oil companies. Many of these violations resulted in court decisions requiring oil company payments to DOE for use in State energy conservation programs. As of September 1987, oil companies had paid about $6 billion into a petroleum overcharge escrow account held by DOE. See U.S. Congress, General Accounting Office, *State's Expenditures of Warner Amendment Oil Overcharge Funds,* GAO/RCED-88-1 *19BR* (Gaithersburg, MD: May 1988).

about energy efficient construction for new commercial buildings.[136]

Some States have R&D agencies that are also active in energy efficiency (table 4-7). These agencies are typically funded by utilities, State revenues, or both and work closely with utilities, regulators, and State government officials to target R&D efforts in areas most relevant to their State needs.

At least 33 States have adopted mandatory building energy codes. Many of the remaining States provide model codes for their counties and local governments. Generally, State codes are based on the prominent codes issued by national organizations, primarily the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) and the Council of American Building Officials (CABO), However, some States such as California and New York have expanded their role from code adopters to code designers.

Local Programs

Historically, local governments have not been active in promoting energy efficiency in the private sector. There are, however, several notable exceptions. A few cities have responded to fiscal pressures by attempting to reduce energy consumption in city-owned buildings and equipment. The city of Phoenix, for example, has an active energy conservation program that has included lighting and heating, ventilating, and air conditioning (HVAC) retrofits to city-owned buildings, automated controls for lighting at city parks, and improved maintenance of HVAC units in city-owned buildings.[137] Electricity and/or gas service in some communities is provided by small municipal utilities, or 'munis,' which may have strong efficiency programs. The city of Palo Alto, California, for example, is served by a city-managed utility that offers a wide range of efficiency programs.

Many communities have building codes that may have energy requirements. Local building codes sometimes extend to the existing building stock as well. In San Francisco, for example, both residential and commercial buildings must meet energy efficiency levels as a condition of resale.[138]

Table 4-7-Selected State-Level Energy Efficiency R&D Organizations

Organization	Year established
California Energy Commission	1975
California Institute for Energy Efficiency	1988
Florida Solar Energy Center	1974
Iowa Energy Center	1990
Kansas Electric Utilities Research Program	1981
New York State Energy Research and Development Authority	1975
North Carolina Alternative Energy Center	1980
Wisconsin Center for Demand-Side Research	1990

SOURCE: Office of Technology Assessment, 1992.

Utility Programs

Utilities are in a unique position to implement efficiency programs for buildings: they have direct access to consumers and fuel use information, they have the resources and expertise to understand and respond to local conditions and markets for their service areas, and they can provide incentives and information to their consumers directly through their regular billing procedures. Readers interested in the role of utilities in efficiency are referred to a separate OTA report.[139] This section briefly outlines the types of building efficiency program utilities currently offer.

Utility involvement in energy efficiency is a relatively new development. Traditionally, utilities viewed their role as providing dependable electric and gas supplies at a reasonable cost; they were not involved in how the energy was used. In recent years, however, uncertainty over future demand, plant siting constraints, environmental regulations, and other concerns have put increasing pressure on

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[136] G. Caan, "The Washington State Energy Office Technical Unit: An Approach to Delivering Technical Services in the Public Sector, " *Proceedings of the ACEEE 1990 Summer Study on Energy Efficiency in Buildings* (Washington DC: American Council for an Energy-Efficient Economy, 1990), p. 7.17.

[137] City of Phoenix, "City of Phoenix Energy Conservation Program, ' Public Works Department, Phoenix, AZ, January 1991.

[138] K. Egel, J. Cook, and B. Knox, "Mandating Energy Efficient Commercial Buildings: San Francisco's Commercial Energy Conservation Ordinance,' *Proceedings of the ACEEE 1990 Summer Study on Energy Efficiency in Buildings* (Washington, DC: American Council for an Energy-Efficient Economy, 1990), p. 7.43.

[139] OTA, ' 'Energy Efficiency and utilities, " forthcoming.

utilities to plan better their future capacity needs.[140] One result of these forces is the emergence of a new concept of utility planning termed 'least-cost planning' (LCP), or, more recently, 'integrated resource planning' (IRP).

A basic idea behind these concepts is that consumers do not require energy per se but energy services (lighting, heating, cooling) and are therefore best served if these services are provided at the lowest overall cost. For example, it may be less expensive for a utility to install energy-efficient lights in offices than to build a new powerplant to meet the demand of less efficient lights. The service provided is the same, but the overall cost to provide it may be lower.[141]

Thus, LCP (or IRP) entails a process in which demand and supply options are evaluated together to determine how to meet consumer energy needs at the lowest cost; such planning is now practiced in at least 23 States.[142] Interest in such planning has also led to the aggressive promotion of demand-side measures in many States. These measures, often referred to as 'demand-side management' (DSM) efforts, include efficiency and other actions that reduce the total cost of energy services (e.g., ice storage, which may actually increase net consumption but which reduces peak electricity demand and therefore reduces net costs).

At present there are over 1,000 utility-run efficiency programs for the residential sector[143] and over 340 for the commercial sector.[144] Many utilities work closely with State regulators and with the private sector in designing, executing, and evaluating their programs. These programs include changes in rate structures, financial incentives such as rebates and loans, information programs providing audits and technical assistance, R&D, and demand-side bidding,

First Cost Reduction: Probably the most popular type of program for encouraging energy efficiency is a reduction in first cost. Tax credits, low-interest loans, grants, and rebates are often used by utilities to provide a financial incentive for efficiency by reducing the up-front costs. For example, over 20 utilities offer rebates to their commercial customers if they purchase energy efficient HVAC equipment.[145] Several utilities provide rebates to their residential customers for buying efficient refrigerators. Low-interest loans are often offered in conjunction with residential audit programs. A utility in Washington State provides its commercial customers with two free compact fluorescent lamps.[146]

Rates: Working with State public utility commissions, utilities have used changes in rate levels and rate structures to influence energy use. Traditionally rates are set at the State level, although the Public Utility Regulatory Policies Act of 1978 (Public Law 95-617) promotes the use of innovative rate structures, such as time-of-day, seasonal, and interruptible rates.

Most utilities currently offer a wide range of rate schedules. For example, the electric utility serving the District of Columbia offers 16 different rate schedules, including time-of-use rates for residences and demand/consumption[147] time-of-day rates for larger commercial customers.[148] The effects of these innovative rate schedules on consumption are

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[140] The electric utility industry is described in detail in U.S. Congress, Office of Technology Assessment, *Electric Power Wheeling and Dealing, OTA-E-409* (Washington, DC: U.S. Government Printing Office, May 1989), ch. 2.

[141] In fact, in this example the service (lighting) probably improves, as new energy-efficient lighting often provides higher quality light as well.

[142] A survey conducted in 1990 found that 23 States are practicing IRP, 8 States are in the process of implementing it. and 11 are considering it. See Edison Electric Institute, Rate Regulation Department, *State Regulatory Developments in Integrated Resource Planning* (Washington, DC: September 1990), p. 2.

[143] Battelle, *1988 Survey of Residential-Sector Demand-Side Management Programs*, EPRI CU-6546 (Palo Alto, CA: Electric power Research Institute, October 1989), p.iii.

[144] Battelle-Columbus Division, 1987 *Survey of Commercial-Sector Demand-Side Management Programs*, EPRI CU-6294 (Palo Alto, CA: Electric Power Research Institute, March 1989), p.iii.

[145] Ibid., p. 2-14.

[146] American Council for an Energy-Efficient Econom, (ACEEE), ' 'Lessons Learned: A Review Of Utility Experience With Conservation and Load Management Programs for Commercial and Industrial Customers, published by the New York State Energy Research and Development Authority (NYSERDA), Report 90-8, April 1990, Appendix.

[147] Meaning that customers are charged for both how much electricity they use at any one time (demand, measured in kW), as well as how much electricity they use over the entire billing period (consumption, measured in kWh).

[148] Potomac Electric Power Co., ' 'Rate Schedules for Electric Service in the District of Columbia,' Rates and Regulatory Practices Group, Apr. 3, 1990.

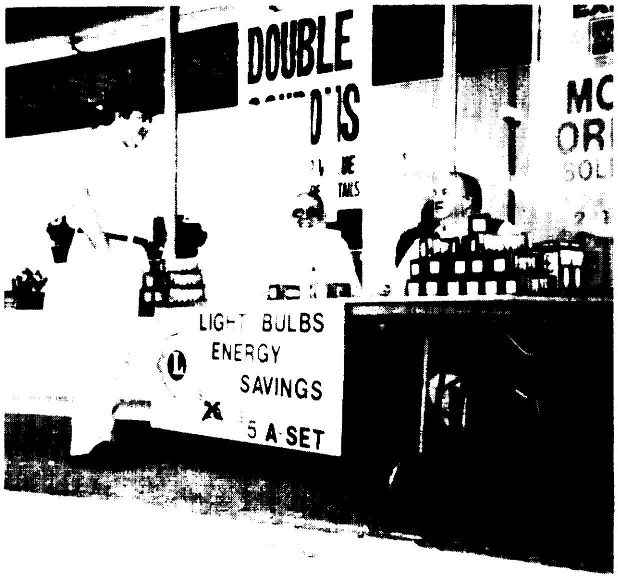

Photo credit: Paul Komor

Some utilities work with local service organizations to advertise, distribute, and sell efficient technologies at or below cost to interested consumers.

not well documented. There is some evidence that equipment design and operation is influenced by rate schedules in large commercial buildings. For example, a large office building in Arizona recently installed an ice-storage machine that makes ice at night when electricity is less expensive and then uses that ice during the day to cool the building.[149] The existence of time-of-use rates provided the necessary incentive.

Direct load control: This entails a utility paying its customers for the right to control directly their appliances, and the idea is used by over 350 Utilitles.[150] A utility serving Maryland, for example, gives residential customers a $9 credit on their monthly electric bill in exchange for the right to turn off their central air conditioner for short periods on peak demand days.

Information programs: Many utilities offer audits to their customers, in which an energy analyst visits the building, takes various measurements, and makes recommendations for specific energy-saving retrofits. In many cases the audits are tied to a low-interest loan for financing the recommended measures. Here again evaluations are scarce, but there is some evidence that coupling an audit with a loan program increases both participation rates and energy savings.[151]

There are other types of information programs as well. Wisconsin utilities, for example, have developed a labeling system for rental housing. The label, similar in appearance to those found on residential appliances, provides a measure of heating energy requirements. Another effort, the Energy Edge Project, is a $16-million program administered by several groups--one utility, two State energy offices, and a private company-and aims to demonstrate and evaluate efficient technologies for new commercial buildings.[152] And the Bonneville Power Administration's 'Blue Clue' program labels highly efficient appliances with blue ribbons.[153]

State regulators now typically require utilities to evaluate their efficiency programs to compare them with supply-side options. Unfortunately program evaluation is quite complex; several groups are working to improve the evaluation methods, but more work is needed. For example, the 'free rider' problem—where program participants would have performed the same actions without the additional incentive-complicates evaluation of these programs.

R&D: Utilities also conduct R&D, both at the individual utility level and via R&D consortia. The Electric Power Research Institute, for example, is funded by voluntary contributions from member utilities. Its 1991 R&D budget was $267 million, and

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[149] ''Ariz. Firm Keeps Energy Costs to a Quarter of Local Average, " *Energy User News,* June 1991, p. 1. In this case, total energy use may actually be higher than that from a traditional system, but electricity demand and energy costs are lower.

[150] Battelle, *1988 Survey of Residential-Sector Demand-Side Management Programs,* EPRI CU-6546 (Palo Alto, CA: Electric Power Research Institute, October 1989), p. 6.2.

[151] S. Nadel, ''Electric Utility Conservation Programs: A Review of the Lessons Taught by a Decade of program Experience, ' *Proceedings of the ACEEE 1990 Summer Study on Energy Efficiency in Buildings* (Washington, DC: American Council for an Energy-Efficient Economy, 1990), p. 8.181.

[152] W. Miller, S. Vogt, G. Vincent, J. Perry, K. Anderson, and G. Gaan, "~SSO13S Learned for the Energy Edge Project for New Commercial Buildings, " *Proceedings of the ACEEE 1990 Summer Study on Energy Efficiency in Buildings* (Washington DC: American Council for an Energy-Efficient Economy, 1990), p.7.1 17.

[153] Battelle, *1988 Survey of Residential-Sector Demand-Side Management Programs,* EPRI CU-6546 (Palo Alto, CA: October 1989), p. 4-17.

$36.2 million (14 percent) of this was budgeted for end-use research.[154] The Gas Research Institute (GRI) is funded primarily through contributions from interstate natural gas pipeline companies. The 1991 GRI budget was approximately $202 million, of which $95 million (47 percent) was allocated to end-use research.[155]

Demand-side bidding: A few utilities have used a bidding process to secure new electricity capacity. For example, a utility might request private companies to submit bids for providing the utility with 100 megawatts (MW) of new capacity. The bidder could use either new supply (e.g., cogeneration) or efficiency (e.g., a lighting retrofit) to 'supply' the needed capacity. Although the concept is conceptually appealing, initial experience with bidding has been mixed, and more research is needed, particularly in bid evaluation and the incorporation of performance uncertainties. In particular, high transaction costs and difficulty in measuring the effects of some efficiency programs (e.g., information and design assistance) have limited its use.[156]

As these examples suggest, a variety of utility programs have been used to implement energy efficiency in buildings, but there is little agreement on what works best, and program evaluation is a continuing concern. By one estimate, utility-run demand-side management programs led to national reductions in electricity consumption of 1.3 to 1.8 percent in 1990. Electricity demand reduction was estimated at 3.7 to 4.2 percent—about 20 gigawatts of summer on-peak demand.[157] The cost-effectiveness of these investments is somewhat uncertain. However, by one estimate, total utility expenditures for DSM are about $1.2 billion annually (1990).[158] This works out to about $180 per kilowatt, or less than one-half the capital cost of a gas turbine.[159] Although the uncertainty of this number must be recognized, it does suggest that in many cases DSM may be less expensive than traditional supply-side options.

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[154] Electric *power Research* Institute, *Research and Development Program 1991-1993* (Palo Alto, CA: January 1991), p. 7.

[155] Gas Research Institute, *1992-1996 Research and Development Plan and 1992 Research and Development Program* (Chicago, IL: April 1991), p.28.

[156] For a detailed discussion of bidding, see C. Goldman and D. Wolcott, ' 'De~d-Side Bidding: Assessing Current Experience, ***Proceedings*** *of the ACEEE J990 Summer Study on Energy Efficiency in Buildings* (Washington, DC: American Council for an Energy-Efficient Economy, 1990), p. 8.53. Also, Strategic Decisions Group, *Bidding for Electric Resources: An Industry Review of Competitive Bid Design and Evaluation,* EPRI CU-6089 (Palo Alto, CA: Electric Power Research Institute, May 1989).

[157] Barakat & Chamberlin, Inc. and EPRI, *Impact of Demand-Side Management on Future Customer Electricity Demand: An Update,* EPRI CU-6953 (Palo Alto, CA: September 1990), pp. **3-6, 3-7.** Savings are relative to a 1988 base year.

[158] S. Nadel, ''Electric Utility ComeNatIon Programs: A Review of the Lessons Taught by a Decade of Program Experience, *Proceedings of the ACEEE 1990 Summer Study on Energy Efficiency in Buildings* (Washington, DC: American Council for an Energy-Efficient Economy, 1990), p. 8.179.

[159] The initial Capital requirement for a gas turbine is about $400 per kilowatt. Electric Power Research Institute, *TAG Technical Assessment Guide-–Electricity Supply 1989,* EPRI P-6587-L (Palo Alto, CA: November 1989), vol. 1, Rev. 6, p. 7-55. Estimate in text assumes that DSM expenditures for 1988, 1989, and 1990 contributed to the DSM savings seen in 1990 and also assumes that DSM costs in 1988 and 1989 were the same as in 1990. This probably overestimates costs, because DSM expenditures have generally increased each year.

Chapter 5

Policy Options for the U.S. Congress

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Boxes

Chapter 5

Policy Options for the U.S. Congress

INTRODUCTION

Energy use in buildings accounts for an increasing share of total U.S. energy consumption—horn 27 percent in 1950 to 33 percent in 1970 to 36 percent in 1990.[1] At present, buildings account for over 60 percent of all electricity and nearly 40 percent of all natural gas used in the United States.[2] Fortunately new, highly efficient technologies are available that can provide needed energy services in buildings (e.g., heating, lighting, and cooling) while using significantly less energy. In many cases these technologies cost more initially, but these initial costs are paid back through reduced energy costs.

OTA has estimated that energy use in U.S. buildings could be reduced about one-third by 2015, relative to projected consumption without policy change, through the use of cost-effective, commercially available technologies.[3] Many other estimates of this savings potential exist and, although the results vary, there is general agreement that the untapped potential for improved energy efficiency in buildings is significant. Exploiting these opportunities would yield important benefits for the United States, including: 1) reduced energy expenditures, freeing up capital for other investments; 2) decreased environmental damage by offsetting energy production and use; and 3) reduced dependence on imported energy, enhancing national security.

There are several arguments for an enhanced Federal Government role in promoting energy efficiency.

—Numerous market imperfections lead to the selection of energy-using equipment that may not be societally optimal. These imperfections are discussed in detail in chapter 3 and include:

- When evaluating energy savings, consumers discount future savings very heavily—up to 50 percent or more;
- A separation between those paying for energy-using equipment and those paying to operate the equipment is common, leading to reduced incentives for efficiency;
- Decisions on the purchase and use of energy-using equipment require comparisons of many product attributes. When consumers make trade-offs during these decisions, which are often complex, these other product attributes often overshadow energy efficiency;
- Individuals pursue several goals when making energy-related decisions, but very few pursue the goal of minimizing life-cycle costs;
- Energy costs are relatively low (e.g., about 1 percent of salary costs in a typical office), so those concerned with cost reduction often focus their attention elsewhere; and
- Energy efficiency is often (mis)perceived as requiring discomfort or sacrifice, limiting its appeal.

Government programs and policies can be used to correct or minimize the effects of these imperfections.

—The numerous, untapped opportunities for energy savings that now exist suggest that current market conditions alone will not ensure the full implementation of these opportunities, although society as a whole may be better off if they were implemented.

—Energy production and use has significant environmental and other externalities (effects not captured in price), requiring government action to correct them.

Yet enthusiasm for a larger Federal role in energy efficiency must be tempered with a recognition of several important points:

- Attempts to increase energy efficiency through regulation or other governmental action may have unanticipated administrative or other costs;

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[1] Industry (37 percent) and transportation (27 percent) account for the remainder. Data include energy losses in the conversion and transmission of electricity. U.S. Department of Energy, Energy Information Administration, *Annual Energy Review 1990,* DOE/EIA-0384(90) (Washington, DC: May 1991), p. 13.

[2] Ibid., pp. 173, 215.

[3] Cost-effective is defined here as positive net present value to the consumer. See ch. 1 for a detailed discussion of energy savings estimates.

- Past Federal efforts to implement energy efficiency have had mixed success (see chapter 4);
- Current levels of energy efficiency reflect consumer preferences given existing economic incentives and levels of information; and
- Consensus on the best methods to promote efficiency is often lacking.

Innovative research and development by both the public and private sectors has yielded a number of highly energy efficient technologies. However at present many of these technologies are not being adopted at cost-effective levels.[4] This chapter discusses policy options to encourage greater use of cost-effective, energy efficient technologies.

POLICY OPTIONS

A variety of Federal policy actions could encourage greater energy efficiency in buildings. Although the options outlined in this chapter are quite diverse, several issues are worth recognizing when considering any options. Perhaps most importantly, there is no single policy that will address all impediments to efficiency. There are multiple technologies, decisionmakers, and energy users in buildings; the barriers to efficiency discussed in chapter 3 are diverse, and so must be the policies to overcome them. Greater attention in the future to program evaluation would yield better information on what works and what needs improvement, but at present levels of knowledge it is clear that several different policy approaches would be needed to improve energy efficiency in buildings.

The diversity of current State and utility programs provide a context to consider Federal policies for improving building energy efficiency. In almost all areas of energy efficiency policy-incentives; information; research, development, and demonstration (RD&D); regulation—numerous States and utilities are more active than the Federal Government. Increased Federal efforts would be most effective if they complemented these existing efforts. In most cases, States and utilities would welcome Federal support and assistance to promote energy efficiency in buildings; however, in a few areas—notably building codes and utility regulation—an enhanced Federal role would be controversial.

Policies for implementing energy efficiency in buildings can be divided into six types:

1. Increasing the incentives for efficiency-As noted in ch. 3, individuals often have few or mixed financial incentives for energy efficiency. Federal policies can address this issue by increasing or improving these incentives, e.g., through tax or pricing changes.
2, Federal leadership through procurement, public recognition, and demonstration-The Federal Government has considerable purchasing power due to its size, and this power can be used to increase the sales and distribution of energy efficient technologies.
3. Research, development, and demonstration for efficiency-The Federal Government conducts RD&D on buildings technologies, and changes in RD&D planning and execution could help improve the value and application of the results.
4. Encouraging utilities to invest in efficiency—Utilities are well-equipped to implement efficiency, and Federal actions can support utility efforts.
5. Mandating efficiency through codes and standards--In some cases regulation may be needed to set minimum efficiency levels, and such regulation may be most appropriate at the Federal level.
6, Improving information and awareness of efficiency opportunities-Information can enhance and support other efficiency programs such as rebates. As the benefits of information are diffuse, a government role in providing information may be appropriate.

Each type of policy is discussed separately, and a number of specific options within that type are presented. These specific options are grouped into three distinct levels, in order of increasing Federal involvement and energy savings. Many other levels are imaginable, but the three levels presented here are intended to illustrate the range of possible policies Congress could consider.

The *basic* level includes relatively low cost, simple policy options that require little or no new legislation or change from present practice. If Congress determines that changes are needed to effect improvements in energy efficiency, then the basic level could be considered as a first step. The *moderate* level includes several options that are more ambitious and in many cases require modify-

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[4] As discussed in ch. 1, there is general but not unanimous agreement that a considerable potential exists for cost-effective energy savings.

ing existing legislation and increasing Federal spending. The *aggressive* level includes options that are quite ambitious, require new legislation, or require an increased Federal role in energy regulation; the options on this level require additional funding.

Most of the policy options offered by OTA are intended to capture economically justifiable efficiency opportunities that are available but not realized under current market conditions. There is one exception: the incorporation of externalities (effects not captured in price) would in all likelihood raise prices and thereby shift this range of opportunities.

As discussed in chapter 4, the national effects of past Federal programs enacted to increase energy efficiency are often not known or have not been measured reliably. The likely effects of future Federal efforts are even more uncertain; technologies change over time, market response to Federal programs is poorly understood, many governmental programs work in tandem with others (making a program-by-program estimate of effects misleading), and the diversity of buildings and individuals affecting their energy use complicates predictions of the effects of any major policy change. Therefore, OTA does not provide estimates of the financial or energy savings associated with these levels or options. Moreover, OTA suggests that readers understand these limitations when considering *any* projections of energy savings associated with any proposed policy option.

Increasing the Incentives for Efficiency

As discussed in chapter 3, individual choices largely determine the level of energy efficiency in buildings—architects designing an office building, engineers specifying lighting systems for a business, or consumers selecting a new refrigerator, These choices are influenced by individual values, information, and perceptions of the costs and benefits of energy efficiency. A basic policy strategy to motivate greater energy efficiency, therefore, is to decrease the expense and/or increase the benefits of saving energy, which is the purpose of incentives.

A variety of incentives are available to encourage energy efficiency in buildings. This discussion focuses on incentives that the Federal Government could consider, including:

- energy pricing, particularly energy taxes, which could incorporate externalities into prices;
- evaluating and improving Federal grant programs that fund measures for building energy efficiency;
- making appliance efficiency rebates nontaxable; and
- incorporating energy efficiency into federally financed home mortgages.

Perhaps the simplest policy to encourage greater efficiency is to raise the price of energy through, for example, taxes. From an economic perspective, a guiding principle in setting prices is to reflect the true costs to society of producing and using goods and services, Energy may be ‘‘underpriced’ ‘—that is, its true cost to society may be higher than what consumers actually pay, because environmental externalities, government RD&D subsidies, and other costs are generally not reflected in energy prices. Several States have attempted to determine exactly what cost to attach to these factors and have integrated these calculations into their energy planning.[5]

Federal options to increase energy prices raise a number of issues, many beyond the scope of this report. For example, some argue that major increases in energy prices could place some U.S. businesses at a competitive disadvantage both domestically and internationally.[6] In addition, increasing energy prices through taxes or other means may raise equity concerns; low-income households, for example,

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[5] About 19 States currently have some provision for incorporating environmental externalities into energy planning. New York State, for example, attaches a penalty of 1.4 cents per kWh for electricity from a coal plant when considering bids for new generation. Vermont adds a 5 percent penalty (“adder”) to supply resources, and a 10 percent credit to demand-side resources, to reflect environmental externalities and the reduced risk of DSM. Massachusetts gives a 5 percent rate-of-return bonus to utilities for demand-side resources to reflect their environmental benefits. However, few States currently have provisions for explicitly incorporating externalities into actual energy prices. See Pace University Center for Environmental Legal Studies, *Environmental Costs of Electricity (New* York: NY, Oceana Publications, Inc., 1990); also Temple, Barker, and Sloane, Inc., Electric Power Research Institute, *Environmental Externalities: An Overview of Theory and Practice,* EPRI CU/EN-7294 (Palo Alto, CA: Electric Power Research Institute, May 1991).

[6] See, e.g., J. Anderson, *‘Presentation to the American Public Power Association’s National Conference,’ Electricity Consumers Resource Council (ELCON), Washington DC, June 18, 1991.

spend a larger share of their income on residential energy than do higher-income households.[7]

Federally funded grants are the principal tool used by the Federal Government, as measured by budget, to encourage energy efficiency in buildings. To illustrate, 84 percent of the Department of Energy (DOE) budget devoted exclusively to buildings energy conservation (including RD&D) is in the form of grants for retrofits to existing buildings; these grants totaled $230 million in 1991, while buildings conservation RD&D totaled $43 million that same year.[8] (Chapter 4 discusses Federal grant programs in detail, including specific suggestions for improving them.) However relatively little is known about the cost-effectiveness of the retrofits performed with these grant dollars, suggesting that greater attention to monitoring and evaluation is warranted.

Federal tax incentives could improve participation in a variety of efficiency programs, particularly those offered by utilities. The current tax treatment of utility rebates, for example, could be considered for change.[9]

In 1989 the Internal Revenue Service (IRS) ruled that utility rebates should be treated as taxable income. Some argue that taxing rebates limits consumer interest in them, thereby reducing the effectiveness of such programs.[10] Although a subsequent IRS ruling maintained that utility bill credits promoting the purchase of efficient appliances are nontaxable, evidence suggests that a cash rebate can be a much more powerful method of promoting efficiency than a bill credit. A rebate provides an immediate cash reward, while a bill credit can be confusing and obscure,[11] Furthermore, as noted in chapter 3, many individuals making equipment selection decisions (e.g., builders and landlords) do not pay the energy bills, making such credits irrelevant to their decisions.

If rebates remain taxable, utilities will either shift to bill credits (thereby missing many energy-related decisions), increase rebate amounts to account for the taxes (requiring greater utility expenditures to achieve the same response), or simply accept a lower response due to the reduced value of the rebate to consumers. The cost to the U.S. Treasury of making rebates nontaxable is uncertain; by one estimate, utilities spend about $200 million annually on residential rebates.[12] Assuming this figure is accurate and that commercial sector rebate spending is the same, and assuming a combined marginal tax rate of 20 percent, the lost revenue by not taxing rebates could be as high as $80 million per year. On the other hand, indirect revenue gains could offset these potential losses if consumer savings were expended on other, taxable activities. Clearly, understanding the effects on the Treasury of making rebates nontaxable would require considerable analysis. The response to utility rebate programs, however, will invariably be lower if rebates continue to be taxed than if they were made tax-free.

Tax credits are another form of tax incentive that could be used to improve energy efficiency in U.S. buildings. As discussed in chapter 4, U.S. experience with residential conservation tax credits reveals uncertain results, but the potential costs and benefits of offering such credits in the future are worth assessing. One drawback with tax credits is that, unlike utility rebates, tax credits are not received at the time of purchase but only after a tax claim is filed.

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[7] U.S Department of Energy, Energy Information Administration, *Household Energy Consumption and Expenditures 1987, part 1: National Data,* DOE/EIA-032 *1(87)* (Washington, DC: October 1989), p. 46. One way to correct the potential equity problems of increasing energy prices is to link price increases with a simultaneous and similar decrease in low-income tax rates. Providing low-income rebates is another option. Either approach could be revenue-neutral.

[8] U.S. Department of Energy, *United States Department of Energy Fiscal Year 1992 Congressional Budget Request,* DOE/CR-0001 (Washington, DC: February 1991), vol. 4, pp. 272-273.

[9] An increasing number of utilities offer rebates t. their customers who purchase energy efficient equipment. In one recent survey, at least 106 U.S. utilities were identified as offering customer rebates. *Rebate Report,* D & R International (Silver Spring, MD), vol. 2, October 1991, pp. 1-7. Rebate programs are seen by many utilities as a powerful tool for implementing efficiency, because rebates for appliances-much like rebates for cars-provide an instant cash reward for the desired behavior.

[10] Determining consumer response to rebate taxation is difficult, but the perceived value of the rebate is certainly reduced by taxation. Research in the residential sector has found that the "hassle factor" is an important constraint on efficiency, and taxing rebates clearly adds to the complexity and paperwork of the program.

[11] See testimony of Thomas D. Morron, Vice President, Edison Electric Institute, before the Senate Committee on Finance, Subcommittee on Energy and Agricultural Taxation, June 14, 1991, p. 8.

[12] C.M. Antinori, "Will Taxes Still Bite Into Rebates?" *Home Energy, vol. 8, No. 3,* May/June 1991, p. 11.

Box 5-A—The Residential Mortgage Industry and the Federal Government

The Federal Government has long played a role in encouraging the availability of housing at a reasonable cost, and much of that Federal support has been through insuring, purchasing, or otherwise supporting mortgages. Today, the Federal Government participates in the mortgage industry in both the primary and the secondary markets. In the primary market, about 18 percent of new single-family home sales are financed with direct Federal Government backing through the Federal Housing Administration (FHA), the Veterans Administration (VA), and the Farmers Home Administration (FmHA) (table 5-A-l).

Table 5-A-l—Financing of New, Privately Owned Single-Family Houses, 1988

Financing source	Percent of houses
Conventional	63
Federally financed:	
FHA-insured.	13
VA-guaranteed.	4
FMHA.	1
Cash/equivalent.	18

NOTE: Percents do not sum to 100 due to rounding.

SOURCE: U.S. Department of Commerce, Bureau of the Census, *Statistica/Abstract of the United States: 7990* (Washington, DC: U.S. Government Printing Office, January 1990), p. 715.

In the secondary market, several institutions created by the Federal Government-notably the Federal Home Loan Mortgage Corporation (Freddie Mac), the Federal National Mortgage Association (Fannie Mae), and the Government National Mortgage Association (Ginnie Mae)-purchase conventional mortgages from original lenders such as banks and credit unions. The requirements of these federally sponsored institutions, therefore, can influence conventional mortgages in areas such as building efficiency.

Energy efficient mortgages (EEMs) are another response to first cost barriers that commonly limit building energy efficiency. A mortgage is typically a long-term, relatively low-interest source of funds and offers a practical means of capitalizing efficiency investments in buildings. The Federal Government plays a significant role in both the primary and secondary mortgage market (box 5-A), suggesting that mortgages could be a viable Federal policy lever to pursue energy efficiency in buildings.

Energy efficient mortgages can work in several ways. Once a new home is deemed "energy efficient," the portion of income a buyer can spend on monthly mortgage payments can be increased—e.g., from 28 to 30 percent. The underlying rationale is that an efficient house will have lower monthly energy costs, and the resulting savings could be applied to the mortgage payment. Homeowners benefit because overall housing costs (which include mortgage and energy) can remain constant or even decrease (box 5-B), and they acquire a more valuable

Box 5-B—How a More Efficient House Can Cost Less

The conventional wisdom holds that efficiency costs more than standard practice. If one uses mortgages to finance efficiency, however, even measures with relatively long paybacks can result in lower, not higher, housing costs.

As discussed in chapter 2, the use of superinsulating technologies can reduce space heating energy requirements by 80 to 90 percent at an additional first cost of about $4,000 to $7,500 per house. The average new gas-heated house in the Midwest costs $477 per year to heat and $81 per year to cool[1] Assuming superinsulation could reduce space-conditioning energy use 85 percent, the dollar savings would total $474 per year ($477 + $81, times 0.85), or about $40 per month. Assuming an additional first cost of $5,750 for the superinsulation, the simple payback (assuming no energy price increases) would be an unimpressive 12.1 years. However, if the additional $5,750 was financed through a 30-year, 8-percent mortgage, the increase in the monthly mortgage bill would be $42. The net additional monthly cost for superinsulation, therefore, would be $42 (addition to mortgage) minus $40 (energy savings), or $2. If energy prices rose at 3 percent per year, energy savings would exceed the addition to the mortgage after 2 years. Thus, after 2 years the superinsulated house would result in a lower monthly housing (mortgage plus energy) cost.

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[1] J. Koomey, J. McMahon, C. Wodley, *Improving the Thermal Integrity of New Single-Family* Detached Residential Buildings, LBL-29416 (Berkeley, CA: Lawrence Berkeley Laboratory, July 1991), p. 34.

house. Lenders can benefit because borrowing increases (assuming risk does not increase as well).

A second type of energy efficient mortgage applies to existing homes. Allowing efficiency improvements to be financed as part of the mortgage provides a relatively low-cost source of capital for efficiency improvements and can also reduce overall housing costs, which include energy payments, if the additional mortgage payment is more than outweighed by the energy cost reduction.

A third type of energy efficient mortgage includes projected energy costs in the mortgage calculations. A typical mortgage is based on a calculation of the costs of principal, interest, taxes, and insurance (PITI). Adding energy costs (PITI+E) to this calculation could improve the financial attraction of a home that costs more but uses less energy. The difficulty with this approach is making a reliable prediction of energy costs, which are influenced by occupant behavior, energy price changes, weather, and other variables.

Provisions for energy efficient mortgages already exist but are almost never used. A random sample of 5,000 Federal Housing Administration (FHA) loan files, for example, found only one loan that used an EEM.[13] Possible explanations for low EEM participation include lack of awareness, paperwork requirements, and the threat of delays or even loan cancellations stemming from the additional requirements.

Incentives: Basic Options

DOE spends about $230 million per year, and the Department of Health and Human Services (HHS) about $130 million per year, on grants for energy conservation retrofits in buildings, yet few data on the cost-effectiveness of these grants are available. Congress could direct DOE and HHS to set aside an adequate amount of program spending for program evaluation. Such evaluations could measure the costs and benefits of each program and identify areas requiring improvement. Utilities typically spend 3 to 10 percent of their demand-side program budget on evaluation. Although OTA was unable to determine exactly what fraction of Federal grant spending is applied to evaluation, it may be considerably lower than this.

Energy costs may not currently reflect their true costs to society due in part to their failure to incorporate environmental and other externalities. Methods to measure and evaluate these externalities need improvement if efficient pricing is to occur. Congress could direct and fund DOE to expand research on the measurement and pricing of externalities associated with energy production, distribution, and consumption. Such externalities need not be limited to environmental or negative effects, and they may not always favor the most energy efficient technologies, but measuring them could reveal their magnitude and importance to the U.S. economy. Of course, regulatory programs can have the effect—whether directly or indirectly-f pricing externalities; for example, Federal and State environmental regulations often require the mitigation of externalities associated with energy production and use, which commonly introduces costs. More directly, several States incorporate environmental externalities to some degree into energy planning. At a minimum, such State efforts could benefit from a better understanding of the true costs of currently uncaptured energy externalities.

Incentives: Moderate Options

Congress could pass legislation making utility rebates nontaxable. Taxing appliance rebates reduces the potential impact of utility incentive programs by limiting the financial gains from purchasing efficient units. By making utility rebates nontaxable, Congress could enhance utility rebate programs.

Congress could enact or increase taxes on the production and use of fuels consumed in the buildings sector. In addition to providing deficit-reducing revenues, such taxes would spur efficiency improvements as well as the market for demand-side services. Even though U.S. energy prices are among the lowest in the industrial world, the benefits of energy taxes would have to be weighed against the potential economic and trade effects of enacting or increasing such taxes.

Congress could direct and fund DOE to provide technical and financial assistance to States interested in measuring and pricing energy externalities. As noted above, at least 19 States have some provisions for incorporating externalities into

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[13] W. Prindle, "Energy Efficient Mortgages: Proposal for a Uniform Program," *Proceedings of the ACEEE 1990 Summer Study on Energy Efficiency in Buildings* (Washington DC: American Council for an Energy-Efficient Economy, 1990), p. 7.155.

their energy planning. DOE could assist these and other States interested in improving this aspect of their energy planning, particularly as the nature and impact of externalities can vary greatly by State.

Congress could direct the Federal housing and national mortgage agencies to simplify and expand their energy efficient mortgage programs. Energy efficient mortgages are available but rarely used. As discussed above, this option could improve the affordability of many homes, which is especially important for first-time buyers, and it could increase the amount of business conducted by lending institutions. Simplifying the paperwork requirements in obtaining energy efficient mortgages, more visible promotion of the programs by the Federal and State Governments and lenders, and possibly improving program design and marketing would encourage greater use of these neglected financial options.

Incentives: Aggressive Options

Congress could mandate the measurement and pricing of energy externalities. This could occur gradually, over a period of years or even decades. At present, the most frequently discussed externality associated with energy production and use is environmental pollution, but the extent and nature of many environmental externalities are often poorly understood, and attempting to assign dollar values to them would be controversial. One currently discussed option is to levy a carbon tax based on the carbon dioxide emissions associated with fossil energy consumption. Other major pollutants associated with building energy use include sulfur oxides (SO_x), nitrogen oxides (NO_x), and chlorofluorocarbons (CFCs). These other externalities could be addressed through end-use taxes (which already exist for major CFCs), reductions of Federal energy supply subsidies, or increases in royalty fees for energy exploration and development on public lands.

A national effort to price energy externalities could begin with the Federal sector. Establishing select procurement criteria that cost major externalities (e.g., the use of CFCs in building heating, ventilating, and air conditioning (HVAC) systems) could provide useful lessons about how to conduct such an effort on a national scale. Federal energy programs could also stress the evaluation and incorporation of externalities in their regulatory efforts, including appliance labeling, building and appliance standards, RD&D planning, and utility demand-side management support.

Federal Leadership: Procurement, Recognition, and Demonstration

The purchasing power of the Federal Government, and the resulting ability to demonstrate innovative technologies and to develop their markets, is immense. Major efficiency gains could be attained through procurement and demonstration efforts that do not rely on conventional policy tools such as national efficiency standards, tax incentives, and information dissemination. In addition, the Federal Government could encourage efficiency through voluntary public recognition programs stressing environmental stewardship, economic competitiveness, or other valued attributes of energy efficiency, These approaches are voluntary and rely primarily on the market.

Policy options to improve the energy efficiency of the Federal sector are discussed in a separate OTA report.[14] That report stressed the value of Federal procurement to support markets for efficient products and services, as well as to demonstrate efficiency measures for private sector applications.[15] Some of these options are discussed below.

Energy efficiency has both environmental and economic benefits, and an innovative, voluntary Federal program has been designed to provide public recognition to organizations for their contributions to environmental protection through energy efficiency. In the Green Lights program, operated by the Global Change Division in the Office of Air and Radiation at the Environmental Protection Agency (EPA), participating companies agree to survey and upgrade lighting equipment, where appropriate, as long as such upgrades are profitable to the company and do not compromise lighting quality. EPA agrees to provide technical support and information and, perhaps more importantly, to provide public recognition to participating companies for their contribu-

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[14] U.S. Congress, Office of Technology Assessment, *Energy Efficiency in the Federal Government: Government by Good Example?, OTA-E-492* (Washington, DC: U.S. Government Printing Office, May 1991).

[15] Ibid., pp. 105-113.

tion to environmental protection.[16] Thus far, corporate response to the program has been impressive, due in part to the high value participants place on public recognition and positive publicity. Furthermore, participating companies welcome a voluntary, mutually beneficial alliance with a regulatory agency.

Another program, called the Golden Carrot, involves the EPA, utilities, environmental organizations, and a State energy office in a voluntary effort to build and demonstrate highly efficient refrigerators. The utilities will offer rebates to consumers that purchase the advanced refrigerators, which are intended to be at least 25 percent more efficient than 1993 Federal standards will require, consumers are given a financial incentive to purchase what promise to be highly efficient units, and manufacturers are guaranteed a market for their product by the utility. With guarantees of Federal procurement, similar programs might enjoy even larger markets.

Federal Leadership: Basic Options

Encourage energy efficiency in Federal buildings by changing procurement guidelines for energy-using equipment so as to incorporate energy efficiency. As mentioned, the Federal market for energy-using technologies is substantial. Procurement policies that advance efficiency could be implemented *and enforced,* Such policies could include revising Federal procurement guidelines to implement life-cycle costing techniques (which would tend to favor cost-effective efficiency technologies); providing financial and other awards (such as bonuses or shared savings) to individuals and agencies responsible for achieving energy cost savings; and establishing guidelines that set minimum efficiency levels for purchased equipment.

Extend the EPA Green Lights concept to other contexts. The EPA program is an innovative voluntary effort that could serve as a model for other programs. For example, the Federal Government could recognize commercial firms that improve significantly (by some pre-determined measure) the efficiency of their space conditioning equipment without compromising comfort. Another possibility is to recognize publicly developers that construct a certain number or fraction of buildings in any year that surpass a given energy efficiency guideline. Such efforts could be recognized for their energy, environmental, or other merits.

Federal Leadership: Moderate Options

Allocate (or increase access to) funds for efficiency improvements in Federal buildings. Resources could be channeled through a revolving Federal fund,[17] as earmarked monies designated exclusively for building efficiency improvements (usable only if energy audits indicate that proposed measures are warranted and cost-effective), or through policies encouraging Federal participation in utility demand-side management, cost sharing, rebate, or other private financing options.

Encourage manufacturers, utilities, and other interested parties to extend the Golden Carrot program concept to other technologies for demonstration and marketing. Collaborative, voluntary programs providing incentives for increased efficiency, such as the Golden Carrot program, could be extended to other technologies-freezers, water heaters, heat pumps, clothes washers—using Federal efficiency standards as benchmarks to surpass,

Federal Leadership: Aggressive Options

Actively promote the demonstration of efficient technologies in Federal buildings to strengthen markets for energy efficient goods and services. One way to promote this is to allow participating agencies to retain some portion of their financial savings in exchange for taking the risk of using an innovative technology.

Federal RD&D in the Buildings Sector

Research, development, and demonstration (RD&D) is the process that generates new technology for adoption in the marketplace. This process drives the improvement of technologies that increase energy efficiency and reduce energy use in buildings. In general, only industry and the State and Federal Governments have the resources and interest to sustain this process.

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[16] According to EPA, ''EPA will publicly recognize successful Green Lights corporations. It intends to credit those companies for their contributions to pollution prevention, and seeks to ensure that customers, shareholders, employees, and the public are aware of their achievements in protecting the environment with energy efficiency. From J. Lawson and B. Kwartin, ''Green Lights on Energy Savings, ' *LD+A*, February 1991, p. 7.

[17] For a state-level example of such a program, see M. Verdict, J. Haberl, D. Claridge, D. O'Neal, W. Heffington, W. Turner, ' 'Monitoring $98 Million in Energy Efficiency Retrofits: The Texas Loanstar Program, ' *Proceedings of the ACEEE 1990 Summer Study on Energy Efficiency in Buildings* (Washington. DC: American Council for an Energy-Efficient Economy, 1990), p. 7.261.

The building sector is highly fragmented by region, size, and function-from builders to equipment manufacturers, architects to real estate professionals. For example, single-family residential construction firms in the United States alone number over 90,000.[18] In addition, there are thousands of building equipment manufacturers and hundreds of architectural and engineering fins.[19] This fragmentation makes it difficult for the building sector to pool its resources to conduct RD&D. In addition, this industry, as with any other in the United States, is driven by the need to sustain profits in the short-term, which tends to discourage RD&D because of its high costs and uncertain returns. Yet RD&D generates technologies that improve performance, increase reliability, save energy, and reduce costs for this sector. As a result, the Federal Government has a critical role to play in identifying, planning, and funding RD&D in the buildings sector.

For all sectors—but buildings in particular-there are several critical issues worth considering in the development of an RD&D agenda for the Nation:

Selecting a mix of research projects given limited resources: The Federal energy RD&D program is a mix of basic and applied research that addresses both demand and supply technologies. (Most of the comments in this section relate to applied research.) The relative attention and funding given to these various project types reveals the relative weighting of priorities (whether or not they are stated) in an RD&D program. Thus, policymakers and program planners have to consider the overall mix of their total RD&D effort in setting programwide research goals-and identify the most promising individual projects worthy of research—in order to determine the optimal allocation of often limited RD&D resources.

Identifying non-hardware research needs: The conventional notion of research involves technological hardware development, but building design tools, improved operations and maintenance (O&M) practices, computer software, and behavior-oriented research offer numerous opportunities to help implement emerging technologies, improve existing programs, and reduce energy use. These non-hardware technologies are worth identifying and improving; they include, for example, computer systems to monitor and regulate whole building systems for optimal energy efficiency, econometric methods to evaluate energy conservation programs, tools for conducting least cost planning, and social science and marketing analyses to improve technology transfer.

Improving program planning by defining and integrating technology-specific and program-specific goals: Technology-specific goals and better RD&D program planning are essential for Congress and DOE to assess the merits of technologies chosen for development, as well as the benefits the Nation can expect to realize with DOE RD&D investments. Without well-defined program goals, there is no guarantee that the selection of technology-specific research projects will adhere to consistent principles or have a consistent direction. And without technology-specific research goals, broad program goals function as little more than wish lists. Both sets of goals (program-wide and technology-specific) should be recognized as interdependent and should be made as specific as possible, with the links between them made clear (box 5-C).

Involving industry in project planning, funding, and execution: This would increase the probability of interest in (and a market for) technologies that are successfully developed and demonstrated. Involving industry (to the extent practical) at the outset of project planning would also improve the chances that new technologies not only save energy but also consider the concerns of manufacturers and others--concerns that are typically broader than just energy efficiency and might include required changes to manufacturing processes, cost, reliability, and consumer interest. The fragmentation of the buildings sector could complicate industry involvement; unlike the transportation sector, where a few major manufacturers dominate the industry, the buildings industry consists of a diversity of firms with greatly differing financial and technical resources. However, the potential benefits of increased industry involvement suggest that its pursuit in RD&D would be worthwhile.

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[18] U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States: 1991* (Washington, DC: U.S. Government Printing Office, 1991), p. 715.

[19] M.A. Brown, *Technology Transfer Strategies of the U.S. Department of Energy's Conservation Program*, ORNL/CON-277 (Oak Ridge, TN: Oak Ridge National Laboratory, December 1988), p. 47.

Box 5-C—The DOE Multi-Year Program Plan

Since 1983, the Department of Energy Office of Conservation and Renewable Energy has used a multiyear planning process to establish national conservation goals and to organize technology-specific projects. Currently termed the "Multi-Year Program Plan" (MYPP), this annual process culminates in the publication of an internal DOE document that covers the 5 fiscal years subsequent to the upcoming year; thus, the MYPP developed in 1991 covers fiscal years 1993 to 1997.[1] While the MYPP establishes ambitious national program goals and outlines the technologies that are being targeted for development to help meet those goals, the document does not generally indicate long-term goals for the actual technologies beyond their development nor does it indicate the expected economic returns from DOE funding allocated for these projects.

For example, the portion of the current MYPP relating to buildings research defines one goal: to hold constant to 2030 the use of nonrenewable energy in U.S. buildings.[2] However, the document neglects to indicate the relationship between this goal and the technology-specific research proposals outlined in the report; there is no ledger that sums up or projects the contribution of the technologies that will contribute to the DOE goal. In short, at least for building-related RD&D, there is no identifiable connection between DOE program objectives and DOE projects. This is important, because the technical merits of any particular project need to be weighed against other proposals; many research ideas have merit, but not all can be pursued. A better planning process will better determine an optimal portfolio of promising conservation projects.

Of course, developing and analyzing methods to integrate long-term program goals with multiyear research plans would shift some resources away from RD&D to internal administration, but this shift could be small relative to the entire Office of Conservation and Renewable Energy budget, and it could improve considerably what is achieved with that budget. At present, the Department could better seine public RD&D objectives through the MYPP process in at least two ways. First, where practicable, DOE could attempt to delineate more clearly the expected end-use results (including costs and benefits) of each technology-related RD&D project, Second, DOE could open the process to include more public and industry review of these planning documents. Such changes to the MYPP planning process could help the Department link better its program objectives with its technology-specific projects.

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[1] U.S. Department of Energy, Office of Conservation and Renewable Energy, *Multi-Year Program Plan Fiscal Years 1993-1997, DOE/CE-0329* (Washington DC: U.S. Department of Energy, April 1991). Note: This document is used for internal DOE plarming and is listed as "administratively confidential." As a result, OTA does not discuss specific projects or budget figures contained in the report.

[2] Ibid., vol. I, p. 6-8.

On the other hand, lack of industry interest in any project is not by itself sufficient reason to abandon a good idea. Federal RD&D policymakers must weigh broader, more long-term issues than can be expected from the building industry. Federal initiative and funding has helped speed the development of key building energy efficiency technologies, such as solid-state ballasts and low-emissivity (low-e) windows, at times when there was little initial industry interest in developing them.[20] Industry interest, therefore, should not solely determine whether the Federal Government funds an RD&D project,

One promising option for increasing industry involvement in project planning is the use of an outside review panel, such as the Critical Review process, which was developed by the DOE conservation office in 1985. This process convened independent panels to assess the merits and direction of DOE conservation RD&D projects under consideration but, as reported by the General Accounting Office (GAO), the Critical Review program was seldom used even though it was recognized as useful in project planning.[21] A program like Critical Review is helpful in promoting industry participation in DOE project planning and implementation,

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[20] H. Geller, J.P. Harris, M.D. Levine, and A.H. Rosenfeld, "The Role of Federal Research and Development in Advancing Energy Efficiency: A $50 Billion Contribution to the US Economy," *Annual Review of Energy 1987* (Palo Alto, CA: Annual Reviews, Inc., 1987), vol. 12, pp. 357-395.

[21] U.S. Congress, General Accounting Office, *ConservationP/arming and Management Should Be Strengthened,* GAO/RCED-90-195 (Gaithersburg, MD: U.S. General Accounting Office, July 1990), pp. 27-35.

especially in assessing issues such as the technical and economic potential of existing technologies, the clarity and soundness of project goals, and potential obstacles to technology transfer once a new technology has been demonstrated successfully. Nonetheless, the Critical Review program was terminated in 1990.[22]

Engaging in demonstration and technology transfer: This is the process by which lessons from the laboratory are applied in practice. Technology transfer is the ultimate goal of RD&D programs. No *applied* research project is truly successful unless its results are implemented. After the development of new efficiency technologies, successful demonstration and marketing are critical to ensure that they reach the market. After an initial emphasis on technology transfer, the DOE RD&D program in the 1980s changed focus. In the last decade, DOE RD&D has concentrated on long-term, high-risk research efforts that the agency believed would not be undertaken by private industry.[23] DOE relied on the private sector to press the transfer of new energy technologies once they were developed, but the results of that reliance were often mixed.

In the buildings sector, for example, DOE-funded research led to the development of residential heat-pump water heaters, a technology that consumes far less energy than conventional electric resistance water heaters. However, these units have shown minimal market penetration due to their high first cost; currently, less than one percent of water heaters sold make use of the new heat pump technology.[24] As these heaters have the potential to achieve large residential energy savings, there is a key role for improved technology transfer because participation of more manufacturers and vendors could lead to reduced costs.

According to a 1989 review by the Oak Ridge National Laboratory, "DOE's technology transfer funds are typically very limited."[25] The most recent DOE report on technology transfer in the DOE buildings program confirms the general emphasis on technology development over technology transfer.[26] Recognizing the need for research with practical applications, DOE has taken an encouraging step with its RD&D agenda. The Department maintained that the energy RD&D program in 1991 would begin to balance better high-risk basic research projects with applied research having more immediate practical applications.[27]

Expanding demonstration and technology transfer activities would increase the probability that the fruits of DOE-funded research gain industry and consumer acceptance and thereby enjoy wider use in the marketplace. To make this change would not necessarily require changes in total funding but could entail a basic requirement that all technology RD&D projects (or the overall RD&D program) incorporate a distinct and adequately budgeted demonstration and technology transfer component prior to their initiation. These resources could then be available whenever successful research projects needed further DOE attention to ensure product development and marketing.

A different kind of arrangement, the cooperative research and development agreement (CRADA), has received increasing attention since the passage of the Federal Technology Transfer Act of 1986 (Public Law 99-502). This statute created incentives for Federal agencies and national laboratories to execute CRADAs to improve the transfer of Federal research results to the private sector. In brief, these agreements ease the restrictions on Federal-private cooperation by, for example, allowing Federal laboratories to grant exclusive licensing arrangements with parties collaborating on RD&D projects (e.g., private industry, State and local governments, and nonprofit groups) and allowing Federal laboratories to use funds provided by nonfederal parties

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[22] Kenneth Friedman, DOE Office of Conservation and Renewable Energy, personal communication% Jan. 16, 1991.

[23] This is reflected in the portfolio of research projects selected in the 1980s, as well as key policy documents published by the agency. For example, see U.S. Department of Energy, *The National Energy Policy Plan,* DOE/S-0040 (Washington, DC: 1985), pp. 34-35.

[24] Carl C. Hiller, Senior Project Manager, Residential Systems, Electric Power Research Institute, personal communication, Mar. 4, 1992. See also M.A. Brown, L.G. Berry, and R.K. Goel, *Commercializing Government-Sponsored Innovations: Twelve Successful Buildings Case Studies,* ORNL/CON-275 (Oak Ridge, TN: Oak Ridge National Laboratory, January 1989), pp. 75, 86, 123.

[25] Ibid., p. 121.

[26] U.S. Department of Energy, Office of Building and Community Systems, *Analysis and Technology Transfer Annual Report 1988, DOE/CH/00016-H2* (Washington, DC: May 1989), pp. ES-1, 2-9.

[27] U.S. Congress, General Accounting Office, *DOE's Allocation of Funds for Basic and Applied Research and Development,* GAO/RCED-90-148BR (Gaithersburg, MD: May 1990), p. 11.

participating in Federal RD&D projects.[28] At present, the DOE Office of Building Technologies (OBT) is participating in at least three CRADAs.[29]

Performing program evaluation: As discussed in chapter 4, formal evaluations of DOE building energy programs, including conservation RD&D, are rare. Such evaluations identify program achievements as well as implementation problems. Although long-range planning and budgeting are conducted annually for 5-year periods in the DOE conservation program, program-wide RD&D evaluations are not conducted on any regular or visible basis.

The general scope of OBT RD&D projects—as well as a select number of their successes—are well-documented, but there is no consistent method employed by the Department that compares the costs and benefits of projects during or after their execution, that evaluates how program planning and funding contribute to actual project results, or that indicates measurable energy and economic gains expected from the improvement of technologies under development. Program evaluations that incorporated these issues would enhance long-term RD&D planning and define better the purposes and expected results of specific RD&D projects. Such evaluations would be most valuable if they allowed cross-program comparisons and considered both demand and supply RD&D.

Funding: A predictable policy option is to increase funding for a particular activity. Although this would expand the scope of the Federal building conservation RD&D effort, it would not, by itself, ensure a better one. Improving planning, setting realistic goals, cooperating more closely with industry, identifying technology transfer opportunities, and performing program evaluations are equally vital to the success of the DOE-applied RD&D program for buildings. Of course, performing most of these tasks would require additional resources, unless Congress and DOE are willing to reduce the number of building conservation RD&D projects and shift more resources to fewer projects. But if Congress determines that the current OBT goal—holding nonrenewable energy use in U.S. buildings constant until 2030-is a realistic and desirable one, then current buildings conservation RD&D funding (in the range of $50 million per year) is probably too low.

RD&D: Basic Options

Congress could require all DOE Office of Building Technologies (OBT) applied research projects reaching the demonstration stage to conduct some minimum level of technology transfer and market assessment. One simple but relatively inflexible method for ensuring such work would be to establish a minimum percentage of funding for these functions as part of all applied OBT projects or, alternatively, as part of the entire program budget. A better method would address the process that incorporates technology transfer into project planning and execution. This would guarantee that technology transfer is conducted for all applied research projects that have demonstrated technological advances. Such a requirement should not apply to basic or high-risk RD&D work, where transferable achievements are not expected in the short-term.

Specific provisions for technology transfer in each applied RD&D projector for the entire applied research program increase the probability that research success is actually applied beyond the laboratory. The Stevenson-Wydler Technology Innovation Act of 1980 (Public Law 96-480) *inter alia* required each Federal laboratory to establish an Office of Research and Technology Applications (ORTA) to conduct technology transfer from the labs to State and local governments and the private sector and directed each lab with a total annual budget exceeding $20 million to place at least one full-time professional in its ORTA. Federal agencies that operated or directed one or more national laboratories were required to earmark a minimum of 0.5 percent of their RD&D budgets to fund technology transfer efforts at their respective agencies and at their labs, including support for each ORTA.[30] This funding earmark was later repealed (Public Law 101-189), because Congress determined that agencies were using their discretionary authority under

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[28] U.S. Congress, General Accounting Office, *Diffusing Innovations: Implementing the Technology Transfer Act of 1986,* GAO/PEMD-91-23 (Gaithersburg, MD: May 1991), pp. 7,76.

[29] U.S. Department of Energy, Office of Conservation and Renewable Energy, *Conservation and Renewable Energy Technologies for Buildings,* DOE/CH10093-85 (Washington, DC: May 1991), p. 20.

[30] Public Law 96-480, 94 Stat. 2318, sec. 11.

the Stevenson-Wydler Act to waive the requirement.[31]

Flexibility in Federal RD&D program planning is essential, but technology transfer is too vital to the success of research programs, in OTA's view, to eliminate completely some minimum level of effort for this function. Congress could consider restoring (and even increasing) the minimum technology transfer funding requirement established by the Stevenson-Wydler Act *and* deny waivers, although such requirements risk inflexibility. One clear problem is determining an adequate level of technology transfer funding that does not significantly reduce the resources for research itself. Other, more flexible approaches for improving technology transfer efforts could address the process by which technology transfer is conducted but could also require careful attention to, and incentives for, such transfer. Such options include greater use of cooperative R&D agreements (CRADAs, discussed above), an industry liaison (separate from designated project managers) to manage technology transfer activities for appropriate RD&D projects, senior management and corporate recognition efforts for successful technology transfer efforts, and a clear and aggressive commitment to Federal procurement for emerging technologies.

Encourage or require DOE to define specific technological goals that relate to program objectives in the DOE Conservation multiyear planning process. As discussed earlier, the DOE Conservation program annually develops a planning document (the Multi-Year Program Plan, or MYPP) that lists proposed RD&D projects for upcoming years. However, the utility of that planning process could be improved by clarifying the actual measurable benefits to consumers that each project aims to achieve. Despite the articulation of overall RD&D program goals in the MYPP, the document fails to clarify how those goals will be achieved by the technology-specific projects proposed. Improving the multiyear planning process in this way would require a shift of some resources to this activity or an increase in the program budget.

Conduct regular RD&D program evaluations for Congress in order to identify the successes, failures, and future direction of projects in the DOE Office of Building Technologies (OBT). Internal methods at the DOE Conservation office notwithstanding, Congress does not have the benefit of reviewing program-wide evaluations of OBT RD&D projects on a regular basis. As a result, the actual benefits of RD&D funding cannot be assessed by Congress in a regular or consistent way. Although they would require additional resources, regular evaluations would measure the progress of DOE building conservation RD&D projects more reliably and would inform Congress better about DOE RD&D progress.

RD&D: Moderate Options

Make greater use of market surveys to assess manufacturer and consumer response to new technologies prior to initiating OBT RD&D projects. Even when program planners correctly identify the most promising technological opportunities for reducing energy use in buildings-related RD&D, there is no guarantee that manufacturers will be able to adopt anew technology or that consumers will respond favorably to that technology. As a result, market surveys performed prior to project initiation can uncover potential problems or opportunities which, if accounted for in the RD&D process, can help ensure that the final product is marketable.[32] In addition, market surveys may uncover institutional issues (e.g., building code requirements) that could impede market success of new technologies. Performing market surveys would require shifting some resources to this activity, perhaps even a minor increase in the OBT budget.

Increase industry involvement in RD&D project planning, funding, and execution. Regardless

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[31] The National Competitiveness Technology Transfer Act of 1989 (Public Law 101-189) repealed the ().5 percent funding earmark, requiring instead that "sufficient funding, either as a separate line item or from the agency's research and development budget" be designated for technology transfer activities. Public Law 101-189, 103 Stat. 1679, sec. 3133(e)(2). As explained in the House Conference report:

> "The conference agreement would repeal the one-half percent funding requirement for technology transfer programs under Stevenson-Wydler and the related waiver provisions. These changes are not intended to reduce that commitment to technology transfer but rather acknowledge that this requirement has been universally waived during the Act's 9-year history and that there is a lack of certainty that one-half percent provides the appropriate amount of funding. '

House Conference Report No. 101-331 (Nov. 7, 1989), p. 761. From *U.S. Code Congressional and Administrative News*, 101st Congress—First Session (St. Paul, MN: West Publishing, 1989), vol. 3, p. 1151.

[32] However, market surveys are not always appropriate. For example, if a fundamentally new technology is under consideration, surveys may have little value or relevance in predicting the eventual market response.

of the technological advances achieved in RD&D programs, industry must eventually adopt and market new technologies before their practical applications can be realized on a large scale. To gain industry's input in RD&D program planning (and to improve the prospects of its adopting RD&D products), industry could be engaged to contribute to this process as early as possible through workshops, requests for proposals, and screening committees consisting of senior DOE managers and industry representatives (e.g., similar to the Critical Review program mentioned above).

Stressing cost sharing and outside funding where possible would help ensure that industry truly invests itself in the Federal RD&D process. Although it does not involve cost sharing, the Small Business Innovation Research (SBIR) program provides grants to small companies attempting to develop and commercialize new technologies, and is a useful model to encourage the involvement of small, competitive firms in project execution.[33] (Often, small firms will pursue RD&D projects that the larger appliance and equipment manufacturers show little initial interest in.[34]) Given the fragmented nature of the buildings sector, early and sustained industry involvement in DOE RD&D project planning, funding, and execution are good options to ensure that projects are well-defined and target clear opportunities for efficiency improvements.

There are potential problems that arise with increased industry involvement, such as the potential for conflicts of interest or controversy over granting exclusive rights to technologies developed with public funding, but the potential gains of correcting the currently low level of industry involvement in DOE RD&D projects could far outweigh the burden of avoiding such problems. One simple measure of industry participation in Federal buildings energy RD&D is the fraction of government-funded research spending awarded to industry. In fiscal year 1988, for example, only 13 percent of OBT RD&D funds were awarded directly to industry. That same year, the DOE industrial and transportation conservation RD&D programs awarded far more of their RD&D funds to industrial firms, 55 and 65 percent respectively (table 5-1).[35]

Table 5-I—Allocation of Research Funds in the U.S. Department of Energy Conservation Program (by percent, fiscal year 1988)

	Buildings	Transportation	Industry
National laboratories	74	18	30
Industry	13	65	55
Universities	3	5	14
Other	10	12	2

SOURCE: M.A. Brown, *Technology Transfer Strategies of the U.S. Department of Energy's Conservation Program,* ORNL/CON-277 (Oak Ridge, TN: Oak Ridge National Laboratory, December 1988), p. 44.

Examine the feasibility of both least-cost and net benefit planning for the DOE applied conservation RD&D programs. The results of such studies should be reported to Congress. One way for DOE to determine the optimal mix of RD&D projects could be to conduct least-cost RD&D planning; that is, to establish a research agenda that attempts to pay the least cost for a given set of anticipated benefits. Defining the parameters of and actually conducting least-cost RD&D planning credibly would be extremely difficult, but not impossible. This option suggests that DOE evaluate the feasibility of adopting a planning method for applied conservation research that pursues a least cost mix of energy efficiency technologies.

As an alternative, DOE could examine the feasibility of performing net benefit RD&D planning, such as that performed by the Gas Research Institute

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[33] The SBIR program is operated by the US. Small Business Administration in conjunction with 11 Federal agencies, including DOE, under authority of the Small Business Innovation Development Act of 1982 (Public Law 97-219). The program funds small businesses to conduct research projects through the development stage; although a major goal of the program is to encourage commercialization, product marketing is not funded by the Federal Government. See U.S. Small Business Administration, Office of Innovation, Research and Technology, *Small Business Innovation Development Act: Eighth Year Results* (Washington, DC: July 1991), 8th Annual Report.

[34] See H. Geller, J.P. Harris, M.D. Levine, and A.H. Rosenfeld, ‘‘The Role of Federal Research and Development in Advancing Energy Efficiency: A $50 Billion Contribution to the US Economy, “ *Annual Review of Energy 1987* (Palo Alto, CA: Annual Reviews, Inc., 1987), vol. 12, pp. 357-395. In addition, the Energy-Related Inventions Program (managed by DOE in conjunction with the National Institute of Standards and Technology) is authorized under the Federal Nonnuclear Energy Research and Development Act of 1974 (Public Law 93-577) and funds energy-related research conducted by small firms. The program has awarded more than $24 million in research monies to 329 projects. U.S. Department of Commerce, National Institute of Standards and Technology, *Energy Related Inventions Program: A Joint Program of the Department of Energy and the National Institute of Standards and Technology: Status Report for Recommendations 251 Through 523* (Washington, DC: March 1991), p. 1-3.

[35] M.A. Brown, *Technology Transfer Strategies of the U.S. Department of Energy's Conservation Program,* ORNL/CON-277 (Oak Ridge, TN: Oak Ridge National Laboratory, December 1988), p. 44.

(GRI), the research arm of the natural gas utility industry. The annual GRI RD&D budget requires Federal Energy Regulatory Commission (FERC) approval. To gain that approval, GRI is required to budget only RD&D projects that are expected to result in net benefits to existing classes of end-use consumers. That is, the projected benefits of RD&D projects must be greater than the projected costs of performing them.[36]

RD&D planning of either kind (least-cost or net benefit) would focus better the DOE conservation RD&D planning effort to ensure that the best opportunities for energy technology RD&D are selected. Such planning would help DOE maximize the benefits of the public investment in conservation RD&D. However, the small size and scope of the OBT program would not warrant the considerable investment in performing such an evaluation by itself; applying such a rigorous standard for research planning would be more appropriate for the entire Office of Conservation and Renewable Energy program, rather than just one part of it.

Establish an ambitious level of technology transfer and marketing efforts for OBT RD&D projects beyond that currently pursued. This level would represent an effort to conduct technology transfer more ambitious than in the basic level, such as assigning a full-time professional staff to assist exclusively with technology transfer within major programs such as OBT. Another option is to set aside a given percentage of the OBT budget to technology transfer. In recent years, OBT has spent 10 percent or less of its RD&D budget on technology transfer.[37] In the future, OBT could designate as much as 15 to 20 percent of its budget for transfer and marketing (at least in cases where technical improvements have been made). Other options—such as increasing the use of CRADAs (discussed above), encouraging personnel exchanges between the national laboratories and industry, and training program management and staff in marketing techniques--could also improve technology transfer efforts.

Increase OBT funding for RD&D work. To some participants in the debate on national RD&D priorities, a substantial funding increase is considered an attractive policy option to enhance any RD&D program, As this report stresses, however, a shift in program emphasis or modest (but targeted) increases in funding for the DOE conservation RD&D program could yield significant returns. The breadth and quality of DOE conservation RD&D efforts would likely increase with increased funding, but Congress should ensure that basic programmatic improvements are made or planned prior to any major funding increases. As discussed in chapter 4, one of the most prolific periods in DOE buildings conservation research (based on demonstrated technological advances resulting in measured energy savings) was during the late 1970s and early 1980s when RD&D funding was high. The 1991 OBT conservation budget, however, was only 44 percent (in current dollars) of the 1980 budget. If Congress increased funding for the Office of Conservation and Renewable Energy program substantially, net benefit or least-cost planning for the program could become a vital yardstick to determine how best to allocate resources between numerous projects in different offices.

RD&D: Aggressive Options

Require DOE to market buildings conservation RD&D results to utilities, State agencies, and its own regulatory programs, including the Office of Codes and Standards (within the Office of Building Technologies). This would help ensure that conservation RD&D results are imparted to interested groups in a timely fashion. These groups are at the center of numerous regulatory, incentive, and other efficiency efforts, suggesting that well-marketed RD&D results would strengthen their ability to keep pace with and even push technical advances. Appointing utility and State liaisons to market RD&D results is one way to achieve this.

Require DOE to perform least-cost or net-benefit-applied conservation RD&D planning. This would be a major departure from current applied conservation RD&D budget and program planning, and it would require a major effort (at least initially). The suggestion does not apply to basic RD&D, where high-risk, long-term work is the norm, and where

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[36] A, Lee Wallace, Director of Regulatory and Legislative Affairs, Gas Research Institute, written communication to OTA, Aug. 16, 1991.

[37] U.S. Department of Energy, Office of Buildings and Community Systems, *Analysis and Technology?' Transfer Annual Report 1988,* DOE/CH/00016-H2 (Washington, DC: May 1989), p. 2-9. *Note:* The proportion of technology transfer funding in an office such as OBT (10 percent) should not be confused with the seemingly modest requirements under the Stevenson-Wydler Act (discussed above), because that legislation channeled resources from entire agency RD&D budgets, not just particular RD&D offices.

ultimate returns are often difficult to predict. However, it is an appropriate concept to consider for Federal agencies conducting applied RD&D, where public monies are being spent for ostensibly identifiable public benefits. If one or both of these planning methods is determined to be feasible, DOE could initiate such an effort to ensure that expected RD&D benefits exceed expected RD&D costs. Of course, either planning method would require several years to implement, but both have the potential to maximize public returns on Federal RD&D investments.

Utilities and Energy Efficiency[38]

Utilities are ideally positioned to promote energy efficiency in buildings. They have monthly contacts with consumers through their billing systems, they have historical and current data on consumer energy consumption, and they provide service throughout the United States. Until recently, however, utility regulation provided utilities with no direct financial incentives to encourage efficiency among their consumers. In fact, under traditional principles of utility regulation, utility profits were tied to sales—the more energy sold by the utility, the greater its revenues and profits.

In recent years, some States have changed utility regulation to provide utilities with financial incentives for efficiency investments. These changes have included both limiting disincentives for efficiency, for example by decoupling revenues from sales, and providing positive incentives for efficiency.[39] Even without financial incentives, many utilities have found that efficiency measures can be a quick and inexpensive way to meet demand growth. In addition, many States and utilities are adopting least-cost planning techniques to ensure appropriate use of efficiency.[40]

At present, utilities are probably the single most important institutional vehicle for implementing efficiency in buildings. For example, there are over 1,000 electric utility-run efficiency programs in the residential sector[41] and over 340 in the commercial sector.[42] These Programs include changes in rate structures, financial incentives for consumers such as rebates and loans, information programs such as audits and technical assistance, RD&D, and demand-side bidding.[43] Another promising option not applied as widely is a reduced hook-up fee for energy efficient buildings, which utilities can use to encourage energy efficient construction.

The results in some States have been quite impressive. In California, for example, utility programs undertaken through 1987 promoting energy efficiency in the residential and commercial sectors were estimated to have cut new capacity needs by over 1,800 megawatts in 1987—the equivalent of about two new large coal or nuclear powerplants.[44]

State regulatory agencies have primary jurisdiction over utility resource planning, demand-side

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[38] The role of utilities in implementing efficiency is discussed in detail in a forthcoming OTA report.

[39] The California Public Utilities Commission uses a rate-setting mechanism known as the Electric Rate Adjustment Mechanism (ERAM), which decouples utility profitability from the amount of electricity sales. For a full discussion of ERAM and other innovative efficiency incentive mechanisms, see J. Cole and M. Cummings, "Making Conservation Profitable: An Assessment of Alternative Demand Side Management Incentives,' *Proceedings of the ACEEE 1990 Summer Study on Energy Efficiency in Buildings* (Washington DC: American Council for an Energy-Efficient Economy, 1990), pp. 5.35 -5<50.

[40] Least-cost planning (LCP) can be defined as "a process of examining all electricity-saving and electricity-producing options to select a mixture of options that minimizes total customer cost." (D. Moskovitz, *Profits and Progress Through Least-Cost Planning* (Washington, *DC:* National Association of Regulatory Utility Commissioners, November 1989), p. vi.) The term integrated resource planning (IRP) is also used. There are few arguments against the *concept* of LCP. Almost all agree that meeting energy service needs at the lowest feasible cost is appropriate. However, there is considerable controversy over the *implementation* of LCP. Calculating costs, structuring regulatory incentives, and allowing for nonutility participants have all proven controversial. Furthermore, concerns about administrative costs, the difficulty in predicting and measuring saved energy, and disagreements over relative subsidies have complicated implementation. The interpretation of just what constitutes LCP varies but, according to one 1990 survey, 23 States had least-cost planning of some kind in operation, and another 8 States were initiating it. Edison Electric Institute, Rate Regulation Department, *State Regulatory Development in Integrated Resource Planning* (Washington, DC: Edison Electric Institute, September 1990), p. 2.

[41] Battelle, *1988 Survey of Residential-Sector Demand-Side Management Programs*, EPRI CU-6546 (Palo Alto, CA: Electric Power Research Institute, October 1989), p. iii.

[42] Battelle-Columbus Division, *1987 Survey of Commercial-Sector Demand-Side Management Programs,* EPRI CU-6294 (Palo Alto, CA: Electric Power Research Institute, March 1989), p. iii.

[43] Some utilities request bids from outside firms for new energy supplies. Extending the bidding process to allow bids for energy savings is called demand-side bidding.

[44] California Energy Commission, *Energy Efficiency Report*, P400-90-003 (Sacramento, CA: October 1990), p. 30. For comparison, a large coal-fired or nuclear powerplant has a capacity of about 900 MW.

management programs, and retail rates. Barring a revolutionary shift in the balance of Federal and State utility jurisdiction, State regulatory agencies will continue to play the major role in efforts to encourage utilities to promote building energy efficiency.

Federal influence over State regulatory authorities and utility-run energy efficiency programs is limited and indirect and is based in part on: 1) management and oversight of ''Federal utilities"—the power marketing administrations and the Tennessee Valley Authority; 2) Federal Energy Regulatory Commission jurisdiction over interstate transactions, wholesale rates, and multistate holding companies regulated under Federal law; and 3) Department of Energy information, technology development, and technical support programs.

There are several examples of Federal Government support for greater consideration of efficiency by utilities. The Pacific Northwest Electric Power Planning and Conservation Act (Public Law 96-501) instituted a regional council for electricity planning in the Pacific Northwest and required that the council consider efficiency as a resource when assessing future electricity supplies. DOE currently funds a least-cost planning research program within the Office of Utility Technologies, with an annual budget of about $3 million in fiscal year 1991.[45] The Clean Air Act Amendments of 1990 (Public Law 101-549) authorize emission allowances for energy conservation (sec. 404(f)), and the Environmental Protection Agency is developing rules to implement these provisions.

Congress could promote utility conservation programs in several ways, including an expansion of DOE technical support, changes in regulatory policies, and changes in Federal utility planning and management. In considering these options, understanding the interaction of State versus Federal regulatory oversight of utilities is important. Historically, utility regulation has long been managed primarily at the State level, and any expanded Federal role could be controversial.

Utilities: Basic Options

National experience with least-cost planning is increasing but uneven, and many utilities have a clear need to understand better the design, operation, and performance of efficiency programs. **Congress could instruct** DOE to expand its research and development related **to the design, operation, and evaluation of utility efficiency programs. Simi**larly, the Federal Government could help States learn from each other about how to implement least-cost planning and how to design, operate, and evaluate energy efficiency programs. **Congress could instruct** DOE to increase its activities as an information clearinghouse for efficiency program design, operation, and evaluation.

The Northwest Power Planning Council, established in response to Federal legislation, is charged with addressing future power requirements in the Pacific Northwest by considering both demand and supply options. Congress **could instruct** DOE to evaluate whether the Northwest Power Planning Council represents a useful model **for energy planning that could be applied to other regions of the country.**

Utilities: Moderate Options

The Federal utilities[46] account for about 19 percent of U.S. electricity sales.[47] Congress could direct the Tennessee Valley Authority (TVA) and **the power marketing administrations to better integrate least-cost planning techniques and principles into their operations and management.** Establishing such requirements would be a first step to ensuring that public monies spent on power generation are applied in the most cost-effective manner possible.

The Federal Energy Regulatory Commission (FERC) has jurisdiction over all wholesale electricity and natural gas transactions in the United States. **Congress** could instruct FERC to examine its ratesetting and other regulatory actions to determine their consistency with State-approved utility least-cost plans.

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[45] U.S. Department of Energy, *U.S. Department of Energy Fiscal Year 1992 Congressional Budget Request, DOE/m-ml (Washington,* DC: February 1991), vol. 4, p. 438.

[46] These include the Federal Power Marketing Administrations (PMAs), which are part of DOE, and the Tennessee Valley Authority (TVA).

[47] U.S. Department of Energy, Energy Information Administration, "Sales of Electricity Available for Resale, " *Financial Statistics of Selected Investor-Owned Electric Utilities 1989*, DOE/EIA-0437(89)/1 (Washington, DC: January 1991), p. 3.

As mentioned above, about 23 States are currently using some form of least-cost planning, and another 8 States are in the process of implementing it. **Congress could instruct** DOE to support through grants, technical support, or other means, State and utility efforts related to the design and implementation of least-cost planning. Such support could be directed at both States that currently use least-cost planning and those considering it. In addition, **Congress could encourage or require States not already doing so to consider adopting least-cost plans.**

Utilities: Aggressive Options

Most of the electricity sales by the federally owned utilities are to other utilities and not to ultimate customers. **Congress could direct the federally owned utilities to provide incentives for or require its customer utilities to adopt least-cost plans.** Such a requirement could be accompanied by technical support from the federally owned utilities to its customer utilities for least-cost plan preparation and implementation.

Mandating Efficiency: Codes and Standards

The government can mandate energy efficiency. Such regulation can be controversial and costly but has been used in the past to achieve social goals, such as ensuring public health and safety in buildings. As noted in chapter 4, codes and standards for energy efficiency already exist in many jurisdictions. This section discusses Federal options to amend current building codes and standards as well as appliance standards. There are advantages and disadvantages to adopting such mandates. For example, the impact of an appliance standards program is easier to determine than that of other policy measures such as information and incentives, because there is less uncertainty in market response. On the other hand, standards may raise the price of appliances and limit consumers flexibility to make their own decisions reflecting their own individual preferences and requirements.[48]

Building codes and standards—The historical function of building codes has been to ensure the health and safety of inhabitants, but recently they have been directed at energy efficiency as well. Building codes are typically implemented and enforced at the local, county, or State level. Local or county codes are often based on a State model code, which is then modified to fit local requirements. Currently all 50 States have some energy efficiency requirements in State building codes, but the scope, stringency, and enforcement of these requirements vary widely. Federal building standards for energy efficiency are mandatory for federally owned or financed buildings and voluntary for other buildings.

Although Congress could direct the improvement of building energy codes in numerous ways, several issues should be recognized to guide choices. First, an increased Federal role in what is traditionally a State and local matter would be controversial. Informal interviews with code professionals and builders revealed strong resistance to a national building code or standard for several reasons, including the potential for reduced flexibility in building design, a possible increase in construction costs that could threaten the marketability of a new home, and uncertainties about often complex provisions, which could lead builders to ‘‘over build’ in order to erase doubts about compliance.

These potential drawbacks could be major barriers to new construction, which understandably concern builders, but their input in the development of flexible and clear building codes could prevent or alleviate many of these problems. In addition, other policies promoted in tandem-such as an aggressive Federal energy efficiency mortgage program or State and utility involvement in pushing incentives such as reduced hook-up fees for efficient buildings—could also improve the marketability of highly efficient buildings.

A second and related point is the importance of enforcement. Codes are often enforced by local and county-level officials and, without their support, implementing code changes would be difficult. (This also raises the issue of Federal assistance in training and assisting code enforcement officials, discussed below.) Inadequate code enforcement could create incentives for noncompliance, because builders adhering to guidelines could experience a competitive disadvantage if those failing to comply are not punished. An additional prerequisite to success, therefore, would include the development

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[48] For example, an efficiency standard for a space heating furnace may be cost-effective under average conditions and use, but if the furnace is installed to back up a solar heating system it may no longer be cost-effective.

of adequate State and local expertise for building professionals to consult for assistance.

Third, the increasing complexity of buildings and codes could complicate the implementation of aggressive codes. The shift toward performance codes rather than prescriptive codes,[49] for example, has been a mixed blessing; performance codes can increase flexibility in building design but can significantly complicate enforcement by requiring complex calculations to demonstrate compliance. Improved methods of building energy analysis, however, could alleviate this problem.

Building Codes and Standards: Basic Options

Assess compliance with and enforcement of existing State building codes as they pertain to energy **efficiency.** OTA interviews with builders suggest that enforcement of State building codes varies greatly; such enforcement generally occurs on the local level, where expertise and resources vary considerably. To determine the status of State efforts, and to guide Federal ones, DOE, the Department of Housing and Urban Development (HUD), and other relevant agencies could assess the level of both compliance with and enforcement of existing State building codes as they pertain to energy efficiency.

One code often used as a benchmark is the Council of American Building Officials Model Energy Code (CABO MEC) for low-rise residential construction; this model code was updated in 1989 (CABO MEC ‘89). About 11 States have codes that equal or surpass the CABO MEC ’89, while about 34 States have codes less stringent.[50] Several studies have found that the CABO MEC ’89 is cost-effective. An analysis by the Alliance to Save Energy, for example, suggests that if the 34 States with codes less stringent than the CABO MEC ’89 adopted that model code, the resulting changes in new homes would achieve paybacks of less than 2 years-based on the estimated incremental rise in construction costs and the resulting energy savings.[51] Furthermore, the Alliance found that in some regions codes stricter than CABO MEC ’89 would provide a 4-year payback.[52] A study by Battelle compared the CABO MEC ’89 to both the CABO MEC ’86 and the HUD Minimum Property Standards (MPS) and found CABO MEC ‘89 the most cost-effective for homeowners—both from a life-cycle cost and a first-year cash flow perspective.[53]

Extension of CABO MEC ’89 requirements to federally financed homes would speed widespread adoption of this code. (This was required of HUD by the Cranston-Gonzalez Affordable Housing Act of 1990 (Public Law 101-165) but is yet to be implemented.) Approximately 18 percent of new single-family homes are financed through the Federal Housing Administration (FHA), the Veterans Administration (VA), and the Farmers Home Administration (FmHA). If these three agencies were to require CABO MEC ’89, then builders would have to build to these requirements in order to sell to home buyers that finance their homes through these agencies. Since many builders design and construct homes before the specific buyer is known, builders would tend to build to CABO MEC ’89 requirements in case a prospective buyer intended using federally assisted financing. The net effect would be that most new homes in the FHA/VA/FmHA price range would be built to CABO MEC ’89 levels.

The Cranston-Gonzalez Affordable Housing Act of 1990 (Public Law 101-625) required the HUD Secretary to promulgate standards that meet or exceed the CABO MEC ‘89.[54] In November 1990 HUD published a proposed rule that: “all [federally financed] detached one and two family dwellings

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[49] Performance codes set a maximum allowable energy consumption level, and thereby allow for any combination of technologies as long as the consumption level is not exceeded. prescriptive codes, in contrast, have specific technical requirements such as minimum insulation levels. Most recent codes, including Council of American Building Officials Model Energy Code, 1989 edition, have both performance and prescriptive elements.

[50] Based on data presented in B.D. Howard and W.R. Prindle, ‘‘Better Building Codes for Energy Efficiency, ’ Final Report (revised) (Washington, DC: The Alliance to Save Energy, September 1991), pp. 5-7.

[51] Ibid., p. 44. One State—Indiana—had a 3-year payback; the rest all had paybacks of less than 2 years.

[52] Ibid., p. 40.

[53] A.D. Lee R.G. Lucas, C.C. Conner, *Comparison of the Economic Effects of Three Residential Energy Codes on Home Buyers* (Richland, WA: Battelle, November 1990), p. iii. These cost-effectiveness studies typically assume that builders use the performance approach (see footnote 49); however OTA interviews with builders suggest that many find the performance approach too complex and therefore use the prescriptive approach. Therefore these studies may overestimate actual cost-effectiveness. This point also suggests a need to provide builders better tools and training to increase use of the performance approach.

[54] Public Law 101-625, 104 Stat. 4093, sec. 109.

and one family townhouses not more than three stories in height shall comply with CABO Model Energy Code, 1989 Edition, including 1990 supplements.'[55] As of February 1992, the final rule was still under consideration by the Office of Management and Budget (OMB). Congress could ensure that section 109 of the Cranston-Gonzalez **Affordable Housing Act of 1990 (Public Law** 101-625) requiring the use of CABO MEC '89 in federally assisted housing is implemented. This would ensure that most new, moderately priced homes meet the CABO MEC '89.

There are other model codes and model standards offered by industry groups. Among the best known are the standards designed by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). This group has developed both residential and commercial standards, and their experience has been instrumental in the development of the DOE building efficiency standards and guidelines. As a result, in conjunction with organizations such as CABO and ASHRAE, DOE **could continue to improve Federal building standards and guidelines and provide implementation materials and support services to promote their use on the State level.** Such support services could include the provision of software technologies to assess compliance and resources to hire and train local and State code enforcement staff.

Building **Codes and Standards: Moderate options**

Congress could direct and fund DOE to provide technical and financial support to those 34 States with residential building codes less stringent than CABO MEC '89 to evaluate the cost-effectiveness of upgrading their codes to the CABO benchmark. Financial incentives could be used to promote code adoption. This would reach the higher-priced homes not eligible for FHA, VA, or FmHA financing.

Codes for commercial buildings already exist as well. The DOE Energy Performance Standards for New Commercial Buildings (1990), designed in conjunct ion with ASHRAE, could be used as a model code. **Congress could direct and fund DOE to provide technical and financial support to** States **considering the adoption of more stringent commercial building codes,** again to evaluate the cost-effectiveness of upgrading the existing State codes. This would allow States to maintain their jurisdiction over building codes but would demonstrate the energy and economic savings potential of improving the State codes.

Another option is to encourage the extension of codes to existing buildings. Retrofit-on-resale ordinances (also known as residential energy conservation ordinances) are used in some areas to require minimal efficiency features when ownership Changes.[56] Congress **could direct and fund DOE to provide technical and financial assistance to communities and States instituting retrofit-on-resale rules.** Such rules reach all buildings, including low-income and rental residences, which are often difficult to reach with other programs.

Congress **could direct and fund DOE to enlarge its efforts at code official training and education.** Code enforcement is a continuing concern, and as codes become more complex training becomes increasingly important.

Building Codes and Standards: **Aggressive Options**

Congress could require States to meet or exceed federally set minimum building efficiency standards, such as the Building Energy Performance Standards (BEPS). This would certainly meet strong resistance from States but would ensure that all codes meet a common, standard level of efficiency, Implementation would require technical and financial assistance to States, as well as oversight to ensure compliance. One way to implement such requirements would be through the State Energy Conservation Program (SECP), which requires States to implement conservation plans that meet certain conditions prior to receiving Federal funding for their programs,

Congress **could encourage or require secondary mortgage market institutions (e.g., the Federal Home Loan Mortgage Corporation) to require new residences to meet the CABO MEC '89 (or some other major code).**

Appliance standards—The principal goal of appliance standards is to eliminate the least efficient new appliances by setting minimum energy effi-

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[55] 55 *Federal Register* 46637 (Nov. 5, 1990)

[56] In San Francisco, for example, both residential and commercial buildings must meet certain minimum energy efficiency levels prior to resale.

ciency levels for new units. Typically, standards establish requirements on the design of an appliance, the minimum efficiency of an appliance, or the maximum energy use of an appliance. Standards improve the efficiency of the appliance stock only at the rate that old appliances are replaced by new, more efficient ones (the turnover rate), plus the rate at which new applications occur.[57]

Other policy options, e.g., energy taxes and financial incentive programs, may also encourage the elimination of the least efficient appliances, but in some situations standards may represent the least-cost option for improving appliance efficiencies. For example, the cumulative national energy consumption for an appliance may be significant, but the cost of operating any single appliance is small. This suggests that extremely aggressive information programs and/or sizable incentives would be necessary to motivate consumers to purchase appliances as efficient as standards would require, especially if the first costs of more efficient appliances were greater. As a result, the cost of applying these other policy options to attain the same level of energy savings as standards may be quite large for some appliances. Conversely, standards could increase the first costs of new appliances, which could affect manufacturers by reducing sales. Appliance price increases might also have regressive effects if lower income groups are less able to purchase them.

As a next step in the DOE appliance standards program, Congress could consider extending the coverage of the National Appliance Energy Conservation Act of 1987 (Public Law 100-12; NAECA). Several appliances, notably lamps and commercial HVAC (heating, ventilating, and air conditioning) equipment, are not presently covered in the NAECA program but use a significant amount of energy. As discussed in chapter 3, those selecting and installing commercial HVAC equipment are typically not those paying the costs of operation, providing an incentive for the selection of low first cost, inefficient equipment. Standards, if set correctly, could eliminate the most inefficient models.

However, there are several potential drawbacks to expanding NAECA coverage to commercial HVAC equipment. First, some commercial building products (e. g., large HVAC systems) are often custom-built, which could require equipment-specific design and testing analyses to determine compliance with efficiency standards. This is in contrast to the residential appliances currently covered by NAECA, which are generally "off the shelf' that is, they are manufactured and sold in relatively uniform sizes and designs, which has eased the development and adoption of their efficiency standards. Furthermore, if standards reduce the availability of equipment (e.g., due to manufacturers exiting the market due to high retooling costs), this could constrain commercial building designers and architects.

DOE already has discretionary authority to add *residential* equipment to the list of NAECA-covered products.[58] The Department could probably add lamps to the NAECA product list under this authority; however, extension of coverage to commercial HVAC equipment would require new legislation.

Appliance Standards: Basic Options

DOE **could examine the feasibility and likely impacts of extending NAECA coverage to appli**ances and equipment **not covered by the program.**

Appliance Standards: Moderate Options

Extend NAECA **coverage to include residential and commercial equipment not currently covered by the program.** A variety of both residential and commercial equipment is not covered by NAECA, including commercial HVAC systems and lamps. Their inclusion in the program would ensure that the least efficient units among them are eliminated from

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[57] While efficiency standards are not designed to affect appliance turnover rates—only the energy consumption of a new appliance when an old one is replaced-they can have an indirect effect on such rates. For example, stringent efficiency standards may increase the first cost of new appliances and thereby discourage some consumers from purchasing new units.

[58] "The Secretary may classify a type of consumer product as :1 covered product if he determines that—(A) classifying products of such type as covered products is necessary or appropriate to carry out the purposes of [his chapter, and (B) average annual per-household energy use by prod ucts of such type is likely to exceed 100 kilowatt-hours (or its Btu equivalent} per year. " 42 U S C. 6292(b)(1)(A)-(B)

the market. This is the basic goal of NAECA, but its coverage remains incomplete.[59]

As noted earlier, there are potential problems with extending equipment efficiency standards to commercial equipment, particularly HVAC systems. As an alternative, Congress could consider a more modest expansion of the appliance standards program, such as adding lamps to the list of NAECA-covered products; currently, NAECA lighting standards apply to fluorescent ballasts only.

Appliance Standards: Aggressive Options

Adopting more stringent cost-effective NAECA standards by identifying equipment efficiency levels that represent longer paybacks than most current standards allow. Despite the large energy savings and economic benefits expected from the NAECA program, additional cost-effective savings may be possible if standards representing longer paybacks are considered. In particular, the payback periods for updated electric appliance standards under NAECA are generally short, ranging from zero years (clothes washers) to roughly 2.5 years (refrigerators and clothes dryers).

To allow an initial determination of the economic feasibility of any proposed appliance standard, NAECA established a rebuttable presumption: any appliance standard is economically justified if the resulting energy savings in the frost year paid back one-third of the additional production costs, which implies that a 3-year payback meets the criterion. The statute requires other considerations prior to final determinations of the technical and economic feasibility of any proposed standard but, as a point of departure, the NAECA rebuttable presumption encouraging standards with no less than 3-year paybacks could be extended to a longer period (e.g., 5 years). More stringent appliance standard levels that represent longer paybacks than those generally chosen by DOE—but that still meet the vital criteria of technological and economic feasibility-are possible. This option suggests that DOE identify and adopt them.

Improving Information and Awareness of Efficiency Opportunities

Programs providing information about energy efficient technologies and practices have been historically quite popular. Information is relatively inexpensive, politically noncontroversial (as few would argue against consumer education), and usually supported by all interested parties. From an economic perspective, poor information receives much of the blame for the neglect of many cost-effective efficiency technologies. Energy information can be imparted in many forms, including labels and rating systems, demonstration programs, energy audits, and workshops.

Unfortunately it is difficult to show conclusively that information programs have significant direct effects on behavior or energy use. Several studies have attempted to measure the effects of information—e.g., labels, audits, feedback on consumption, and advertising-on behavior, but the results are generally inconclusive. This is not to suggest that information has no effect, only that the effect is very difficult to measure. The evidence does suggest that information *alone* may not have much direct influence on behavior in many cases.[60] Information programs are built on the premise that people will generally do what is cost-effective if they know what specific opportunities exist. As discussed in chapter 3, however, consumers and other decisionmakers often define cost-effective differently than do analysts, and consumers often lack the incentive or motivation to use energy efficient technologies. In such cases information alone will have little effect.

There are, however, several reasons to promote information programs. A demonstration program, for example, may not have much effect by itself, but may have considerable success when combined with a financial incentive. Several State and utility programs, such as those offering rebates, depend on a credible energy rating. Determining compliance with building energy codes could be easier if energy-using equipment was clearly labeled for energy consumption. And increased consumer awareness of, and interest in, energy efficiency could

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[59] Lamps, for example, are not covered by the program but, according to the American Council for an Energy-Efficient Economy, lamp efficiency standards could save more than 7 quads of primary energy by 2010 worth an estimated $30 billion (1990 dollars). Howard Geller, Executive Director, American Council for An Energy Efficient Economy, personal communication% July 3, 1991.

[60] As one review of information programs concluded, "informational programs are not sufficient to induce individuals to engage in resource conserving behaviors." R. Katzev and T. Johnson, Promoting *Energy Conservation* (Boulder, CO: Westview Press, 1987), p. 25.

influence builders, architects, vendors, and others. The synergistic effects of information when combined with incentive programs and the need for credible ratings to support rebates, codes, and other programs suggest that information programs deserve attention.

There are several arguments for increasing the Federal role in improving the availability and quality of energy-related information. The benefits of improved information are diffuse and difficult to measure, making it difficult for utilities to justify large expenditures on such programs. However the benefits, although admittedly difficult to document, are certainly not zero, suggesting a government role in providing information is appropriate. Furthermore information must be credible in order to be effective, and the Federal Government may be perceived as more credible than other sources with a direct economic interest in the outcome of a consumer investment.

As discussed in chapter 4, the Federal Government currently administers several energy information programs. The Energy Policy and Conservation Act (Public Law 94-163), as amended, requires that certain energy-using consumer products be labeled for their energy use and/or annual energy costs. The Residential Conservation Service was a federally funded program that provided building occupants with information on the benefits of building retrofits. Several DOE programs provide energy efficiency information through demonstrations, educational programs, workshops, and other methods.

Analyses of past Federal efforts to provide energy-related information indicate that information programs are more effective if they are:

- targeted at specific people and specific behaviors;
- combined with other programs, such as incentives; and
- evaluated regularly, and the results of these evaluations are then used to improve the program.

Several options to improve the goals and coverage of these programs are detailed below.

Information: Basic Options

At present, several energy-using consumer products are exempted from labeling requirements.[61] **Congress could instruct the Federal Trade Commission (FTC) to revisit its 1979 exemption rulings for appliance energy labeling.** Recent technical advances[62] and secondary effects on manufacturers[63] should be included in the analysis.

At present, energy labeling is restricted to residential equipment. **Congress could instruct the FTC and/or DOE to assess the feasibility of extending labeling requirements to commercial sector equipment.** HVAC equipment, office equipment such as computers and copiers, lighting equipment[64] and commercial refrigeration equipment could be considered.[65]

Windows and lamps are significant energy users in the residential sector but are not presently covered by the labeling requirements. Congress **could extend labeling requirements to windows and lamps.**

Congress could instruct the FTC and/or DOE to investigate alternative label designs that might inform consumers better. There are several ways the present label format could be altered, including:

- showing life-cycle operating costs;
- providing dollars (a readily understood unit of measure) wherever possible; and
- including data on all technologies that provide the service, rather than just the single technology, as a comparison.[66]

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[61] Products currently exempted include clothes dryers, some home heating equipment, television sets, and kitchen ranges and ovens.

[62] For example, the original rulemaking exempted clothes dryers because of the very small variation in operating costs among then-existing models. However, as noted in ch. 2, new dryer technologies such as heat pumps could cut dryer energy use (and operating costs) significantly.

[63] The existence of a label may spur a manufacturer to produce a highly efficient product it would not otherwise produce, as the label would provide a marketing advantage over other models.

[64] Labels for light ballasts were required by the NAECA amendments of 1988 (Public Law 100-357).

[65] Such labeling efforts would require close cooperation with industry to ensure that testing and labeling procedures are credible and accurate.

[66] For example, labels on electric water heaters show estimated annual operating costs for that unit, as well as the range for all electric water heaters of a comparable size. Instead, the labels could show a range for all comparable water heating technologies, such as heat pump water heaters and gas water heaters.

Information: Moderate Options

The existence of a credible, accurate home energy rating system would allow consumers to compare the energy efficiency of different homes, would make it easier for mortgages to incorporate energy efficiency, and would provide a credible measure of success for builders using energy efficient technologies and practices. Congress **could direct DOE to explore methods for producing an accurate, verifiable whole-building rating, and to provide technical support for State and utility programs that rate whole buildings.**[67] To produce a credible rating, a number of technical questions require resolution.[68]

Efficiency is sometimes viewed as requiring sacrifice, and some consumers distrust innovative, energy efficient technologies. In many cases, however, energy efficiency offers other benefits as well; for example, more efficient lights in commercial buildings may provide more attractive illumination in addition to saving energy. Demonstration projects showing that efficiency works can dispel outdated beliefs equating conservation with discomfort and inconvenience. Congress **could encourage DOE to work with manufacturers, designers, and builders to demonstrate energy efficient equipment that works.** For example, DOE could sponsor an architectural design competition for energy efficient buildings that use efficient, commercially available technologies, and grants to finance the actual construction of these designs could be provided. In return for the grant, a builder could agree to hold open houses, during which other builders and consumers could see the buildings in operation.

Identifying and implementing efficiency opportunities in existing buildings sometimes requires specialized knowledge. Involving architecture and engineering schools in building energy audits would provide that knowledge and would also encourage interest in building science in the next generation of technically skilled people. Congress could encourage DOE to set up a building audit program involving architecture and engineering schools.

Information: Aggressive Options

Congress could require point-of-sale disclosure of whole-building energy ratings. Such ratings could be applied to both new and existing buildings. Methods to produce such ratings are still under development, but when they are improved their use could be mandated. As an intermediate step, their use could be limited to federally financed sales.

ASSEMBLING THE OPTIONS

No single policy or program will be sufficient to generate substantial improvements in energy efficiency; the barriers limiting such efficiency are diverse and so must be the policies to overcome them. To assist with the selection of options, the three levels of options discussed above are assembled into three packages below. Many such packages could be constructed; the three described here are intended only to illustrate the range of options Congress could consider. Basic options are low cost options that could be implemented relatively easily (box 5-D). Moderate options are somewhat more ambitious and may require new legislation and moderate increases in spending but would result in considerable efficiency gains (box 5-E). Aggressive options include changes in the Federal role in energy regulation and could be quite controversial. Nevertheless, OTA believes they could result in significant improvements in national energy efficiency (box 5-F).

Decisions by Congress as to what level to consider and what specific options to pursue will of necessity be guided by political, financial, and other considerations. However it should be noted that, with the exception of the pricing options, at all three levels only those technologies that would be economically justified using life-cycle costing techniques are promoted.[69]

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[67] Several States and utilities already have home energy rating systems in place. See R. Vories, " What Makes Rating Systems Tick," *Home Energy,* vol. *6, No. 2,* March/April *1989, p. 22.*

[68] For example, using past consumption data as a basis for a rating is thought to be inaccurate due to the effects of occupant behavior. How large is this effect, and what data are needed to control for this effect? For new buildings, can short-term measurements of consumption under test conditions provide a reasonable estimate of long-term consumption? Can commercial buildings be rated as well as residences?

[69] Economically justified is used here relative to current and forecasted energy prices. A fourth level, maximum technical potential regardless of cost-effectiveness, could be considered by the Congress under extreme conditions. Such a level is not discussed here.

Box 5-D—The Basic Package

Incentives

- Direct the Departments of Energy (DOE) and Health and Human Services to set aside an adequate amount of program spending for program evaluation; particularly to determine the cost-effectiveness of low-income weatherization.
- Direct and fund DOE to expand research on the measurement and pricing of externalities associated with energy production, distribution, and consumption.

Federal leadership

- Encourage energy efficiency in Federal buildings by upgrading procurement guidelines for energy-using equipment so as to incorporate energy efficiency.
- Extend the Environmental Protection Agency (EPA) Green Lights concept to other end users.

Research, development, and demonstration

- Require all DOE Office of Building Technologies applied research projects reaching the demonstration stage to conduct some minimum level of technology transfer and market assessment.
- Encourage or require DOE to define specific technological goals that relate to program objectives in the DOE Conservation multiyear planning process.
- Conduct regular RD&D program evaluations for Congress to identify the successes, failures, and future direction of projects in the DOE Office of Building Technologies.

Utilities

- Instruct DOE to expand its research and development related to the design, operation, and evaluation of utility efficiency programs.
- Instruct DOE to increase its activities as an information clearinghouse for efficiency program design, operation, and evaluation.
- Instruct DOE to evaluate whether the Northwest Power Planning Council represents a useful model for energy planning that could be applied to other regions of the country.

Mandates

- Assess compliance with and enforcement of existing State building codes as they pertain to energy efficiency.
- Ensure that section 109 of the Cranston-Gonzalez Affordable Housing Act of 1990 (Public Law 101-625) requiring the use of the Council of American Building Officials Model Energy Code, 1989 Edition (CABO MEC '89) in Department of Housing and Urban Development assisted housing is implemented.
- In conjunction with organizations such as the Council of American Building Officials and the American Society of Heating, Refrigerating, and Air-Conditioning Engineers, instruct DOE to continue to improve Federal building standards and guidelines and provide implementation materials and support services to promote their use on the State level.
- Instruct DOE to examine the feasibility and likely impacts of extending the coverage of the National Appliance Energy Conservation Act of 1987 to include appliances and equipment not covered by the program.

Information

- Instruct the Federal Trade Commission (FTC) to revisit its 1979 exemption rulings for appliance energy labeling.
- Instruct the FTC and/or DOE to assess the feasibility of extending labeling requirements to **commercial** sector equipment.
- Extend labeling requirements to windows and lamps.
- Instruct the FTC and/or DOE to investigate alternative label designs that might inform consumers better.

Box S-E—The Moderate Package

Incentives

- Pass legislation making utility rebates nontaxable.
- Enact or increase taxes on the production and use of fuels consumed in the buildings sector.
- Direct and fund DOE to provide technical and financial assistance to States interested in measuring and pricing energy externalities.
- Direct the Federal housing and national mortgage agencies to simplify and expand their energy efficient mortgage programs.

Federal leadership

- Allocate (or increase access to) funds for efficiency improvements in Federal buildings.
- Encourage manufacturers, utilities, and other interested parties to extend the Golden Carrot concept to other technologies for demonstration and marketing.

Research, development, and demonstration

- Make greater use of market surveys to assess manufacturer and consumer response to potential new technologies prior to initiating Office of Building Technologies (OBT) RD&D projects.
- Increase industry involvement in RD&D project planning, funding, and execution.
- Examine the feasibility of both least-cost and net-benefit planning for DOE applied conservation RD&D programs.
- Establish an ambitious level of technology transfer and marketing efforts for RD&D projects of OBT beyond that currently pursued.
- Increase OBT funding for RD&D work

Utilities

- Direct the Tennessee Valley Authority and the power marketing administrations to integrate better least-cost planning techniques and principles into their operations and management.
- Instruct the Federal Energy Regulatory Commission to examine its rate setting and other regulatory actions to determine their consistency with State-approved utility least-cost plans.
- Instruct DOE to support through grants, technical support, or other means State and utility efforts related to the design and implementation of least-cost planning.
- Encourage or require States not already doing so to consider adopting least-cost plans.

Mandates

- Direct and fund DOE to provide technical and financial support to those 34 States with residential building codes less stringent than CABO MEC '89 to evaluate the cost-effectiveness of upgrading their codes to the CABO benchmark.
- Direct and fired DOE to provide technical and financial support to States considering the adoption of more stringent commercial building codes.
- Direct and fired DOE to provide technical and financial assistance to communities and States instituting retrofit-on-resale rules.
- Direct and fund DOE to enlarge their efforts at code official training and education.
- Extend National Appliance Energy Conservation Act of 1987 coverage to include residential and commercial equipment not currently covered by the program.

Information

- Direct DOE to explore methods for producing an accurate, verifiable whole- building rating, and to provide technical support for State and utility programs that rate whole buildings.
- Encourage DOE to work with manufacturers, designers, and builders to demonstrate energy efficient equipment that works.
- Encourage DOE to set Up a building energy audit program involving architecture and engineering schools.

Box 5-F—The Aggressive Package

Incentives

- Mandate the **measurement and pricing of energy externalities.**

Federal leadership

- **Instruct DOE to promote actively the demonstration of efficient technologies in Federal buildings to strengthen markets for energy efficient goods and services.**

Research, development, and demonstration

- Require DOE to market buildings conservation RD&D results to utilities, State agencies, and its own regulatory programs, including the Office of Codes and Standards (within the Office of Building Technologies).
- Require DOE to perform least-cost or net-benefit conservation RD&D planning.

Utilities

- **Direct** federally owned utilities to provide incentives to, or require, its customer utilities to adopt least-cost plans.

Mandates

- Require States to meet or exceed federally set minimum building efficiency standards, such as the Building Energy Performance Standards (BEPS).
- Adopt more stringent cost-effective National Appliance Energy Conservation Act standards by identifying equipment efficiency levels that represent longer paybacks than most current standards allow.
- Encourage or require secondary mortgage market institutions (e.g., the Federal Home Loan Mortgage Corporation) to require residences to meet the Council of American Officials Model Energy Code 1989 Edition (or some other major code).

Information

- Require point-of-sale disclosure of whole-building energy ratings.

SUMMARY AND CONCLUSIONS

OTA has shown that there are numerous opportunities to increase the efficiency of energy use in the residential and commercial sectors. Energy efficient technologies that would Provide net economic benefits “are commercially available yet often neglected by consumers. OTA has offered policy options to promote greater use of these technologies. These options are grouped into three levels: basic, moderate, and aggressive.

It is useful to compare the options discussed here to those contained in the National Energy Strategy (NES), a comprehensive strategy proposed by the Administration in 1991. The intent is to provide a sense of how the NES options related to residential and commercial energy efficiency compare to those offered by OTA. Box 5-G summarizes the NES options related to building energy efficiency. To illustrate the similarities and differences, options from the NES[70] and from OTA are compared~

NES: Increase support for research and development to:

- reduce costs and improve performance of residential energy technologies;
- reduce costs and improve performance of commercial-building energy technologies, including lighting systems, windows, heating and cooling equipment, and design techniques; and
- develop methods [in both the residential and commercial *sectors]* of measuring and improving indoor comfort and environmental quality.[71]

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[70] These Options are from the *National Energy Strategy,* 1st *cd., 1991/1992* (Washington, DC: U.S. Government Printing Office, February 1991), pp. 40-53.

[71] Ibid., pp. 41, 49.

Box 5-G-The National Energy Strategy: Summary of Options[1]

1. Increase support for research and development to:
   - reduce costs and improve performance of residential and commercial-building energy technologies.
   - develop methods of measuring and improving indoor comfort and environmental quality.

2. Increase energy efficiency of new housing by:
   - providing technical information and assistance to industry, utilities, and State and local governments.
   - assisting State and local governments in adopting and enforcing Federal energy-efficiency standards through local building codes*
   - requiring new federally subsidized homes and new manufactured housing to conform to more stringent energy-efficiency standards.

3. Retrofit existing residences by:
   - supporting home energy ratings and the use of energy-efficiency criteria in mortgage loans.
   - helping States to implement effective programs to retrofit housing occupied by low-income households.
   - demonstrating exemplary energy management in federally supported public housing.
   - retrofitting existing federally owned housing.

4. Improve the energy efficiency of residential appliances by using existing authority to update residential appliance efficiency standards to keep pace with new technology.

5. Provide information and technical assistance to:
   - support industry, utilities, and State and local governments in developing and implementing effective programs, including adoption of Federal efficiency guidelines in local building codes.
   - extend Federal performance testing and labeling to lighting products and other equipment.
   - accelerate commercial application of new technologies.

6. Implement efficiency guidelines and standards where needed for
   - lighting ballasts.
   - new buildings,

7. Exercise Federal leadership by:
   - increasing energy efficiency in Federal building design, operation, and procurement through improved management.
   - using Federal facilities to test promising new technologies.

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[1] From *National Energy Strategy: Powerful Ideas for America*, 1st ed. (Washington, DC: U.S. Government Printing Office, February 1991), pp. 41,49.

The NES identifies cost reduction and improved technical performance as key goals for buildings-related RD&D. In contrast, OTA's discussion stresses that implementation, rather than just improved technical performance, is of key concern. As the options in this report suggest, improving RD&D project planning and implementation through regular use of market surveys, increased industry involvement in project planning, and more emphasis on technology transfer would provide better assurances that applied RD&D projects will ultimately have practical applications. Examining least-cost or net benefit RD&D planning could be used to further assist DOE in ensuring that RD&D projects result in net societal benefits. And if feasible, actually implementing either RD&D planning method would better ensure that public RD&D funds are targeted at the most promising efficiency opportunities.

NES: Increase energy efficiency of new housing by:

- providing technical information and assistance to industry, utilities, and State and local governments.

NES: Retrofit existing residences by:

- helping States to implement effective programs to retrofit housing occupied by low-income households.

NES: Provide information and technical assistance [in the commercial sector] to:

- support industry, utilities, and State and local governments in developing and implementing effective programs, including adoption of Federal efficiency guidelines in local building codes.[72]

Both OTA and the NES stress the importance of supporting State and utility efforts to improve energy efficiency. OTA's analysis, however, points to the importance of frequent, rigorous program evaluation to determine how best to spend limited resources for maximum benefit. To this end, OTA offers policy options to encourage more frequent and more rigorous evaluation of Federal spending. In addition, OTA's options include those directed at assisting State and utility efforts designed to address all environmental and other externalities (not just indoor air quality) of energy production and use, Such efforts would allow decisionmakers to determine the level and desirability of incorporating the social costs of providing and using energy in their jurisdictions or service areas. Even more aggressive would be a Federal requirement to incorporate environmental and other externalities in energy planning and pricing. Both the NES and OTA suggest that DOE and FERC work to expand the adoption of least-cost planning by utilities.

NES: Increase energy efficiency of new housing by:

- assisting State and local governments in adopting and enforcing Federal energy-efficiency standards through local building codes, and
- requiring new federally subsidized homes and new manufactured housing to conform to more stringent energy-efficiency standards.

NES: Improve the energy efficiency of residential appliances by using existing authority to update residential appliance efficiency standards to keep pace with new technology. Implement efficiency guidelines and standards where needed for 'lighting ballasts and new buildings.' '[73]

The NES options relating to mandatory appliance standards suggest that no changes are needed to current coverage or authority. In contrast, OTA has offered several options, including examining the feasibility and effects of extending the appliance standards program to additional products. The NES options relating to building codes and standards are relatively similar to the OTA options, but Federal priorities are not well-defined in the NES. In fact, OTA in this report provides options that include Federal Goverment analysis of existing compliance with State and local energy codes, technical support for the 34 States with codes less stringent than the CABO MEC '89 to encourage their improvement, and coordination with trade groups (e.g., the Council of American Building Officials and the American Society of Heating, Refrigerating, and Air-Conditioning Engineers) to promote the wider adoption of existing energy codes and building energy standards (whether Federal or otherwise) that are the most suitable for interested States.

In these and other areas, the options offered by the NES generally fall at or below those offered by OTA at the ''basic' level. This suggests that the NES options do not represent the full range of options Congress could consider to implement energy efficiency in the residential and commercial sectors. Distinctions between NES and OTA policy options, however, do not suggest the desirability of any single option nor any single level of action. To be sure, no one policy option can be expected to secure the triple interest in forging a national energy policy: to improve economic competitiveness and growth by encouraging net reductions in national energy spending; to foster national security by reducing energy imports; and to safeguard the national and global environment by reducing the emissions associated with energy production and use. A reliable, comprehensive, and secure national energy policy will invariably include a range of options working on a variety of levels.

This report does not advance any one policy option nor any package as a national energy solution; it does, however, expand the menu of options for energy efficiency in U.S. buildings presented in the National Energy Strategy.

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[72] Ibid.

[73] Ibid.

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