Chapter 3

Federal Spending on Energy Used in Commercial and Residential Buildings

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The Federal Government owns and leases about 500,000 buildings of various sizes, construction, and uses. In fiscal year 1989, the energy used in these buildings cost the U.S. Treasury about $3.5 billion. In addition, the Federal Government spends approximately $4 billion each year subsidizing the utility bills of about 9 million lower income households through various assistance programs. Much of the electricity, natural gas, and petroleum purchased with this combined $7.5 billion is inefficiently used. Although the responsible Federal agencies have not analyzed basic energy- and cost-saving opportunities in Federal facilities, apparently at least 25 percent of the energy could be saved using a wide variety of currently available, cost-effective measures. Similar opportunities appear to exist in subsidized households.

FEDERAL ENERGY USE IN COMMERCIAL BUILDINGS[1]

As of 1986[2] there were just over 4 million commercial buildings with 57 billion square feet of floor space in the United States. The main uses of these buildings are highly varied, including offices, retail shops, schools, and hospitals (see table 3-la). The Federal Government owns over 51,000 of these commercial buildings with between 1 and 2 billion square feet of floor space,[3] and has about 7 percent additional floor space under lease.[4] As in the private sector, Federal building uses are diverse (see table 3-lb).

By far the largest Federal user of energy in commercial buildings is the Department of Defense (DOD), with about two-thirds of the total floor space. This does not include DOD's buildings in foreign countries. DOD commercial buildings include the complete range of functions: offices, warehouses, hospitals, retail stores, cafeterias, churches, etc. Figure 3-1 shows facilities energy use by the main Federal energy-using departments.

Federal agencies own most of the commercial building space they occupy. However, Federal agencies also often lease space either from private companies or from the General Services Administration (GSA), which owns and leases commercial space on their behalf. Because GSA often manages property for other agencies, it is the third largest owner (after DOD and the U.S. Postal Service (USPS)) of Federal buildings.

Enormous amounts of energy in several forms are used just to make the buildings inhabitable, that is, to provide light, heat, ventilation, and air conditioning. Large amounts of additional energy are used to power the wide assortment of appliances and equipment used in the buildings, ranging from computers to conveyor belts to stoves. In total, $61 billion in electricity, natural gas, fuel oil, district heat, and propane were consumed in 1986 to operate the Nation's commercial buildings.[5] Federally owned and occupied nonresidential buildings accounted for over 6 percent of that total.[6]

[1]Defined according to the Energy Information Administration's Nonresidential Buildings Energy Consumption Survey as: "roofed and walled structures used predominantly for a nonresidential, nonagricultural, and nonindustrial purposes and larger than 1000 square feet." U.S. Department of Energy, Energy Information Administration *Nonresidential Buildings Energy Consumption Survey: Characteristics of Commercial Buildings 1986,* DOE/EIA-0246 (Washington, DC: U.S. Government Printing Office, September 1988), p. 3.

[2]The year 1986 is the most recent for which data are available. However, each year approximately 100,000 new commercial buildings are constructed. Ibid., p. 82.

[3]Ibid., table 25, p. 79 reports about 1.1 billion square feet in its survey; U.S. General Services Administration, "Inventory Report of Real Property Owned by the United States Throughout the World," p. 11, Sept. 30, 1989, reports about 1.9 billion square feet in the United States.

[4]From U.S. General Services Administration, "~ventow Report on Real Property Leased to the United States Throughout the World," 1989. That report does not distinguish between residential and nonresidential uses, nor does it note building size.

[5]U.S. Energy Information Administration, "Nonresidential Buildings Energy Consumption Survey: Commercial Buildings Consumption and Expenditures 1986," DOE/EIA 0318(86), table 1, May 1989, p. 4.

[6]Total spending on energy for all federally owned buildings was $4 billion in fiscal year 1987, according to U.S. Department of Energy, Assistant Secretary, Conservation and Renewable Energy, "Annual Report on Federal Government Energy Management Fiscal Year 1987." Around $200 million of that was in military family housing. An additional amount was spent on energy used in leased buildings for which the Federal Government does not pay utilities directly.

Table 3-la—Commercial Buildings in the United States

	All buildings	
Building activity	Number of buildings (1,000)	Total floor space (million sq. ft.)
Assembly	571	7,287
Education	240	7,200
Food sales	102	712
Food service	201	1,277
Health care	51	2,104
Lodging	137	2,785
Mercantile/service	1,273	12,710
Office	607	9,499
Public safety	50	665
Warehouse	487	8,540
Other	94	3,730
Total	3,813	56,508

SOURCE: U.S. Department of Energy, Energy Information Administration, "Commercial Buildings Consumption and Expenditures 1986," DOE/EIA-0318(86), May 1989, p. 9.

Table 3-1 b—Federal Buildings in the United States

	Total floor space (million sq. ft.)
Service	431
Office	510
Research and development	124
Industrial	123
Hospitals	131
Storage	462
Schools	122
Other	103
Housing	705

SOURCE: U.S. General Services Administration, "Summary Report of Real Property Owned by the United States Throughout the World as of September 30, 1988," GSA Public Buildings Service.

Electricity Use

Electricity is the dominant energy form used in commercial buildings in terms of total annual spending ($47 billion in 1986, $2 b Federa1).[7] Electricity is essential for powering lights, electronic equipment, and the wide array of motors found in everything from elevators to conveyor belts to heating, ventilating, and air-conditioning (HVAC) equipment, and is also used for heating and cooking. It is also the most expensive per unit of energy delivered to the Federal Government (at $17/million Btu, electricity is four times more costly than natural gas).

Precisely how is electricity used in Federal commercial buildings? Although a large body of information is available, the amount of electricity actually used in any given building for any function such as lighting or office equipment can be only approximated since individual appliances or devices are not individually metered. Buildings "typically have a single meter tracking the total amount of electricity being used by all devices. Some Federal facilities such as military bases and other multibuilding complexes have even less information available. These facilities may have only a few meters monitoring energy use for a facility with hundreds or thousands of buildings. The lack of detailed information about energy use in Federal buildings is a frequently cited impediment to the analyses and programs needed to implement cost-saving efficiency measures.

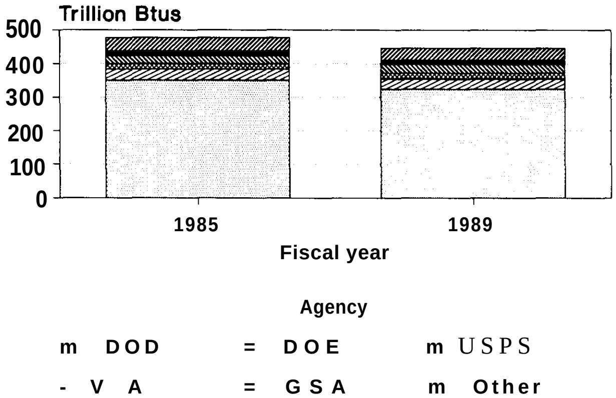
Due to the wide variety of building uses, geographic and weather conditions, type and age of construction, maintenance histories, and other factors, the amount of energy used in different buildings is highly variable. As weather conditions change from year to year, HVAC demand can change significantly. This complicates efforts to identify and monitor the performance of widely applicable energy- and cost-saving measures. It also complicates efforts to set standards of performance, such as maximum energy use per square foot, and to compare buildings. Each building has unique energy-use patterns and cost-saving opportunities.

Despite the limitations on detailed or site-specif information, there are some general estimates of the relative consumption of different uses. Lighting and air conditioning are the largest overall uses of commercial building electricity, although estimates vary. For example, one Electric Power Research Institute (EPRI) study estimated that lighting and cooling, respectively, consume 41 percent (since revised to 34 percent) and 31 percent of commercial building electricity.[8] As should be expected, the study's estimates varied greatly by building type; for example, hotels were estimated to use only 23 percent of their electricity for lighting, with 43 percent used for cooling. Reflecting the uncertainty inherent in determining detailed energy uses, other

[7] U.S. Energy Information Administration, op. Cit., footnote 5.

[8] Georgia Institute of Technology, *The Commend Planning System: National and Regional* Data a& Analysis, EPRI EM-4486 (Palo Alto, CA: Electric Power Research Institute, March 1986), p. B-37. Current best estimate of 34 percent for lighting from letter from Clark Gellings, Electric Power Research Institute, Feb. 15, 1991.

Figure 3-l—Federal Facilities Energy Use



NOTE: Site accounting used for electricity (see ch. 2).

SOURCE: U.S. Department of Energy, Federal Energy Management Program, "Report on Federal Government Energy Management and Conservation Programs," October 1990.

studies have produced quite different estimates. For example, a Gas Research Institute (GRI) study estimated that only 26 percent of electricity used in buildings is for lighting (11 percent in hotels), far less than EPRI's current estimate of 34 percent.[9] However, both studies agree that lighting and HVAC together account for over 70 percent of total commercial building electricity use.

Natural Gas

Natural gas is the second most heavily used energy source in the Nation's commercial buildings. It is the dominant energy source for space heating, water heating, and cooking, and accounted for $8.4 billion in 1986.[10] The Federal share of this spending was around $0.5 billion. As in the case with electricity, no one knows precisely how much natural gas is consumed in different uses. However, fewer devices use natural gas, so both metering and estimating use are less complicated. GRI estimates that space heating alone accounts for over two-thirds of gas use in commercial buildings, with under 4 percent used for water heating. The remainder is consumed in miscellaneous uses including cooking and cooling.

Fuel Oil and Miscellaneous

Fuel oil is used in just 12 percent of commercial buildings, mainly for space heating, with a total bill of $2 billion. A disproportionately large share, 25 percent or 17.4 million barrels/year, of that total is used in Federal facilities. The fuel oil is used almost entirely for space heating.

Some of the Nation's largest buildings use district heat (e.g., steam or hot water generated in a central plant and distributed to a number of buildings) for space heating, water heating, and cooking, with a total bill of $2.6 billion. There is also some use of district cooling. Federal buildings use a disproportionately large amount of district heat relative to other buildings. This is consistent with the high level of oil use, and reflects the use of fuel oil to generate steam for district heating systems. The remaining energy forms (e.g., propane and wood) are far less common and used mainly for space heating.

FEDERAL SPENDING ON RESIDENTIAL ENERGY USE

As of 1989 there were over 90 million households for about 240 million people in the United States.[11] The Federal Government subsidizes or pays part or all of the utility bills in about 9 million of these households. Two executive agencies are responsible for the vast majority of Federal expenditures on residential energy use: the Departments of Housing and Urban Development (HUD) and Health and Human Services (HHS). These two agencies subsidize or provide assistance payments for residential utility bills for low-income Americans. In addition, DOD houses 1.4 million military personnel and their dependents in family housing, and a few other agencies have a few thousand residences.

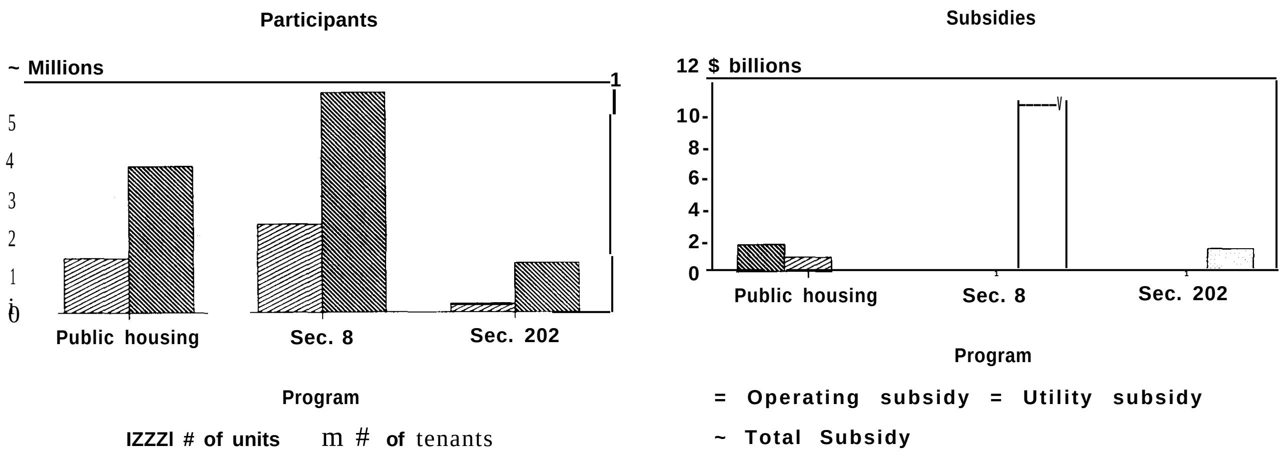
In total, $98 billion in electricity, natural gas, fuel oil, district heat, and propane were consumed in the Nation's homes in 1987 to operate appliances and

[9] Gas Research Institute, *Baseline Projection Data Book* (Washington, DC: 1989), P. 122.

[10] U.S. Department of Energy Information Administration, op. cit., footnote 5, table 2, p. 5-6.

[11] This population estimate does not include the homeless and people living in institutions (e.g., military barracks, prisons). U.S. Bureau Of the Census, *Statistical Abstract of the United States: 1990*, 110th ed. (Washington DC: 1990), pp. 2,45.

Figure 3-2—HUD-Assisted Housing Participants and Subsidies, 1989



SOURCE: U.S. Department of Housing and Urban Development.

provide hot water, heating, and cooling.[12] In 1989, the Federal Government's share of housing energy costs was about $4 billion.

Housing and Urban Development

Each year, HUD spends from $2 to $3 billion subsidizing the energy bills for 3.6 million federally assisted housing units (see figure 3-2).[13] There are two main HUD-assisted housing programs: a low-income public housing program and the Section 8[14] rental housing assistance program which can be used in privately owned housing.[15] Both programs are administered by HUD-regulated local public housing authorities (PHAs), of which there are about 2,700 nationwide.

Public Housing

Under the public housing program, local public housing authorities and Indian housing authorities develop, own, and manage housing projects. They receive HUD subsidies for construction, rehabilitation, and operating costs. Currently, approximately 1.4 million housing units in nearly 10,000 individual projects are administered by 2,700 PHAs. In total, about 3.8 million people live in public housing.

Energy expenditures constitute a large fraction of HUD's total spending on public housing. HUD's payment subsidy for utilities in these units for fiscal year 1989 was over $900 million (most was for energy, but this figure also includes water and sewer).[16]

Tenants of public housing typically pay 30 percent of their adjusted family income toward rent plus utilities, with the remainder of costs paid for by the housing authority (which is reimbursed by HUD). HUD does not keep account of the *total* annual spending on utilities including both HUD and tenant copayments.

Section 8

HUD's Section 8 low-income assistance program subsidizes 2.3 million housing units. Unlike public housing, Section 8 housing maybe privately owned. Through the Section 8 program, HUD subsidizes total housing costs, including both rent and utilities

[12] The year 1987 is the most recent for which detailed data are available for residential energy use. However, each year over 1 million new households are added to the existing stock. U.S. Department of Energy, Energy Information Agency, *Household Energy Consumption and Expenditures 1987 Part 1: National Data,* DOE/EIA 0321/1(87) (Washington, DC: U.S. Government Printing Office, October 1989), table ES1, p. viii.

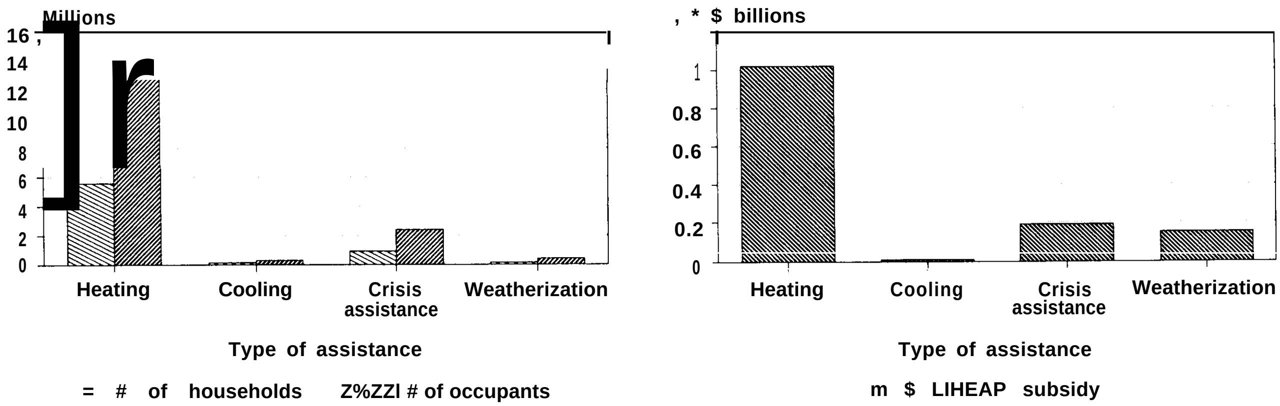
[13] J.M. MacDonald et al., Existing Building *Efficiency Research, 1987-1988, Oak* Ridge National Laboratory, ORNL/CON-268 (Washington, DC: U.S. Government Printing Office, August 1988), p. 25.

[14] Section 8 from the United States Housing Act of 1937, as amended (42 U.S.C.1437f) (1990, Cumulative Annual Pocket Part).

[15] For a historical overview of HUD-assisted-housing programs, see Grace Milgram, Library of Congress, Congressional Research Service, *Housing Policy: Low-and Moderate-Income, E388106* (Washington, DC: Congressional Research Service, Aug. 29, 1990).

[16] John Comerford, U.S. Department of Housing and Urban Development personal communication, Oct. 17, 1990.

Figure 3-3-HHS-Assisted Housing Participants and Operating Subsidies, Fiscal Year 1989



SOURCE: Number of occupants based on average household size in the United States. U.S. Department of Health and Human Services, Office of Energy Assistance, "Low Income Home Energy Assistance Program Report to Congress for FY 1989," October 1990.

for low-income, elderly, or handicapped tenants of participating rental properties. HUD subsidizes the difference between "fair market rent" (including utility expenses) and 30 percent of tenant adjusted income.

HUD does not keep track of energy use and spending in Section 8-assisted housing. As a result, less is known about the cost of energy in Section 8 housing compared to the public housing program. However, based on the amount of energy spending in public housing ($650/unit annually), a reasonable estimate of annual Section 8 subsidies which are used for energy is $1.5 billion. As with public housing, this estimate does not include the amount paid for by tenants.

Health and Human Services[17]

HHS' Low Income Home Energy Assistance Program (LIHEAP)[18] assists low-income households in meeting costs of residential heating or cooling. Some LIHEAP recipients live in HUD-assisted housing, but the majority do not. HHS provides grants to the States and to Indian tribes and territories which administer the program. In fiscal year 1989, HHS spending on LIHEAP totaled $1.4 billion. States supplemented this amount with oil overcharge funds ($174 million), LIHEAP carry-overs from fiscal year 1988 ($82 million), and a small amount of State funds ($6 million). In total, around 15 million[19] people in about 6 million households were assisted with heating and cooling subsidies (see figure 3-3). The 6 million households receiving LIHEAP assistance represent only around 23 percent of those eligible under the Federal maximum income standard. That is, over 25 million households meet the Federal maximum income standard for LIHEAP assistance. States often apply more restrictive standards.

LIHEAP assistance covers some but not all of the total cost of a recipient's energy use for heating and cooling. For example, approximately 50 percent of a typical recipient's heating costs are paid by LIHEAP, with the remainder paid by the recipient or other sources. Twenty-one percent or about 1.3 million LIHEAP households live in HUD-assisted housing, so they receive energy subsidies or assistance from both HUD and HHS.

Until 1994, States are also allowed to divert 10 percent of LIHEAP funds to nonenergy block grants such as social services, community services, and

[17] This S,,ti,,is based on information contained in U.S. Department of Health and Human Services, Office of Energy Assistance, "LowIncomeHome Energy Assistance Program Report to Congress for FY 1989," October 1990.

[18] The Low Income Home Energy Assistance Program is authorized by Tide XXVI of the Omnibus Budget Reconciliation Act of 1981 (OBRA), Public Law 97-35, as amended.

[19] HHS does not track the number of people assisted b, LIHEAP. This estimate is based on average household size in the United States.

alcohol, drug abuse, and mental health services. In fiscal year 1989,28 States did so, most of them to the maximum amount, reducing the total spending on energy assistance.

The majority of LIHEAP recipients use natural gas as their primary heating source, with fuel oil and electricity far below. Compared to all U.S. households, LIHEAP recipients use far less electric heating and more liquefied petroleum gas (LPG) and kerosene (see figure 3-4).

Department of Defense

DOD houses over 1.4 million military personnel and their dependents in 422,000 multifamily and single family housing units worldwide (see figure 3-5). Most reside in the United States, but large concentrations are in several other countries. The U.S. Army, largest of the services, has just under half the total housing units and just over half of the total served population. In addition to family housing, military barracks house a large number of troops which are not included in these totals.

Generally, energy used in individual units is neither separately metered nor charged for. Total energy use in military housing is around 53 billion MBtus annually. This energy cost the Federal Government around $200 million based on the average cost of energy.

Main Energy Uses in Federally Owned or Assisted Housing[20]

As in the commercial sector, only a few main energy uses constitute the majority of residential energy consumption and spending (see figure 3-6). By far the highest on the list both in terms of total energy use and spending is space heating. Heating energy use and expenditures vary greatly depending on factors such as climate, type of building, size of household, and condition. For example, an average household in west coast States spends one-third as much on heating as a New England household, and an average single family household spends twice the amount on heating as one in a large apartment building. As an indication of increased energy efficiency in construction over time, homes built since 1980 use only two-thirds the energy of homes built before 1950, after adjusting for weather and home size. Natural gas supplies over two-thirds of the energy used for space heating. Most of the rest (20 percent) is provided by fuel oil and kerosene, with the remainder split between electricity and LPG (5 percent each).

Nearly every household has a water heater, which on average consumes 18 MBtu/year, making that the next largest residential energy use. As with space heating, natural gas provides two-thirds of the energy used in water heaters. Some large apartment complexes (common among assisted housing projects and some military housing) may have a central boiler providing water heating and/or space heating.

Refrigerators are the largest single use of residential electricity, consuming about 20 percent of the total. Nearly every household has a refrigerator, and on average, it consumes around 1,500 kWh/year. Air conditioning is the second largest residential electricity use after refrigerators. Unlike refrigerator use, energy use for air conditioning depends strongly on household location and type. For example, only a third of households in the relatively cool Northeast even have air conditioning, compared to 80 percent in the South.[21] And those air conditioning units in the South consume on average more than double the amount used in units in the Northeast. Air conditioning depends strongly on income levels. Households below the poverty line are a third less likely to have air conditioning than the average household. A large list of other uses constitute the remaining 16 percent of household energy. These include cooking, dishwashers, clothes washing and drying, lighting, and electronic equipment such as televisions.

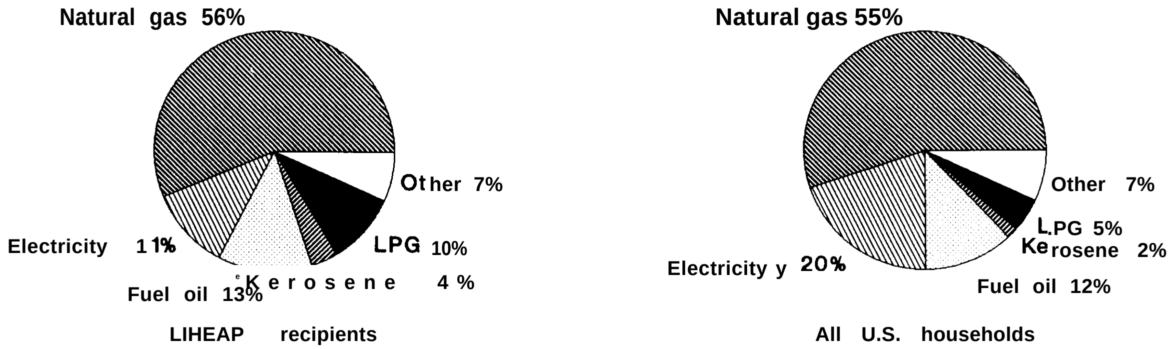
As in the case with U.S. housing generally, energy use in federally assisted and owned households is diverse, reflecting the diverse nature of the building stock and weather conditions across the country.[22] There are many building styles in public housing projects, ranging from high-rise apartments to low-rise apartments to groups of two- or three-story duplexes. Large projects may have several hundred units. Age and condition of public housing varies widely, too. Many projects were constructed prior to

[20] The information in this section is derived from, op. cit., footnote 12. The descriptions here are true of housing in general, although federally owned or assisted households have some different attributes.

[21] U.S. Department of Energy, Energy Information Administration, op. cit., footnote 12, tables 7, 32, ES1, October 1989.

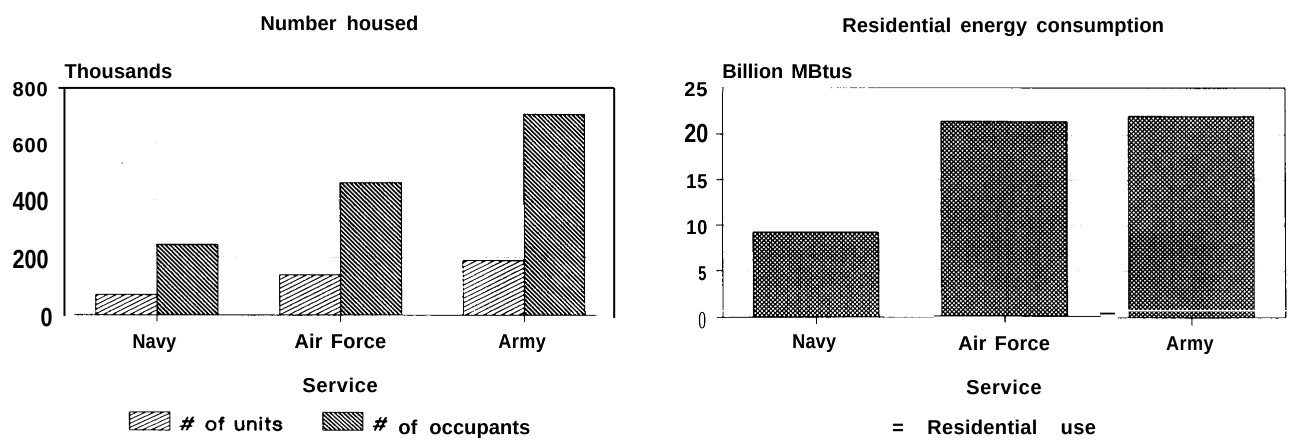
[22] See Perkins & Will and Ehrenkrantz Group, ''An Evaluation of the Physical Condition of Public Housing Stock, Vol. 4,'' HUD Report H2850, 1980.

Figure 3-4—Primary Heating Source, LIHEAP Households and All U.S. Households, 1989



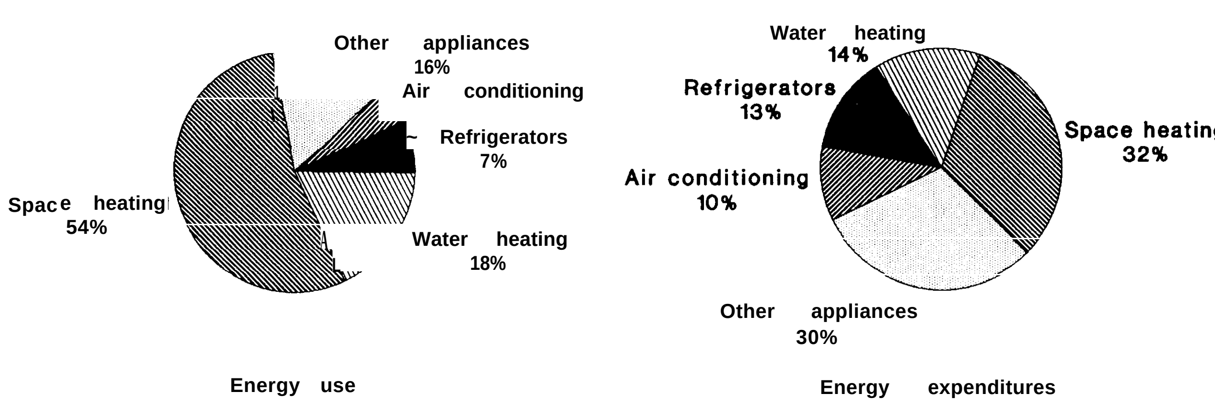
SOURCE: U.S. Department of Health and Human Services, Office of Energy Assistance, "Low Income Home Energy Assistance Program Report to Congress for FY 1989," October 1990.

Figure 3-5—Military Family Housing, 1989



NOTE: Source accounting used for electricity.
SOURCE: U.S. Department of Defense.

Figure 3-6—Residential Energy Use and Expenditures, 1987



SOURCE: U.S. Department of Energy, Energy Information Administration, "Household Energy Consumption 1987," DOE/EIA-0321/1(87) (Washington, DC: U.S. Government Printing Office, October 1989).

the first oil-price shock in 1973, and were built with accordingly low insulation levels. HHS-assisted and military households have a similar broad range, with the addition of single family houses. Even within a given complex, units can have widely varying energy use. For example, an end unit in an apartment building, with more exposed walls and windows, may require considerably more fuel for heating than an interior unit. Similarly, the same unit with different occupancy levels can have different energy use.

HOW MUCH CAN THE FEDERAL GOVERNMENT TRIM FROM ITS BUILDING ENERGY BUDGETS?

Federally Owned and Leased Buildings

There is little question that a large fraction of the Federal Government's $3.5 billion direct annual spending **on energy in its buildings could be greatly reduced using cost-effective, well-proven technologies.** For example, at the five federally owned or leased facilities in OTA's commercial case studies (see ''Chapter 5: Case Studies"), the facility managers estimated that an average savings of at least 25 percent in annual operating cost and energy use appears achievable with proven and highly cost-effective technology. This level of saving requires no change in occupant comfort or productivity; rather, it involves more effective use of energy, either through more efficient equipment or through improved operations and maintenance practices.

OTA's case study estimates included only highly cost-effective options in which the capital costs and other costs of implementation are small compared to the savings, with simple paybacks of under 3 years. A less stringent economic test which is more consistent with the cost of capital in the United States would likely produce considerably higher estimates. For example, the 3 year payback represents a long-term return on investment of about 30 percent, far higher than the average rate of return on electric utility investments (about 14 percent in 1991) or the Treasury's cost of funds (currently under 8 percent).

Several recent analyses of the potential for energy efficiency in commercial buildings in the United States have estimated that gains of 25 percent or more are technically and economically feasible.[23] While these analyses do not focus on Federal facilities, they are indicative of the potential for typical buildings. Whether Federal facilities offer more or fewer opportunities for improvement is speculative.

The Federal Energy Management Program has not developed estimates either of the government's potential energy and cost savings nor of the capital and other resources required to attain those savings. Similarly, none of the individual energy-using Federal agencies contacted by OTA have produced estimates for their own facilities. All cite difficulties of performing the information collection and analyses required for even approximate estimates. Although building audits mandated under the Energy Conservation Policy Act were conducted at most major facilities in the past decade, there has been no Federal effort to compile the results, much less to keep results current. The same is true of the facility energy surveys mandated under the Federal Energy Management Improvement Act of 1988.

The lack of reasonably detailed, comprehensive analytical effort to date should not be interpreted as representing a lack of energy efficiency opportunities. Although Federal agencies have not published overall estimates of prospects for efficiency gains, they often take the public position that large gains are possible.[24] It is important to note that many easy, low risk (or risk-free) energy- and cost-saving measures with excellent economic characteristics have yet to be implemented at Federal facilities. The best options currently available appear to be excellent ways to reduce costs, energy, and environmental impacts under virtually any set of reasonable assumptions of future energy prices.

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[23] For example, see R.S. Carlsmith et al., "Energy Efficiency: How Far Can We 00?" ORNLJI'M-11441, Oak Ridge National Laboratory, OakRidge, TN, January 1990; and Barakat & Chamberlin, Inc., ''Efflcient Electricity Use: Estimates of Maximum Energy Savings," EPRI CU-6746, Electric Power Research Institute, March 1990; and Committee on Alternative Energy Research and Development Strategies, National Research Council, *Confronting Climate Change: Strategies for Energy Research and Development,* DOE/EH189027P-H1 (Washington, DC, August 1990), pp. 80-90.

[24] For example, see U.S. Department of Energy, Federal Energy Management Program, ''Annual Report on Federal Government Energy Management and Conservation programs Fiscal Year 1989, ' Oct. 3, 1990, p. 26-41; and Executive Order 12759, signed Apr. 17, 1991, which includes a provision for a 20-percent reduction in both buildings and industrial facilities by 2000.

Federally Assisted Households

As in the case with the Federal Government's commercial buildings, there seems little question that increased use of existing, proven technologies would reduce a large fraction of the $4 billion in residential **energy paid for by the government in federally owned and assisted households. These** gains require no change in occupant comfort. For example, a program of early refrigerator retirement coupled with using the most efficient models available offers the prospect of reducing Federal residential electricity expenditures by a few percent. Such an early retirement program for other appliances such as water heaters and washing machines could also cost-effectively save both gas and electricity. These energy- and cost-saving appliance opportunities exist in all types of federally owned and assisted households.

Since space heating is the leading residential energy use, many opportunities for energy and cost savings depend on promoting higher efficiency heating equipment and weatherization programs. Opportunities for savings are large. For example, a comprehensive study of energy-saving opportunities in public housing published by HUD in 1988 estimated the potential for over 30-percent savings with an average payback of 4.5 years for capital invested.[25] These results were consistent with a study performed a decade earlier.[26] OTA's case study of one public housing authority found that at least 30-percent gains could be realized using highly cost-effective measures such as weatherstripping and insulation. Several field studies of program implementation have verified that large savings are possible, although the performance in different projects has been highly variable.

Results of field studies of low-income weatherization programs (e.g., those funded by HHS and DOE) have found considerable savings potential, although results are variable.[27] To gain a better understanding of the potential gains and best methods to use, DOE's Weatherization Assistance Program recently began a comprehensive 3-year, $5-million review of performance. This analysis should help identify the economically and technically most effective programs for the future. HHS has not analyzed the effectiveness of LIHEAP weatherization funds in reducing energy use and reducing the future need for LIHEAP tiding, but is providing input to DOE's Weatherization Assistance Program study. Analyses of the relative merits of energy assistance and weatherization assistance have been largely left to the individual States which administer the HHS funds.

Although weatherization and rehabilitation programs have been promoted in federally assisted households, much remains to be done. For example, HUD's 1988 study of modernization needs found that the total one-time investment required to bring properties up to minimum standards and "enhance their long-term viability" (including safety, health, and environmental improvements as well as energy) amounted to over $20 billion.[28] However, annual spending on modernization has been only $1.6 billion during the past several years.[29] Similarly, each year less than 1 percent of the low-income households eligible for LIHEAP utility payments are weatherized under either LIHEAP or DOE's weatherization assistance programs.

It is difficult to estimate total spending on energy efficiency at HUD: funds spent on general rehabilitation often include some energy measures but are not listed as energy efficiency efforts. For example, double-pane insulated windows may be used when replacing broken single-pane windows. The result is considerable improvement in the building's resistance to heat loss, but may not be noted as an energy upgrade. Similarly, repair of flat roofs may be accompanied by added insulation. Because the primary reason for an energy efficiency upgrade maybe

[25] The study identified capital improvements and repairs, such as fixing windows and upgrading HVAC equipment, costing $939 million which would save $211 million annually. In addition, window repairs and improved operation and maintenance practices costing $98 million and needing to be repeated every 3 to 5 years would save$112 million annually. These Operations& Maintenance practices include weatherstripping and caulking. Abt Associates, "Study of the Modernization Needs of the Public and Indian Housing Stock," HUD-1130-PDR, March 1988, pp. 83-84. Note that HUD's total annual utility spending for public housing is around $900 million, as described previously.

[26] Perkins & Will and Ehrenkrantz Group, op. cit., footnote **.

[27] See for example, many of the articles in *Proceedings from the ACEEE 1990 Summer Study on Energy Efficiency in Buildings* (Washington DC: American Council for an Energy-Efficient Economy, 1990), vol. 1 to 10.

[28] Abt Associates, op. cit., footnote 25.

[29] U.S. Housing and Urban Development, "Programs of HUD 1989- 1990," HUD-214-PA(17), October 1989, P. 75.

basic maintenance, keeping track of spending and implementation of efficiency measures is complicated.

ENERGY- AND COST-SAVING MEASURES: ARE THEY TRULY WORKING OPTIONS FOR THE FEDERAL GOVERNMENT?

For nearly every application of energy in residential and commercial buildings, measures are available that can improve the efficiency of use.[30] Many, but certainly not all, have attractive cost and performance characteristics. Deciding which measures to pursue, if any, often requires careful engineering and economic analyses. Successful programs, those which reduce energy use and overall costs, also often require ongoing, dedicated efforts to ensure that they work initially and continue to work. This section examines some of the useful lessons from the past decade of energy efficiency programs.

There Are Many Effective Energy Efficiency Measures

The variety of currently available efficiency measures and the range of economic and performance characteristics is large. Many currently available measures appear to have excellent economic and performance characteristics and have been proven in use, although they are not yet standard practice. There is a large and growing body of applied research into the performance of a variety of energy efficiency programs.[31] There is also a large body of less formal information in trade journals which report on the results of efficiency measures.[32] These report on a continuing stream of successful energy management efforts following a wide range of approaches.

New Technologies Do Not Always Work as Planned

After many years of energy efficiency efforts throughout the U.S. economy, including within the Federal Government, it is clear that energy efficiency programs can work well. It is also clear that some energy efficiency technologies and programs have not always performed as well as expected. Both research and trade journals report a steady stream of projects performing below expectations. (They also show a steady stream of projects which perform excellently.) Sometimes new technology does not perform as it should, as in the case of the excessive failure rate of some early electronic ballasts. As a corollary, technologies are continually being imroved and refined, or disappear from the market. Again, electronic ballasts provide an example with the high reliability they now have demonstrated.

As with any evolving technology (and as with many well-established technologies), some products have marginal to poor performance and economics but have yet to be driven off the market. Naturally, this greatly complicates the job of facility managers in implementing cost- and energy-saving technologies.

Also, because of the wide variety of buildings, uses, technologies, and other conditions, it is also possible that good technologies can be misapplied, resulting in poor performance or unmet economic expectations.[33] For example, because compact fluorescent lamps are larger and heavier than the incandescent lamps they replace, there are many light fixtures in which they cannot be used. Also, although the color of light produced is good, it is not identical to incandescent light. A program to replace all incandescent lamps in a building with compact fluorescent which neglects those facts could produce considerable dissatisfaction.

Savings Estimates Often Differ From Actual Savings

Estimates of potential savings are important for program planning, but the aim of energy management programs is to realize actual reductions in energy use and overall costs. Analyses of past energy efficiency programs have often found that savings were less than expected, sometimes by large

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[30] An ongoing OTA study, "Residential and Commercial Energy Efficiency," is examining the difference between estimates and actual results in-depth.

[31] See for example, U.S. Department of Energy, *Buildings Energy Technology*, any issue; or *Proceedings from the ACEEE Summer Study on Energy Efficiency in Buildings* (Washington, DC: American Council for an Energy-Efficient Economy), Biennial, any issue.

[32] See, for example, any issue of *Energy User News*, published monthly.

[33] One example of a publication which has detailed articles about a wide range of energy. savings opportunities in actual use is *Energy User News*, published monthly. The real world, site-specific information presented there can be of great use in reducing the risk of using new energy efficiency measures.

amounts. There are many reasons. Sometimes technologies simply do not perform as planned. Savings estimates are often based on idealized engineering analyses which may be distinctly different from conditions found in practice. Generally, measuring the actual impact of a conservation measure is difficult due to the lack of detailed energy use metering and the variability in use resulting from weather and occupancy changes.

Applicability of Efficiency Measures Is Often Site-Specific

Some energy- and cost-saving measures are generally good practice and should be widely applied, requiring relatively simple engineering or economic analysis. For example, use of motion detectors to control lights in occasionally used spaces such as restrooms, conference rooms, and private offices makes economic sense and performs well in most such circumstances. Eventually, use of these approaches may become the rule rather than the exception that they currently are. Another example is the apparently cost-effective and reliable combination of high efficiency electronic ballasts coupled with fluorescent "T-8" tubes.

Other measures have highly site-specific economic and performance characteristics, requiring fairly detailed engineering and economic analyses. For example, the benefits of adding an energy management system depend on the type of heating, ventilating, and air conditioning equipment in place (and possible plans to replace existing equipment), as well as the building's schedule, external characteristics and internal layout and occupancy. Similarly, opportunities to delamp, or reduce lighting in overlit areas, can only be determined from a site survey which evaluates current lighting levels and the levels which would result after delamping. While the applicability of these measures is site-specific, conducting site surveys including engineering and economic analyses to identify candidate measures followed by funding, staffing, and implementation should be a reasonable general practice. To realize the potential cost and energy savings, the site survey would have to be followed by detailed audits and implementation where indicated.[34]

The desirability of any measure depends on several factors including the performance, initial cost, operating costs or cost savings, environmental impacts, and risk. All measures cost something but some, such as performing preventive maintenance on steam traps are nearly free, are well-proven (thus entail little technical risk), and can generate considerable savings. Other measures, such as replacing existing low efficiency light fixtures and lamps with high efficiency systems, may involve a capital expenditure which is rapidly paid back through reduced operating costs. Still other measures, such as the early retirement and replacement of a moderately efficient air conditioner with a more efficient but commercially unproven unit, may or may not pay back.

Successful Implementation Often Requires Ongoing Effort

Energy efficiency measures generally involve change. There are changes either to equipment or to operating and maintenance practices, and there are continuing changes in the available technologies. At any facility, ensuring that the best practices and equipment are being applied requires ongoing, dedicated effort. This is critical not only for ensuring that the technologies work as planned and for refining them when needed, but also for separating successful approaches from poor ones.

EFFICIENT TECHNOLOGIES FOR MAJOR ENERGY USES

This section examines some of the main energy uses found in Federal commercial and residential buildings, and some technologies applicable to energy efficiency gains.[35]

Lighting

Lighting is ubiquitous in commercial buildings, and is responsible for around 25 to 50 percent of electricity use in those buildings. In addition to the energy used directly by the lights, heat produced by

[34] For an in-depth discussion of energy audits, see Albert Thumann, *Handbook of Energy Audits* (Lilburn, GA: Fairmont Press, Inc., 1983).

[35] For an exhaustive description of a wide range of energy efficient measures, see for example, *Architect's and Engineer's Guide to Energy Conservation in Existing Building: Volume 2-Energy Conservation Opportunities*, prepared for U.S. Department of Energy, DOE/RL/01830P-H4, April 1990. That report describes 118 energy conservation opportunities using currently available products which could be considered for commercial buildings. Also see Battelle-Columbus Division and Enviro-Management & Research, Inc., *DSM Technology Alternatives*, EPRI EM-5457 (Palo Alto, CA: Electric Power Research Institute, October 1987), for descriptions of 99 energy efficiency technologies which can affect electricity use.

lights contributes significantly to air conditioning loads in commercial buildings, indirectly contributing to additional electricity demand. Lighting is afar smaller contributor to residential energy use, but still affords some economic opportunities.

Many lighting measures for commercial building applications have been heavily researched over the past two decades.[36] During this time, a wide range of approaches and products for improving the performance of lighting have been pursued and implemented. Several lighting measures now available appear to offer considerable energy- and cost-saving potential, with attractive reliability and performance. (Table 3-2 summarizes the main approaches to the more efficient use of electricity for lighting.) The three main approaches are: reduce unneeded illumination, increase efficiency of lamps, and increase efficiency of fixtures.

Table 3-2—Lighting Efficiency Measures

Reduce unneeded illumlnat!on
Delamp overlit areas
Use task lighting
Use lighting controls
Occupancy sensors and timers
Daylight with automatic dimmers
Increase efficiency of lamps and ballasts
Use high-efficiency lamps
Use high-efficiency ballasts
Increase efficiency of light fixtures
Use reflectors and high-efficiency fixtures
Clean and maintain fixtures

SOURCE: Office of Technology Assessment, 1991.

General Services Administration together with the Department of Energy (DOE) have announced a $10-million program to make use of energy efficient lighting measures in the National Capital Region. This program will take advantage of an energy efficiency incentive program offered by the Potomac Electric Power Co., the local electric utility.

The Defense Logistics Agency (DLA) takes the lead for Federal procurement of lamps and ballasts and resale to other agencies. In 1989, this responsibility was transferred from GSA, which retains main responsibility for other lighting products such as futures. DLA does not emphasize high efficiency products in its role as main provider of bulbs and ballasts.

Reduce Unneeded Illumination

Delamp overlit areas, use task lighting. Any effort to reduce illumination levels needs to be based on a careful, site-specific analysis of illumination requirements. Failure to do so can cause worker dissatisfaction and perhaps reduced performance, neither of which are consistent with energy efficiency efforts.

However, buildings often have higher illumination levels than needed for occupant comfort. Minimum illumination levels are specified by facility engineers, the Illumination Engineering Society, and others depending on the type of activity. For example, GSA requires 50 foot-candles of illumination for desks, and 30 foot-candles for hallways. Lighting levels can be reduced very inexpensively by removing lamps, as in the case of removing two lamps and disconnecting one of the ballasts in a four-lamp fixture. Using lower output lamps may also reduce power, as in using 34-watt fluorescent tubes to replace standard 40-watt tubes. In this case, the 34-watt tubes are slightly more efficient than the 40-watt tubes, and light levels are not proportionately reduced. Task lighting allows reducing overall light levels by increasing light on the desk or working surface.

Use lighting controls such as occupancy sensors, timers, and daylighting with automatic dimmers. A variety of methods for turning lights off when not needed have been developed and demonstrated in practice.[37] Turning lights off which are not needed can both reduce energy use and extend replacement time for the lamps. Frequent switching reduces fluorescent lamp operating lives, but with modern tubes only a short period of being turned off compensates for the additional switching. Automatic switching using occupancy sensors is more reliable and convenient than manual switching, and is well suited to bathrooms, conference rooms, and some hallways and private offices. Simple timed switches are inexpensive, and perform well in locations such as storerooms. Several brands of occupancy sensors have established good operating records, and when installed in a suitable location

[36]See Albert Thumann, Lighting *Efficiency* Applications (Lilburn, GA: Fairmont Press Inc., 1989).

[37]See, for example F. Rubinstein and R. Verderber, ''Automatic Lighting Controls Demonstration,'' prepared for Pacific Gas& Electric Co., March 1990. This project, which combined a variety of control strategies centering around dimming electronic ballasts, demonstrated savings of over 50 percent with a payback of under 2 years for a small office space.

have good economic characteristics. Detailed site surveys and analyses are not required for occupancy sensors and timers. However, a reasonable estimate of the schedule of use of lights and the opportunity for curtailing use is needed.

Automatic dimming controls sense lighting levels and turn down lights when daylight is present. They may be suitable for use in offices at building perimeters or near skylights. Daylighting is finding increased use in new buildings and retrofits, but is not widely applied. Opportunities are highly site-specific.

Increase Efficiency of Lamps and Ballasts

Tremendous advances have been realized in the efficiency of bulbs and ballasts over the past decade, many of which are not widely used in Federal facilities. Most of the commonly used types of lamps, including fluorescent, incandescent, mercury vapor, metal halide, and high- and low-pressure sodium, have all had significant performance improvements. Demand for some new high-efficiency compact fluorescent lamps and electronic ballasts has grown so rapidly that it may outstrip supply.[38]

Fluorescent Lamps and Ballasts—Many high efficiency lamps and electronic or hybrid electronic/magnetic ballasts that replace standard fluorescent tubes and standard magnetic ballasts have been commercialized. Laboratory studies indicate that the most efficient combination presents savings opportunities of up to 39 percent compared with standard tubes and ballasts.[39] Table 3-3 compares the efficiency of different combinations of ballasts and lamp efficiencies for "cool white" 4-foot tubes. At least some of the products available have been well-proven in widespread use and noted in industry press.[40] In 1988, electronic ballasts captured around 4 percent of the market, a small amount but enough to prove reliability.[41]

Table 3-3 also shows the bulk costs of ballasts and tubes. Generally, the higher the efficiency of lamps and ballasts, the higher the first cost. However, the cost of lamps and ballasts is less than the cost of the electricity those components will use in their lifetime. Paybacks for replacement and for use in new construction are often rapid, under 3 years. For example, the T-8 tubes and electronic ballasts appear to have clearly superior economic characteristics compared with standard fluorescent for use in new construction and when existing components reach the end of their life. Performance is comparable or superior to that of standard systems, with better color and reduced flicker, although some ballasts may generate power quality problems such as unwanted harmonics. In many cases, early replacement (e.g., replacing a still-functioning lamp) with high efficiency components is economically attractive.

Prior to 1990, standard magnetic ballasts, hybrid electronic/magnetic ballasts, and electronic ballasts were all available in the commercial market from several manufacturers. However, the National Appliance Efficiency Act of 1988 set a minimum efficiency standard for most common ballasts which removes standard ballasts from the domestic market. Even though the least efficient ballasts are no longer manufactured, existing stocks are still marketed. This, together with their long 10-year lifetime, means that these costly-to-operate devices will continue to consume excessive amounts of electricity and Federal energy dollars for several years.

Incandescent Lamps—While the majority of lighting fixtures in most commercial buildings are fluorescent, some incandescent lamps are also used. In contrast, most residential lighting is incandescent. Over the last few years, fluorescent lighting technology has gradually improved, with the lights gradually becoming small and light enough to substitute for screw-in incandescent lamps in certain fixtures. These compact fluorescent lamps consume only about 25 percent of the power of a standard incandescent lamp of the same light output. However, compact fluorescent lamps remain considerably heavier and larger than incandescent lamps, and thus cannot always be used in the existing fixtures.

[38] "As DSM Programs Gain, Consultant Warns of Possible Lamp Shortages," *Electric Utility Week*, Feb. 25, 1991, p. 14.

[39] "Performance of Electronic Ballasts and Lighting Controllers With 34-W Fluorescent Lamps: Final Report," Lawrence Berkeley Laboratory, February 1988.

[40] See for example, R.S. Abesamis, P. Black, and J. Kessel, "Field Experience With High-Frequency Ballasts," *IEEE Transactions on Industry Applications*, vol. 26, No. 5, p. 810811, which describes the successful application of over 45,000 high-frequency electronic ballasts at the University of California at Berkeley.

[41] U.S. Department of Energy, "Trends in Energy-Efficient Lighting, Conservation and Renewable Energy Inquiry and Referral Service (CAREIRS), March 1990.

Table 3-3-Comparison of Fluorescent Lamps
(77 test room— 4-lamp recessed troffer, plastic lens)

Lamp type	Ballast	Ballast factor[1a]	Watts[a]	Relative light Output[2a]	Relative light output/watt[a]	cost[5bc]
T-12 standard (40 W)	Standard magnetic[4]	0.95	174	100	100	n/a
T-12 energy-saving (34 W) rare earth tri-phosphor	Standard magnetic[4]	0.90	155	93	104	n/a
T-12 standard (40 W)	Energy-saving magnetic	0.95	162	101	108	26.80
T-12 energy-saving (34 W) rare earth tri-phosphor	Energy-saving magnetic	0.88	139	91	114	27.80
T-8 lamp (32 W)[3].	T-8 electronic	0.92	106	98	161	47.80

NOTES: 1. Data in test normalized to ballast factors shown in this column for magnetic ballasts. Factors shown for electronic ballasts are measured values of sample.
2. Relative light output based on initial (100 hour) rated lamp lumen output.
3. Life rated at 15,000 hours. All other systems shown are rated at 20,000 hours.
4. Standard magnetic ballasts are only available for export since the National Energy Appliance Conservation Act (NEACA) passed in 1989.
5. Cost column is the cost of the lamp multiplied by four, plus the cost of the ballast.

SOURCES: [a]National Electrical Contractors Association.
[b]Jim Osborne, Magnetek, personal communication, February 1991.
[c]Customer Service, General Electric Lighting, personal communication, Mar. 11, 1991.

A compact fluorescent lamp is far more expensive than the incandescent it replaces. For example, a 15-watt compact fluorescent purchased by the Federal Government costs around $7, compared to about $0.30 for the 60-watt incandescent it replaces.[42] However, savings on both energy costs and maintenance costs can be very high if the lamp operates a few hours a day or more. For example, for lights turned on 8 or more hours per day on weekdays, compact fluorescent lamps can pay for themselves in under 1 year.[43] Maintenance savings result because the fluorescent lamps have a lifetime 10 times longer than standard incandescent, potentially decreasing maintenance and replacement costs considerably. However, for an incandescent turned on only 1 hour per day, the potential savings are small relative to the cost of a compact fluorescent.

Use of compact fluorescent replacements for incandescent lamps is increasing in the commercial sector. However, further advances (notably in size and weight) are necessary before they become the rule rather than the exception for even heavily used lights. For occasionally used lights, considerable reduction in first cost is also necessary.

For incandescent fixtures in which compact fluorescent lamps are too heavy or too large to work, higher efficiency incandescent are available which reduce consumption by 10 to 20 percent and produce the same light output.

Use High Efficiency Fixtures

In the past several years, a large number of new fixtures have been marketed, intended to improve the distribution of light, increase efficiency, and improve visual comfort. The key features of high efficiency fixtures are reflectors and lenses which direct light toward the working space. High reflectance silver or aluminum reflectors inserted into fluorescent fixtures can increase fixture efficiency by 20 to 35 percent.[44] Also, because the efficiency of fluorescent tubes decreases outside a certain range of operating temperatures, a feature of efficient fixture design allows heat dissipation to maintain optimal bulb temperatures.[45] Measuring the performance of fixtures is difficult, depending not only on the level of illumination resulting, but the distribution of light at the working surface.

42 General Electric Customer's Service, personal communication, Mar. 26, 1991.

43 Annual savings in cost-of-energy is about:

(8 hour/day)* (235 days/year)* (0.045 kilowatts)* ($0.07/kilowatt-hour) = $6/yew,

Incandescent lamps, with an average lifetime of 1,000 hours, must be replaced twice per year if operated 8 hours daily, so the compact fluorescent additionally saves about 1/2 hour of labor, approximately $10 for typical maintenance workers. Note that benefits from reduced maintenance may not accrue if maintenance workers are made idle but remain on the payroll.

44 T.K. McGowan and H.H. Whitmore, "Performance of Fluorescent Reflector Inserts," GE Lighting, Nela Park, OH, undated.

45 See *Energy Conservation* Potential *Associated With Thermally Efficient Fluorescent Fixtures*, Lawrence Berkeley Laboratory, CA, prepared for Department of Energy, Washington DC, June 89.

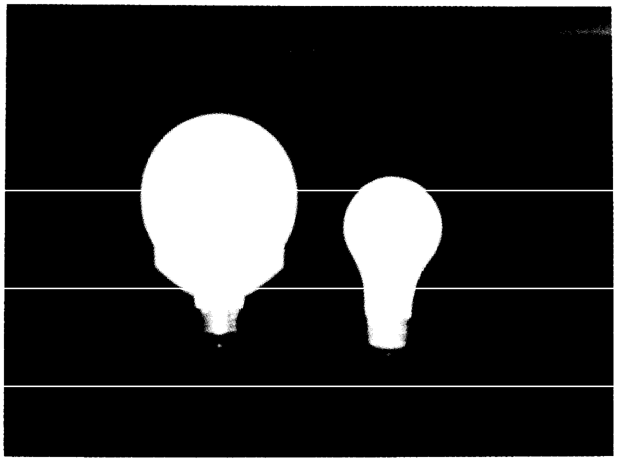

Photo credit: Christine Onrubia

Compact fluorescent lamps are nearly four times more efficient than incandescent lamps, but are too large to fit in many popular fixtures.

To keep any fixtures operating optimally, basic maintenance in the form of cleaning is required. The light from very dirty fluorescent fixtures and lamps may be less than 70 percent the light from the same equipment when clean.[46] It is possible that high efficiency fixtures may be more susceptible to dirt-induced degradation than standard counterparts.

Future Directions in Lighting Efficiency

Advances in lighting technology are continuing along a variety of fronts. Better lamps, ballasts, and fixtures are all being pursued by manufacturers. These efforts should continue to improve the prospects for efficiency, applicability, and customer acceptance. One area which could benefit from additional effort is product testing. Performance, including efficiency, visual comfort, and reliability of new products is often difficult to gauge. Because lighting technologies are constantly evolving, systematic testing and reporting from a reliable source could be of considerable help to building managers, with their limited time and resources to explore the vast array of available options.

Heating, Ventilation, and Air Conditioning

As with lighting, HVAC is ubiquitous in commercial and residential buildings, including those owned and assisted by the Federal Government. In many buildings, heating, ventilating, and air conditioning, in total, account for the majority of both electric energy use and energy use overall.

During the past two decades, many approaches have been heavily researched which can reduce the energy needed for heating, ventilating, and air conditioning.[47] (Table 3-4 summarizes the main approaches to the more efficient use of energy for HVAC.) The two main approaches are: improve the building envelope and increase efficiency of HVAC equipment including efficient operation and maintenance.

Improve Building Envelope

HVAC use depends in part on the amount of heat gained (during summer) or lost (during winter) through a building's envelope (the exterior walls, windows, doors, roof, and floors). Envelope improvements control heat gain or loss to reduce the load on HVAC systems. With many HVAC-related measures, retrofitting existing buildings is more difficult and expensive than installing them during construction, highlighting the importance of good initial design for new Federal buildings.

Infiltration, the unintended and uncontrolled entry of outside air into a building, may add considerably to a building's heating and air conditioning load. Some measures to control infiltration such as caulking and weatherstripping doors and windows, and ensuring windows are kept closed when HVAC is being used, are low cost and part of a good, ongoing facility maintenance program. These measures should be pursued at all Federal facilities. Other measures such as adding vestibules or revolving doors or vapor barriers in walls require capital spending but may be worthwhile in some buildings.

Conduction, the transfer of heat through walls, roofs, windows, floors, and doors, also contributes to heating and air conditioning demand. Opportunities for adding insulation in any Federal facility depend greatly on the type of building, including its age, location, condition, type of construction, and existing insulation. There are a variety of insulation products available for walls, floors, and ceilings, some of which have been manufactured using chlorofluorocarbons (CFCs). These products will be

[46] Illuminating Engineering Society, *Lighting Handbook (New York, NY: 1972).*

[47] For an in-depth discussion of many well-established measures, see D. Paul Mehta and A. Thumann, *Handbook of Energy Engineering* (Lilburn, GA: Fairmont Press, Inc., 1989).

Table 3-4—HVAC[a]-Related Efficiency Measures

Improve the building envelope
Reduce infiltration
Caulk and weatherstripping
Vestibules and revolving doors
Insulate
Roofs walls, floors
Storm doors and windows
Vapor barriers in roofs and walls
Reduce solar heat gain through windows and roofs
Shading
Reflective window films
Reflective roof surfaces
Increase efficiency of HVAC systems
Perform system maintenance regularly
Operate equipment efficiently
Install and use an energy management system
Install efficient equipment
Ventilation equipment
Chillers, air conditioners, and cooling systems
Boilers and furnaces
Distribution systems

[a]Heating, ventilation, and air conditioning.

SOURCE: Office of Technology Assessment, 1991.

effected by restrictions on production and use of CFCs due to the atmospheric environmental impacts. Both relatively new and long-existing products are also available to decrease conduction through doors and windows. Storm doors and windows, a long-proven technology, reduce heat gain or loss. New “low emissivity” or “insulating glass” windows, used with or without storm windows, can greatly further reduce heat transfer.

Solar heat gain through windows and roofs can add considerably to cooling loads and decrease winter heating loads. Both window and roof solar heat gain can be controlled using simple and inexpensive measures in many cases. For example, the amount of solar heat gained through a roof can be reduced by using reflective or light-color paints on the roof. Solar heat gained through windows can be reduced using reflective films or shading, either with roof or wall overhangs or with trees for some low buildings. The benefits of measures to control heat gain depend on many factors including building size, orientation toward the sun, side of the building effected, and climate. Selecting measures requires a careful analysis of these factors as well as the tradeoff between the benefits in summer and the potential losses in winter.

Increase Efficiency of HVAC Systems

Space heating in Federal facilities is provided with a variety of equipment. Most facilities use natural gas or oil in a boiler which makes steam or hot water, or a furnace which makes warm air. The steam, hot water, or warm air is distributed through a building using a system of pipes or ducts. Many buildings also use electricity for heating, using heat pumps or electric resistance heaters, which often need no distribution system.[48] There is a similar variety of cooling equipment including central chillers which produce either chilled water or air, and local heat pumps or air conditioning units. Often, the same system of pipes or ducts is used for both heating and cooling, depending on the season.

Preventive Maintenance--Besides turning equipment off when not needed, the simplest and most basic energy efficiency measure for HVAC systems is a program of regular preventive maintenance. All HVAC system equipment including distribution equipment, requires regular maintenance for peak performance and efficiency, but will continue to function (inefficiently) even if not properly maintained, For that reason, regular preventive maintenance, rather than maintenance when equipment fails is essential.

The list of maintenance items can be long and depends on the specific equipment.[49] Some maintenance steps such as cleaning burner tips in boilers using heavy fuel oil and checking controls may be required as frequently as daily and may almost be considered part of efficient operations. Others need to be performed weekly or monthly or annually. Examples include such functions as cleaning or replacing air filters in ducts and air conditioners, cleaning boiler surfaces, cleaning evaporators and condensers in chillers, and repairing leaks in ducts, pipes, and boilers. Simple maintenance steps, if not already being performed, could lead to considerable cost savings.

Anecdotal evidence indicates that at least some potential gains exist. For example, one study of the HVAC system at DOE’s Forrestal building in

[48]U.S. Department of Energy, Energy Information Administration, *Nonresidential Buildings Energy consumption Survey: Commercial Buildings Consumption and Expenditures 1986*, DOE/EIA 0246(86) (Washington, DC: U.S. Government Printing Office, May 1989), p. 168.

[49]For a discussion of maintenance practices, see Paul D. Mehta and A. Thumann, *Handbook of Energy Engineering* (Lilburn, GA: Fairmont Press, Inc., 1989), ch. 14, “Energy Management.”

Washington, DC found that an intensive program of steam trap maintenance and repairs together with simple operational changes such as turning the steam system off on weekends reduced total building energy costs by over 6 percent, or $260,000.[50] Similarly, one review of twelve variable-air-volume air conditioning systems at six Navy facilities found that 'the general level of operating and maintenance services being supplied is very poor and not sufficient to make . . . systems function properly. There appears to be no effective preventive maintenance/inspection program. ' '[51] Finally, at OTA's site visits to four federally owned facilities, personnel in at least two sites expressed some doubt that HVAC maintenance or operations were carefully conducted for efficiency. There seem to be no systematic mechanisms or incentives to ensure that HVAC systems in Federal facilities are properly maintained for peak efficiency. This is not to say that Federal agencies ignore operations and maintenance issues. GSA, for example, requires building managers to keep plans for efficient operation, and has standards for maintenance intended to ensure efficiency. Examining the different approaches taken by Federal agencies and private-sector facility managers to see which work best, and applying those methods throughout Federal facilities could be very productive.

Efficient Operation-Closely related to efficient maintenance, efficient operation is another low cost measure to minimize energy use and cost. Efficient operation involves carefully monitoring ambient temperature and humidity as well as heating and cooling demand, and operating equipment accordingly. As with maintenance, there are a variety of measures to pursue which together help ensure efficient operation. For example, in systems with multiple chillers, efficiency can be improved by isolating one or more units during periods of light cooling demands (e.g., early mornings). Another simple method is to adjust boiler or chiller output to the minimum required level, which depends on heating and cooling demand. Also, use of economizer cycles, which use outside air for cooling when temperature and humidity are suitable, can produce substantial savings. The opportunities for energy- and cost-savings from efficient operations depend on the type of equipment, the characteristics of the facilities, and the efficiency of current operations.

Energy Management and Control Systems— Sometimes, adding new equipment can help improve the efficient operations of existing equipment. One type of such equipment, developed largely to ensure efficient operations of existing HVAC systems, is the building energy management and control system (EMCS). There are several commercial vendors of EMCS.

The functions performed by an EMCS can be as simple as shutting off the HVAC system after normal business hours. However, there are also increasingly sophisticated, computer-based systems with perhaps thousands of temperature and humidity monitoring points throughout a facility, as well as monitors of ambient conditions and HVAC equipment performance. This information, coupled with detailed, automated control of the HVAC equipment's fuel, air, temperature, and other equipment settings, can be used to minimize energy and operating cost. Also, the remote and continuous monitoring of the performance of HVAC system components allows operators to identify areas needing maintenance. For example, an EMCS can continuously monitor the input and output water temperatures and fuel use in a boiler, which together indicate the boiler's efficiency. Reduced efficiency indicates that maintenance is needed, possibly as simple as cleaning boiler surfaces or burners tips.

Properly installed, maintained, and used, an EMCS can greatly aid in reducing operating and maintenance costs. It also can help measure and document energy savings. However, it is not a magic tool. To reach its full potential, an EMCS requires not only a combination of good equipment, and proper design and installation by the vendor, but also an ongoing period of training, followup work, and maintenance by the HVAC operators. HVAC operators need to have time to dedicate to learning the system capabilities, and experiment with different approaches to using both- the HVAC and EMCS equipment. For example, operators can experiment with different boiler temperature settings which

[50] Jeff S. Haberl and E. James Vajda, ''Use of Metered Data Analysis To Improve Building Operation and Maintenance: Early Results From Two Federal Complexes," paper presented at American Council for an Energy-Efficient Economy, 1988 Summer Study on Energy Efficiency in Buildings, Asilomar, CA, Aug. 28 to Sept. 3, 1988.

[51] Tom R. Todd, ''Maintenance of Variable-Air Volume HVAC Systems, " in Federal Construction Council, *Technical Report No. 95: Maintenance of Mechanical Systems in Buildings* (Washington DC: National Academy Press, 1990), pp. 19-23.

depend on ambient temperatures and humidity, as well as temperatures and humidity at different points within the buildings being heated. Because every facility is unique, the opportunities for EMCS to improve HVAC operation must be individually tailored. This requires a capable, well-trained, and interested operations staff.

Many EMCS' have been installed in Federal facilities, and individual agencies have supported ongoing efforts to improve their performance. However, results to date are mixed.[52] All of the four federally owned commercial facilities in OTA's site visits had some sort of EMCS equipment, some of it fairly old. However, in at least two cases the EMCS equipment was not being used as intended in its design, apparently due to some combination of improper design, installation, maintenance, and training. According to one study, ". . . Federal agencies have had significantly more HVAC control problems than private owners. "[53] That study suggested that adopting some private sector approaches could improve performance in Federal facilities. Those include giving consulting engineers more flexibility in designing systems; requiring consulting engineers to write more detailed specifications (e.g., the accuracy and location of thermometers and the precise conditions which should cause valves to be opened or closed); and involving the consulting engineers in the installation and startup of new systems to ensure they are properly operational and that agency personnel are properly instructed.

Install Efficient Equipment

Much HVAC equipment in use today in Federal facilities is quite old. Large improvements have occurred in the efficiencies of chillers, air conditioners, boilers, furnaces, and the motors which power pumps and fans in HVAC equipment.[54] For example, a new packaged air conditioning unit may consume 30 percent less energy than one manufactured in the 1960s. High efficiency heat pumps have attractive cost and performance characteristics in warmer climates, providing both air conditioning in summer and space heating in winter. As old equipment is replaced over time, efficiency will generally increase. However, there is a fairly wide range of efficiency in equipment being produced today. Typically, higher efficiency equipment is more expensive than less efficient counterparts, but generates cost savings over its long life. Trading off between higher frost cost and lower operating costs requires careful engineering and economic analysis.

Some components can be kept working for decades. Because equipment costs are high, replacing working equipment is often not cost effective. Still, some of the HVAC equipment in Federal facilities may be past its economic life. Unfortunately, analysis of whether replacing an existing unit would reduce net costs is usually not made: equipment is used until it ceases to work.

Miscellaneous Energy Uses

Miscellaneous energy uses include everything not mentioned above. They are a small but rapidly growing portion of building energy use, with developments such as office automation and computing, advanced medical scanning technologies, and simulators gaining use. Some of the other many miscellaneous uses are more traditional, such as water heating, cooking, refrigeration, and elevators.

There are many opportunities for efficiency improvements in miscellaneous energy uses (see box 3-A). For example, water heating for commercial use can be made more efficient with well-proven approaches including using new heaters with pulsed combustion and better insulated tanks, and insulating distribution piping. Another example of an opportunity for increasing miscellaneous use efficiency is in new electric motors. Motors are used in a variety of commercial applications, from elevators to HVAC pumps and fans to postal automation equipment. The most efficient electric motors available in today's markets are considerably more

[52] For an example of a system which has to date failed to meet expectations, see F. Boercker and J. McEvers, "A Post-Installation Review of the Energy Monitoring and Control System at Red River Army Depot," Oak Ridge National Laboratory, O RIWJTM-10137, May 1990. Other installations have had successful EMCS applications. See, for example, Douglas A. Decker, "A Self Financing Energy Conservation Concept for the Federal Government," *Strategic Planning for Energy andthe Environment,* vol. 10, No. 3, winter 1990-91, pp. 64-66, which describes cost savings at the U.S. Army's Fort Eustis, VA using EMCS.

[53] See Building Research Board, National Research Council, *Controls for Heating, Ventilating, and Air-Conditioning Systems* (Washington, DC: National Academy Press, 1988), pp. 23-24,43,44.

[54] For a description of high-efficiency electrical HVAC equipment, see Resource Dynamics Corp., *Handbook of High-Efficiency Electric Equipment and Cogeneration System Optionsfor CommercialBuildings,* EPRI CU-6661, December 1989; and D.W. Abrams, P.E. & Associates, *Commercial Heat Pump Water Heaters Applications Handbook,* EPRI CU-6666 (Palo Alto, CA: Electric Power Research Institute, January 1990).

Box 3-A—A New, Improved Exit Sign: What Difference Could It Make?

There are hundreds of thousands of exit signs in Federal commercial buildings, consuming in total several megawatts of power around the clock.

Exit signs are one excellent example of energy- and cost-saving technological progress, even though they represent only a tiny fraction of total electricity use in buildings. For decades, exit signs in commercial buildings have commonly been lit by a pair of standard incandescent lamps. Though at $0.20 each they are cheap to buy, these lamps are expensive to use since they operate inefficiently around the clock. Each sign consumes from 210 to 1,050 kWh/year at a cost of $15 to $75; the need to replace these lamps as they burn out as often as every 2 months adds around $60 annually to their total cost.[1]

Photo credit: Gilbert Emergency Lighting

If used in all Federal facilities, exit signs using light-emitting diodes could be a cost-effective way to save several megawatts of electric generating capacity.

By replacing the incandescent lamps in existing signs with compact fluorescent lamps, energy costs are considerably decreased to between $7 and $11. Even more significantly, the 10,000-hour life of a compact fluorescent means the $6 lamp needs replacement less than once per year, giving an average annual maintenance cost of only $14. The total annual savings compared to an incandescent exit sign are between $55 and $110. Lower operating and maintenance costs in the first few months alone more than pay back the higher initial lamp and ballast cost of $15 and installation.

While the compact fluorescent is a clear advance over incandescent-based exit signs, a further improved exit sign technology has recently been commercialized. Exit signs relying on light-emitting diodes (LED) are even more energy efficient and less expensive to operate, using as little as 6.7 watts. Furthermore, these signs need infrequent replacement or maintenance (the electrical components have a life expectancy of 25 to 30 years). LED signs are available under a General Services Administration authorized Federal Supply Schedule[2] for as low as $71.47, only slightly more expensive than a new exit sign using incandescent lamps and actually less expensive than anew sign with a compact fluorescent.[3] Thus, when purchasing new exit signs (e.g., for new construction), LEDs should produce net cost savings right from the start or soon thereafter. Even when used to replace an existing fluorescent-lamp exit sign, they should produce a simple payback of under 4 years.

[1] This example uses the following assumptions: electricity costs $0.07/kWh; each standard fixture uses a pair of incandescent lamps totaling from 24 to 120 watts, or a single 12-to 18-watt compact fluorescent; average incandescent lamp life is 2,000 hours; lamp replacement requires $10 in labor costs which can be put to other productive use or displaced. Note that ifa facility has surplus maintenance workers, labor cost savings will not actually accrue. These assumptions are adapted from "Exit Signs: Save Energy and Money," *Energy & Environmental News*, Naval Energy and Environmental Support Activity, Port Hueneme, CA (reprinted in U.S. DOE, *FEMP Update*, Federal Energy Management Program, winter 1988, p. 11).

[2] GSA contract #GS07F-1862A with Don Gilbert Industries, Inc., Mar. 26, 1990 to Aug. 31, 1994.

[3] Standard electrical exit signs using incandescent lamps cost as little as $61.50. GSA Contract Catalog GS07F-18188, Mar. 1, 1990 to Aug. 31, 1994, EMED Co., Inc., p, 11. While the lamps are described in the catalog as "extra long life energy saving lamps," according to the manufacturer they are incandescent rather than fluorescent. Telephone conversation with customer services department, Nov. 26, 1990.

efficient than older motors (also far more efficient than the least efficient models currently available). Also, developments in adjustable speed drives can create higher efficiencies by allowing a motor's electric power input to vary with the load and may be suitable in some applications.

Refrigerators

Refrigerators offer an opportunity for a large reduction in electricity use in the *9* million federally owned or assisted households. Each year around half a million new refrigerators are purchased for these households. The average refrigerator now operating in the United States uses over 1,500 kWh/year.[55] The most efficient commercially available models of similar size use less than 60 percent of that amount.[56] The stock of refrigerators in federally owned and assisted households may include smaller units with fewer energy-using features, such as through-the-door ice and water dispensing, than the national average, slightly reducing the average potential gains there.

Some of the potential is gradually being captured. The National Appliance Energy Conservation Act of 1988 (NAECA) set minimum standards for several appliances, including refrigerators. However, even with NAECA, the long lives of refrigerators (over 15 years) ensures that inefficient units will continue to be used in Federal facilities for many years unless retired early. Further, even as refrigerators are replaced in federally owned and assisted households, there is no guarantee that the most energy efficient units will be selected rather than those minimally meeting the standards. As in the purchase of any energy-consuming device, several factors such as durability and features must be considered as well as first cost and energy use when selecting a refrigerator. In addition to opportunities in buying more efficient refrigerators, regular maintenance (i.e., cleaning condenser coils) can improve efficiency.

New Miscellaneous Uses

Most new miscellaneous energy uses rely on electricity. All are used because of the significant improvements in performance or productivity they bring. These new miscellaneous uses contribute to increasing energy use at Federal facilities (or smaller energy savings). However, these increasing uses of energy are not only legitimate, but may be essential to increasing overall Federal productivity and services. For example, use of automated mail sorting equipment can increase energy consumption in mail facilities (see case study of the U.S. Postal Service San Diego Division in ch. 5). At the same time, it helps speed deliveries and reduce labor requirements.

Some new miscellaneous energy uses, while increasing electricity use in the Federal buildings can actually contribute to reduced overall energy use. For example, military use of simulators has increased tremendously over the past decade. Military training on simulators is used for a wide range of equipment, including various aircraft, tanks, and even small arms. A flight simulator can use a considerable amount of electricity. However, the amount of jet fuel used in an actual training flight is far more than enough to compensate for the electricity.

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[55] U.S. Department of Energy, Energy Information Administration, Housing *Characteristics 1987*, DOE/EIA-0314(87) (Washington, DC: U.S. Government Printing Office, May 1989), p. 10.

[56] *1990 Directory of Certified Refrigerators and Freezers* (Chicago, IL: Association of Home Appliance Manufacturers, January 1990).