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CUTTING ENERGY COSTS IN PUBLIC HOUSING: TECHNICAL ISSUES, INSTITUTIONAL BARRIERS, AND RESEARCH NEEDS

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ABSTRACT

The federal Department of Housing and Urban Development (HUD) spends approximately $1 billion each year to pay all or part of the energy bills for approximately 1.2 million public housing units. Preliminary analysis of this sector indicates that a significant potential exists for increased energy conservation activity. However, these potential savings are currently not being realized for a number of reasons, such as a lack of technical information on the effectiveness of various conservation measures, retrofit costs and paybacks, available financing mechanisms, and a general tendency toward master-metering that eliminates almost any incentive on the part of the tenants to conserve energy.

As part of a U.S. Department of Energy (DOE) program on multifamily retrofit performance, Lawrence Berkeley Laboratory initiated an effort to learn what is known about energy use and conservation in the public housing sector. In this report, we provide a summary of that information including a profile of the existing data on energy use patterns and conservation potential in public housing drawn from two major reports, from a survey of 40 large public housing authorities, from a 1983 Conference, and from contacts with various HUD staff. We present the physical characteristics of existing public housing buildings, their energy use patterns, and the potential for conservation. We also describe technical, informational, economic, behavioral, and institutional barriers that hinder the efforts of local housing authorities and HUD to promote energy conservation. We identify a set of research topics that can help overcome existing barriers. For each topic, we develop a brief research agenda for pursuit by DOE over the next few years. We have initiated studies on four of the areas (reported elsewhere) including analyses of baseline energy use, retrofit performance, conservation investments, and the monitoring of solar hot water retrofits at one San Francisco housing project.

INTRODUCTION

The potential for energy and cost savings in public housing is great.[1] The financial, institutional, technical and social barriers, however, are also tremendous. There is an indisputable need to reduce long-term energy costs through cost-effective retrofit measures. Investment in such options will maintain and improve the federal housing stock, reduce energy consumption, and improve tenant comfort levels. All of these attributes, in turn, can have an enormous impact both on the federal energy bill and on the burden that increased energy prices have placed on the economy as a whole.

The U.S. Department of Housing and Urban Development (HUD) is the federal agency charged with overseeing public and other federally-assisted housing. Government revenues pay substantially all energy-related expenses for public housing. Federal monies are invested in the housing construction and are used to make improvements, to support upkeep, and to pay utility bills (either through direct payments to the utility or through substantial bill subsidies to the tenant). The energy bill for public housing is approximately $1 billion. Furthermore, energy costs will probably continue to rise because a significant fraction of the public housing stock relies on natural gas for heat, and deregulated gas prices are forecasted to increase at a faster rate than other fuel prices.

Public housing authorities have recently begun to address the need to contain rising energy costs through various retrofit projects funded by HUD, utility companies, or the local housing authorities themselves (using HUD operating funds). However, actual measured data on energy usage, or data on the performance of energy saving measures, are virtually nonexistent. Thus, many local authorities are forced to make decisions about conservation investment strategies without sound technical support. HUD has established guidelines for public housing energy audits and has developed a procedure for reviewing and approving energy-efficiency investments. However, the retrofit selection process allows enormous discretion to local housing officials who may not have available to them information on the most recent advances in the technology of building retrofits or know how to rank the many energy conservation opportunities.

This document profiles the existing data on energy use patterns and conservation in public housing. The background information was gathered as part of the multifamily retrofit research program sponsored by the U.S. Department of Energy (DOE). We describe the physical characteristics of existing buildings, energy use trends, conservation potential, and barriers to retrofit activity, and identify what research is needed to overcome these barriers.

Information on building characteristics and energy use patterns are drawn primarily from two major reports: the Perkins & Will and Ehrenkrantz report (henceforth, called the Ehrenkrantz report)[2] and the Council of Large Public Housing Authorities report (CLPHA).[3] Conservation potential estimates are based on utility billing data from Northeast public housing authorities and on information in the Ehrenkrantz report. The retrofit barriers and research needs are drawn from a survey of 40 large public housing authorities, from a 1983 Conference of the National Association of Housing and Redevelopment Officials (NAHRO), and from our contacts with various HUD staff.

BUILDING CHARACTERISTICS

HUD spends approximately $2 billion each year to pay all or part of the energy bills for about 3.6 million housing units, consisting of 1.75 million Section 8 units*, 1.2 million public housing units, 0.16 million Section 202 units†, and 0.5 million units covered under other programs. Our discussion in this report will deal with the public housing sector only.

The Ehrenkrantz study estimated that the approximately 1.2 million public housing units (9,900 projects managed by 2700 local housing authorities) house more than 3.4 million occupants (61% are minorities). Table 1 provides a summary of the national public housing stock. About 76% of the dwellings are designated as family units, while the remaining 24% are occupied by the elderly. The buildings are classified as low-rise (four stories or less) and high-rise (five stories or more). It is further estimated that over 50% of the units are family low-rise apartments. The typical single project contains 119 units and was built before 1965. The great majority of public housing units (nearly 80%), in fact, were completed prior to the 1973 oil crisis.[4] We show the trend of public housing completions from 1939-1983 in Figure 1.

The varying regional distribution of public housing becomes apparent when the dwelling units are aggregated according to their HUD region. As shown in Table 2, a significant fraction of the units (37%) are located in the East (Regions I, II, and III) followed by the South (Regions IV and VI), Midwest (Regions V and VII), and West (Regions VIII, IX, and X).

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* In Section 8 housing, HUD pays the difference between what a lower income household can afford and the fair market rent for an adequate housing unit.

† Section 202 involves direct loans for housing for the elderly or handicapped.

Table 1
National Public Housing Characteristics*

Project Type	Projects	%	Units	%	Average Age (years)
Family Low-rise[1]	826	8.3	361,240	30.8	23
Family Low-rise[2]	4589	46.3	307,524	26.2	18
Elderly[3]	3181	32.1	279,656	23.9	12
Family High-rise[4]	493	5.0	200,810	17.1	20
Family High-rise[5]	815	8.2	23,254	2.0	14
Total	9904	100	1,172,486	100	16

1. Four or less stories with more than 200 units.
2. Four or less stories with less than 200 units.
3. 50% or more units designated for the elderly.
4. Five or more stories with more than 200 units.
5. Five or more stories with less than 200 units.

*Source: Perkins & Will and Ehrenkrantz Group, 1980. "An Evaluation of the Physical Condition of Public Housing Stock, Vol. 1: Final Report," p. 11.

Table 2
Public Dwelling Units by HUD Region*

Region		Units	% of Total
I	Boston	79,792	6.8
II	New York	223,564	19.1
III	Philadelphia	134,190	11.4
IV	Atlanta	251,267	21.4
V	Chicago	194,352	16.6
VI	Dallas	122,865	10.5
VII	Kansas City	41,877	3.6
VIII	Denver	21,575	1.8
IX	San Francisco	74,920	6.4
X	Seattle	28,101	2.4
	Total	1,172,486	

*Source: Perkins & Will and Ehrenkrantz Group, 1980. "An Evaluation of the Physical Condition of Public Housing Stock, Vol 1: Final Report."

In an effort to disaggregate the public housing stock even further, the Ehrenkrantz study organized the buildings data into 12 building characteristics (8 of which represent most of the stock) and 5 climate zones. The categories distinguish between low-rise and high-rise, type of heating system (space heating where the source is located within the apartment and central heating where the source is centrally located), and type of fuel used for space heating (e.g., oil, gas, or electric). The five zones are defined according to the average yearly number of heating degree-days (HDD) at base 65 F. Table 3 summarizes the resulting distribution of public housing units. According to this characterization, over 69% of the units are low-rise and, more specifically, 46% are low-rise with gas space heating systems.† In addition, we note that 45% of all units are in climate zone 3 (4000-6000 HDD).

Table 3
Distribution of Public Housing Units by Building Type and Climate Zone*

	Climate Zones					
Building Type	1	2	3	4	5	Total
Low-rise, Sh, Oil	6,124	2,653	15,159	4,200	767	28,903
Low-rise, Sh, Gas	103,933	150,002	170,407	53,230	8,477	486,049
Low-rise, Sh, Electric	20,701	16,511	27,641	8,240	3,682	76,775
Low-rise, Ch, Oil	-	4,259	38,985	16,328	5,599	65,171
Low-rise, Ch, Gas	1,568	6,686	43,138	16,103	5,348	72,843
[Low-rise Totals]:	132,326	180,111	295,330	98,101	23,873	729,741
High-rise, Sh, Electric	6,055	9,105	23,741	9,488	1,148	49,537
High-rise, Ch, Oil	-	971	118,413	42,352	5,593	167,329
High-rise, Ch, Gas	5,606	18,529	42,484	32,118	11,439	110,176
[High-rise Totals]:	11,661	28,605	184,638	83,958	18,180	327,042
Total Units	143,987	208,716	479,968	182,059	42,053	1,056,783**
% of Total	(13.6%)	(19.8%)	(45.4%)	(17.2%)	(4%)	

** Total does not include Hawaii, Puerto Rico, and U.S. Virgin Islands, and represents about 90% of the total federally supported public housing.

Sh = space heating; source within dwelling unit [1] = 0-2000 HDD
Ch = central heating; source centrally-located [2] = 2000-4000 HDD
Low-rise = four stories or less; no elevator [3] = 4000-6000 HDD
High-rise = five stories or more; elevator [4] = 6000-8000 HDD

*Source: Perkins & Will and the Ehrenkrantz Group, 1980 "An Evaluation of the Physical Condition of Public Housing Stock, Vol. 4: Energy Conservation," p. 107.

ENERGY USE PATTERNS

The Ehrenkrantz study also estimated average energy consumption in the public housing sector. These estimates were derived from a subsample of 350 randomly selected projects using standard ASHRAE calculation procedures. As presented in Table 4, the data, organized according to the eight aggregated building types mentioned previously, include average on-site energy use, expressed in MBtu/unit (MBtu = 10^6 Btu), and as a fraction of total energy use.

† It should be noted that very different distributions result when the data are analyzed according to the number of buildings or the number of projects.

Table 4
Average Energy Consumption in Public Housing*

Building Type	% Total	Average Energy (MBtu)	% Total 1980 Energy Costs: Heating (%)	DHW (%)	Lighting & Appliances (%)	Other† (%)
Low, Sh, Gas	46.0	153	48.7	17.5	27.4	2.1
High, Ch, Oil	15.8	100	41.3	17.2	36.1	5.2
High, Ch, Gas	10.4	102	39.7	11.1	39.6	7.0
Low, Ch, Gas	6.9	208	62.1	17.3	19.8	0.6
Low, Sh, Elec‡	7.3	116	54.9	27.6	12.9	1.1
Low, Ch, Oil	6.2	178	60.6	17.6	21.5	0.2
High, Sh, Elec‡	4.7	88	59.9	16.6	21.1	1.6
Low, Sh, Oil	2.7	160	57.7	19.8	21.5	1.0
Avg. All Types	--	146	52.2	17.6	25.9	2.2

† Other end uses include: ventilation, outdoor lighting, water pumping, and elevators.
An additional 2.1% in cooling energy costs is not included.
Sh = space heating; source within dwelling unit. Ch = central heating; source centrally-located.
Low = four stories or less; no elevator. High = five stories or more; elevator.
‡ Average site energy use.

* Source: Perkins & Will and Ehrenkrantz Group, 1980. "An Evaluation of the Physical Condition of Public Housing Stock, Vol. 4."

Average energy consumption estimates range from a high of 208 MBtu/unit for low-rise buildings with central heated gas systems to a low of 88 MBtu/unit for high-rise buildings with electric space heating. Comparisons between fuel and electrically-heated buildings should be made cautiously, however, because the data reflect *on-site* energy use. The use of site energy tends to mask differences in price and efficiency of producing and distributing fuel versus electricity. The on-site conversion of electricity into heat is highly efficient, so fewer Btus are consumed on-site. However, electricity generation and transmission involves significant off-site losses (a site electricity Btu is approximately three times more expensive than a Btu of gas or oil). Hence, electrical heated units generally consume fewer Btus per dwelling unit, although utility costs are not much lower. Annual site energy usage is 146 MBtu/unit in a typical public housing unit compared to 77 MBtu/unit for the average U.S. multifamily unit.+

Public housing's higher consumption is due, in part, to its differing physical characteristics. The Ehrenkrantz estimate is based on an average apartment size of 850 square feet, while the national average multifamily units are about 817 square feet per dwelling.

+ The average multifamily consumption level is derived from data on apartments with five or more units recorded in the recent Residential Energy Consumption Survey data published by DOE/EIA.[5]

Public housing energy consumption figures also include energy used for common area lighting and project office space. In addition, public housing residents may have larger families and be at home more of the time. At present, it is very difficult to make accurate comparisons of energy use in public housing with other multifamily residential units.

Table 4 contains estimates of average energy consumption for each end use by building type. Space heating accounts for more than 60% of the energy consumed by a public housing unit (see Fig. 2). Hot water heating is the second largest energy user (22%). The range varies, however, depending on the type of building, its heating system, and fuel type. Energy costs give a more representative comparison of end uses. When the average end-use estimates are presented as a percentage of total energy **costs**, lighting and appliances move into second place. We also show energy use by fuel type, both as a percentage of site energy consumption and as a percentage of total energy costs (Figs. 3). In both cases, natural gas accounts for the majority of the energy used in the public housing sector. The contribution from electricity increases significantly when the data are presented as energy costs rather than site energy.

In June 1982, the Council of Large Public Housing Authorities (CLPHA) published the results of a survey on energy consumption for approximately 100 large and medium-sized public housing authorities (PHAs) over a three-year period (1978-1981).[3] CLPHA attempted to isolate space heating usage, expressed in Btu/unit and Btu/unit/HDD. The information was collected by CLPHA from utility adjustment forms submitted by the PHA to HUD at the end of the fiscal year. CLPHA staff made follow-up telephone calls to the PHAs to verify and correct the data.

Several important findings emerge from the survey and data analysis. With regard to the average annual space heating energy, the PHAs in the coldest climates have the highest consumption per unit. However, there is also wide variation within the same climate zone as shown in Table 5. PHAs in colder climates use fewer Btus/unit/HDD than those in warmer climates. The relationship between unit energy consumption and heating degree-days, however, was found to be nonlinear, especially in the warmer climates. The wide variation in Btu/unit/HDD suggests that factors such as management and maintenance may play important roles in determining energy use.

Several methodological problems noted in the CLPHA report probably influenced the results and require further study. These research issues include: (1) the analytical procedure used to allocate electricity used for space heat; (2) the relationship between energy use and climate variables such as heating degree-days; and (3) the process used to disaggregate heating bills paid by tenants from those paid by the local PHA. Finally, the

Table 5
Space Heating Energy Use in Public Housing by Climate Zone*

Location	HDD	MBtu/unit	MBtu/unit-HDD
Hawaii	0	25	-
Miami	236	28	-
Los Angeles	622	39	67
Orlando	684	30	44
Tampa	736	44	65
Jacksonville	1403	21	14
New Orleans	1484	64	43
Houston	1514	43	24
San Antonio	1585	53	33
Montgomery	2238	33	14
Fort Worth	2422	77	28
El Paso	2539	69	26
Birmingham	2770	69	24
San Francisco	2880	89	30
Atlanta	2954	77	25
Memphis	3061	89	29
Oklahoma City	3619	94	23
Chattanooga	3641	49	13
Raleigh	3672	112	32
Norfolk	3686	102	29
Knoxville	3775	89	11
Nashville	3834	66	17
Richmond	3984	103	26
Portland, OR	4174	47	10
Seattle	4285	44	11
New York City	4789	106	22
Baltimore	4826	123	27
Newark	5050	143	30
Philadelphia	5081	147	29
Cincinnati	5182	99	18
St. Louis	5207	109	22
Kansas City	5354	142	16
Denver	5423	140	23
Boston	5719	138	24
Omaha	6217	107	16
Pittsburgh	6296	136	22
Cleveland	6568	161	25
Buffalo	6694	152	23
Detroit	6879	157	23
Chicago	6944	167	24

*Estimates taken from CLPHA Report (see Reference 3) represent average consumption (heating only) for three-year period (1978-81) sorted by HDD.

analysis of energy consumption conducted by CLPHA used energy data aggregated for each housing authority. Hence, key variables such as age and type of building, size and condition of dwelling units, type of heating system (central or individual) and control, fuel type, type of occupant (elderly or family), and previous retrofit activity, that influence energy use patterns can not be accounted for in this type of analysis.

Analyses of these variables would be useful in order to develop energy use indices or other means of estimating actual energy consumption patterns at the local project level. This type of information can also be used by HUD as a basis for establishing guidelines for reviewing and approving PHA operating budgets and modernization applications. Energy use indices or trends can also help HUD and PHAs design effective energy management initiatives to minimize their future energy demands.

CONSERVATION POTENTIAL

HUD Conservation Investments

Although housing authorities have become increasingly interested in energy issues during the last several years, current energy conservation activities are generally perceived to be modest in the largest authorities and almost non-existent in the smallest.[6] Of course, some large and small PHAs are engaged in extensive energy managment programs; New York City, St. Paul, and Phillipsburg, NJ are examples of local authorities which have been saving dollars through conservation since the mid-1970s. Most conservation efforts to date have concentrated on installing commonly accepted shell improvements, typically having short paybacks.

Almost all of these improvements have been funded through HUD's Comprehensive Improvement Assistance Program (CIAP), commonly called HUD Modernization. CIAP was established in 1980 to upgrade living conditions, correct physical deficiencies, and achieve operating efficiency and economy in public housing. Capital improvements are generally financed over a 20-year period. In FY 1982, $112.5 million in capital resources were provided through HUD Modernization for energy retrofits (see Table 6 for the regional allocation of the HUD Modernization funds for FY 1982).[7]

Local governments and utilities have also developed some interesting demonstration projects. One such program involves the use of a zero-interest loan program (ZIP) from a local utility company to finance various energy conservation measures in San Francisco public housing.[8] The smaller PHAs, with a staff of 2-15, frequently need technical assistance to conduct the comprehensive energy audit required by HUD, and to implement an energy retrofit plan.

Projected Energy and Cost Savings

There is significant potential for energy savings. Energy usage in public housing is higher on a per-dwelling-unit basis than private sector housing. This can be accounted for, in part, by the older housing stock and lack of energy conservation activity. The Ehrenkrantz report provided estimates of the conservation potential based on an analysis of 58 energy conservation opportunities (ECOs) applied to a randomly selected sample of

Table 6
Regional Distribution of Retrofit Funds—FY 1982
(in Millions of Dollars)

Region	Office	Funds	% of Total
I	Boston	14.8	13.2
II	New York	47.3	42.1
III	Philadelphia	13.1	11.7
IV	Atlanta	12.9	11.5
V	Chicago	10.6	9.4
VI	Dallas	4.9	4.4
VII	Kansas City	2.0	1.8
VIII	Denver	0.9	0.7
IX	San Francisco	5.1	4.5
X	Seattle	0.8	0.7
Total		112.4	

public housing projects.[2] Appendix A lists the ECOs evaluated in the study.

All ECOs with a discounted payback of less than 15 years (assuming a discount rate of 10%) were considered.* This 15-year marginal payback level yielded an average retrofit investment of $1347/unit (1980 dollars exclusive of fees or profit) with corresponding annual energy savings of $324 per unit. The Ehrenkrantz study reported that this investment would reduce on-site energy consumption for the average unit from the estimated 146 MBtu per year to 68 MBtu a year, or approximately 53% (see Table 7). The estimated dollar value of annual energy savings varies from $117 to $696 per unit with capital costs for retrofit ranging from $550 to $2100.

When the recommended building retrofits are extrapolated to the overall public housing stock, the required investment amounts to over $2 billion. It was estimated that the savings from this program would accrue annually, yielding an energy savings of about 1.5 quads by the year 2000. The analysis assumed a three-year implementation program starting in 1981 and a 4% replacement rate of existing public housing. This potential is considerably higher than the technical savings of 1 quad estimated by the Congressional Office of Technology Assessment for the entire multi-family sector (including federally-supported housing).[9]

Recently, HUD commissioned ABT Associates to conduct a follow-on study to the Ehrenkrantz analysis. This study will include a detailed analysis of the significant energy conservation opportunities in a subset of 300 projects selected from a total project sample of 1369. The study sample will be drawn from over 100 public housing authorities

* Such a high discount rate based on economic conditions in the late 1970s may not be as appropriate for energy decisions made today.

Table 7
Summary of Energy and Cost Savings*
(per dwelling unit)

Building Type	Average Energy Use (MBtu)	Energy Savings (MBtu)	Average Yearly Savings (1980 $)	Average Costs (1980 $)	Payback Time (yrs.)
Low-Rise, Sh, Gas	153	92	315	1750	5.6
High-Rise, Sh, Gas	100	43	149	550	3.7
High-Rise, Ch, Gas	102	33	117	600	5.1
Low-Rise, Sh, Elect†	116	63	696	1220	1.8
Low-Rise, Sh, Gas	208	135	437	1210	2.8
Low-Rise, Ch, Oil	178	110	432	1510	3.5
High-Rise, Sh, Elect†	88	30	239	965	4.0
Low-Rise, Sh, Oil	160	87	378	2100	5.6
Avg. All Types	146	68	324	1347	4.2

Sh = space heating; source within dwelling unit. Ch = central heating; source centrally-located.
Low-rise = four stories or less; no elevator. High-rise = five stories or more; elevator.
† = average site energy use

*Source: Perkins & Will and Ehrenkrantz Group, 1980. "An Evaluation of the Physical Condition of Public Housing Stock, Vol. 4: Energy Conservation."

distributed nationwide. National estimates, based on the 300-project subsample, will be constructed for current energy use in public housing, and energy savings associated with implementation of repair and replacement actions and with additional economically justifiable retrofits.

Measured Energy Savings

There are little measured data on the actual effects of building retrofits in public housing projects. The available data indicate that substantial savings have been achieved, although large variations are observed both in energy savings and in costs per unit of energy saved (see Fig. 4). For example, space heat and hot water usage declined by 44% at Page Homes, a 159-unit public housing complex in Trenton, New Jersey, after the installation of a microcomputer-based boiler control system (data point 02.1 in Fig. 4). High indoor temperatures (average 82 F) and the buildings' relative energy inefficiency before retrofit help account for the impressive energy savings.[10] Average space heat energy consumption declined by 13.9 MBtu/yr (22%) in four New York City Housing Authority (NYCHA) buildings retrofitted with thermostatic radiator valves (data point 08 in Fig. 4), another example of a successful heating system retrofit. Lower energy savings per dollar invested were achieved in a NYCHA window retrofit project that installed double-glazed thermal-break aluminum windows in nine apartment complexes. Average savings in the nine buildings were 12 MBtu (18%) for an investment of $1070 per apartment unit (data point 09). Pre-retrofitted space heat levels were already fairly low in these buildings (62-71 MBtu) as a result of NYCHA's ongoing energy conservation efforts.[11] Their relative energy efficiency, compared to other multi-unit buildings, partially accounts for the lower return on investment. Appendix B contains a more complete summary of the documented energy savings that result from retrofit activities in public housing.

BARRIERS TO RETROFIT and RESEARCH NEEDS

Barriers to Retrofit

Rising energy costs have created an ever widening gap between the necessary expenses of a local PHA and the income that it obtains from rents, a force that compels local PHAs to address energy use and conservation. The difference between costs and income is made up by operating subsidies from HUD. Annual contributions from HUD (i.e., operating subsidies) are used to help PHAs maintain and operate their projects, establish operating reserves, and offset operating deficiencies. For example, in FY 1983 $1.3 billion was appropriated for operating subsidies. Yet a variety of technical, informational, economic, behavioral, and institutional barriers hinder the efforts of PHAs and HUD to promote energy conservation in public housing (see Table 8). We will now discuss these barriers in more detail.

Table 8
Summary of Barriers to Conservation in Public Housing

Technical
• Little technical analysis of retrofit actions already taken • Decisions made without adequate technical information • Condition of housing may make retrofits impossible
Informational
• Lack of knowledge about building stock • Lack of data on energy use patterns • No network for exchange of information • Availability and quality of information varies
Economic, Behavioral, and Institutional
• Tenants seldom included in retrofit process • No incentive for tenants to conserve energy • Cost-effective investments not always implemented • HUD policies discourage conservation by PHAs

Technical Barriers

Over the last decade, HUD and many local housing authorities have sponsored major retrofit projects in response to the "energy crisis," but little analysis has been (as through conservation efforts), they split the savings 50/50 as well. In addition, the subsidy in following years is reduced so as to fully recapture these savings. Investments in the public housing stock do benefit taxpayers, however, by improving the physical characteristics of the buildings and by keeping overall costs down.

Cost-effective conservation investments are not always implemented due to various economic and institutional barriers. For example, PHAs that use third-party financing strategies have installed solar and other innovative energy devices rather than retrofits with shorter payback times because of solar and investment tax credits that significantly improve the economic viability of the venture. In some cases, local PHAs are unable to adequately fund highly cost-effective options, including improved operation and maintenance practices and lighting conversions, under existing conservation programs. Large capital expenditures, such as boiler replacements, must be justified as part of HUD's Modernization program, in which conservation potential and reduced life-cycle operating costs are secondary criteria. Although a great potential for saving energy exists in public housing, the current institutional framework may inhibit the attainment of that goal. Appendix C contains a review of behavioral and institutional issues in public housing.

Research Needs

We have identified nine research projects that can help overcome existing barriers to conservation. We focus the effort on public housing because of the availability of data, but other federally-assisted housing programs should also be evaluated in the future. Improvement in existing information transfer mechanisms is also needed, a strategy that can also help to alleviate certain barriers.

A summary of research needs based on the LBL survey and on contacts with others in public housing is presented in Table 9.

Table 9

Summary of Research Needs in Public Housing

- Characterize the building stock and energy use trends
- Analyze existing retrofit performance data
- Evaluate financing and subsidy policy alternatives
- Evaluate energy audits and audit procedures
- Analyze the trend towards individual metering
- Develop simplified audit and analysis methods
- Detailed monitoring of retrofit performance
- Evaluate tenant incentive programs
- Develop information dissemination strategies

Baseline Energy Use Analysis

Analysis of available baseline energy use data from selected multifamily buildings is needed. This effort includes collecting utility billing data for several years, calculating weather-corrected consumption levels, and analyzing the data to estimate the influence of building and operating characteristics on variations in energy consumption. The results of this type of analysis can provide useful information in support of developing simplified building audit and energy analysis methods for multifamily housing. This research addresses the apparent lack of accurate energy use estimates in multifamily units both in the private and public sectors. Additional benefits of such a study are the insights gained into unusual energy use patterns (e.g., seasonal cooking, water heating).

A natural follow-on to the Baseline Energy Use Analysis is a comparison of the implied energy costs on a per dwelling-unit basis. By developing energy use indices for a variety of building types and locations, it becomes possible to couple these measured energy consumption levels with regional energy prices to determine corresponding utility subsidies. These results may then be compared with current subsidy levels. Of particular interest to HUD planners, energy price forecasts for the same regions can be used to estimate future costs.

Analysis of Existing Retrofit Performance Data

The objective of this project is to compile and analyze building and energy consumption data for past and current retrofit activities in public housing. Key user groups (e.g., HUD and local PHAs) have identified the evaluation of measured savings as an important research area. Results from this project will provide a good summary of retrofit experience in public housing and should identify factors associated with successful and failed conservation strategies. In addition, cost/savings estimates for various measures should emerge from the analysis.

Evaluation of Financing and Subsidy Policy Alternatives

A major impediment to more widespread implementation of energy conservation by the PHAs may be their perception that the current HUD utility subsidy system makes it difficult to benefit from saving energy. It is possible, using simple microcomputer software, to model the allocation of the dollar savings from conservation retrofits to HUD and the PHAs. This type of model makes it possible to evaluate various investment opportunities (before retrofit) and select financing options to maximize benefits. Variations of the current three-year rolling base period for setting utility subsidies, and the 50/50 recapture of annual savings can be easily investigated. In addition, HUD payment of new maintenance costs associated with the retrofit and recapture of such savings can also be modeled. More information is required on alternative methods of funding retrofits. Detailed case studies are needed of various innovative financing mechanisms in the private sector including utility-sponsored programs and energy service companies that use third-party financing arrangements such as micro-utilities or shared savings. In general, public housing managers lack relevant information on alternative methods of funding retrofits and find that the existing subsidy system often makes it impossible to attract third-party financing.

Evaluation of HUD Energy Audit Procedures

Local housing authorities use a variety of techniques including the HUD Conservation Workbook, to assess their energy conservation needs. Energy audits have been conducted by local authority staff, utilities, private contractors, and in some cases by low-income tenants. The uniformity and validity of the audits will become an important parameter in the overall effectiveness of the Modernization program. A critical evaluation of the actual procedures used by local PHAs is needed to determine if the auditing procedure and recommendations on conservation are technically accurate. Results of this research could be used to validate or improve the audit procedures as well as to help characterize public housing in general. The evaluation will provide HUD with information on the quality and uniformity of the audits. The proposed research project will also evaluate the completeness and accuracy of the HUD Workbook. If possible, the research findings will be generalized to help guide PHAs in the selection and implementation of audit procedures.

Analysis of Energy Management Systems

Energy management strategies may involve different levels of control over the energy consumption process. We have identified the following three areas that require further research and analysis: (1) control of occupant energy use patterns through different utility billing strategies (individual versus master meters), (2) control of the central heating distribution system, and (3) building temperature control. A former HUD policy with regard to energy conservation in public housing was the active promotion of conversion from master-metering tenants' utilities to either check-metering or individual metering. Average savings in electricity use of 15 to 20% and in natural gas of 5 to 7% have been estimated after converting from master to individual meters.[13] These projections, however, are for multifamily buildings where tenants are financially responsible for the energy they use. A definitive study of the energy- and cost-effectiveness of meter conversions in the public housing sector is needed. This is especially true in light of recent litigation against HUD brought by various tenants' groups.

Development of Simplified Energy Analysis Methods

HUD and PHAs could benefit from the development of simplified models of building energy performance for various building types. Once developed, these models could be used at the local level to identify projects with energy management problems and to help local authorities target their retrofit efforts. Several tasks are required to develop a simplified method for energy analysis. They include: collection of physical building characteristics and operating conditions from other studies (e.g., HUD-sponsored ABT study), calculation of energy use for representative building types and heating systems using computer simulations, validation of predicted results with measured consumption data, and development of energy use indices that allow comparison of energy consumption by key determinants such as climate, building type, and occupant characteristics.

Conduct Retrofit Performance Monitoring

A detailed program of monitoring and evaluation of retrofit measures is needed in multifamily buildings. The public or other federally-assisted housing sector provides an opportunity to conduct such a program, especially as it relates to opportunities for retrofit during rehabilitation. A monitoring program will characterize energy savings more fully, will evaluate the installation and performance of specific retrofits, and will assess the effects of building occupants. In addition, significant end uses in major multifamily building types can be identified and used for estimating future retrofit potential and for assessing the accuracy of engineering end use estimates.

Tenant Education and Incentives Demonstrations

The potential for energy savings through mechanisms such as tenant education and cash incentives for conservation may be equally as great as the potential for making physical energy improvements to the buildings. "Technical fixes" can only result in energy savings if building occupants make a concerted effort to reduce their energy use. Little research has been done to quantify energy savings and cost-effectiveness of tenant incentives programs in public housing.

Information Transfer

There is no systematic or coordinated network for disseminating information on energy use and conservation to public housing managers, building and maintenance staffs, and tenants. An effective technology transfer program should provide an avenue for determining the information needs of the various participants and relevant organizations, create a means for obtaining technical advice and comment on issues, research tasks and study results, and allow for a smooth transfer of research results and recommendations to the appropriate user group. An information dissemination plan should also emphasize the use of simplified, practical, and low-cost approaches. Possible information transfer options are: (1) use of an informal network of people who are interested in public and other federally-assisted housing, (2) formation of an advisory panel with representatives from DOE, HUD, local PHAs, the national laboratories, universities and other groups with an interest in public housing and expertise in energy analysis, (3) workshops or conferences on the topic held periodically and at different regional locations, or (4) development of a computerized database containing energy-related data, the most recent retrofit information, and news of energy experts and manufacturers. Any combination of these options could serve as a way to meet the information transfer goal.

CONCLUSIONS

The purpose of this report is to summarize what is known about energy use and conservation in the public housing sector. This information will be used by DOE in preparing their research agenda on the potential for retrofit activity in multifamily housing. From our review of available literature and through contacts with local housing authorities and others, we have reached the following major conclusions:

- The annual public housing energy bill paid in part by HUD to local PHAs is very high. Since 1970, these payments have risen from $250 million to more than $1 billion.

- The vast majority of public housing units (nearly 80%) were completed prior to 1973, when world oil prices increased dramatically. Therefore, energy conservation was not considered in either the design or construction of these buildings.

- The potential for saving energy (and money) in public housing is great. Estimated savings of over 50% have been projected in a major HUD-sponsored study and verified by actual field data.

- Since 1980, retrofit activities have occurred, but for the most part, there have been very few evaluations of their performance. Therefore, local authorities have access to little information to guide their future conservation decisions.

- There are many disincentives or barriers that discourage the PHAs from achieving their savings potential. One important impediment to more widespread conservation efforts is the existing HUD policy on utility subsidies related to rolling base periods and 50/50 recapture of annual energy savings.

- A well-coordinated information network is needed to disseminate energy-related information to local housing authorities. There is a lack of credible information at the local PHA level on the effectiveness of various conservation measures, their costs and paybacks, and available financing mechanisms for implementing them.

As part of the DOE's multifamily retrofit program in FY-1986, we addressed four research topics in public housing. First, we evaluated the energy savings and cost-effectiveness of existing retrofits for which we have at least one year of pre- and post-retrofit data.[14] Second, we examined the relative financial impact on HUD and PHAs for four retrofit case studies of various funding strategies taken by two housing authorities.[15] Next, we monitored the performance of solar hot water retrofits and patterns of hot water usage at one San Francisco housing project.[16] Finally, we are performing an assessment of the baseline energy use patterns at several housing authorities across the country. A report on the baseline analysis will be completed by the end of 1986.

Support of public housing research in the future should focus on the other research areas identified in this report. We are pursuing a joint arrangement between DOE and HUD to bring together both the energy and housing interests into one co-funded program. We believe that public housing research offers a big payoff to the federal government. Increasing the availability of credible information and offering proper incentives to PHAs can spur a substantial amount of retrofit activity, stimulate more private sector investment in public housing, and ultimately ease HUD's energy and modernization cost burden.

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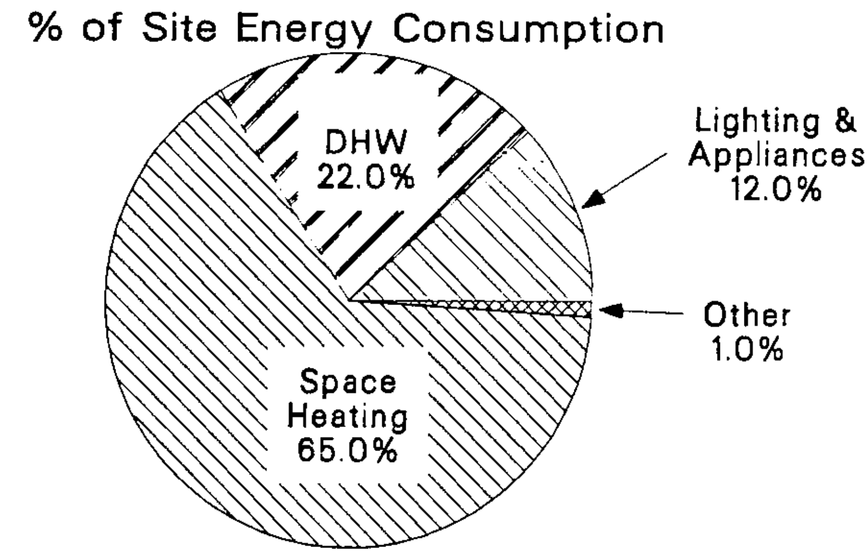
ENERGY USE IN PUBLIC HOUSING BY END USE



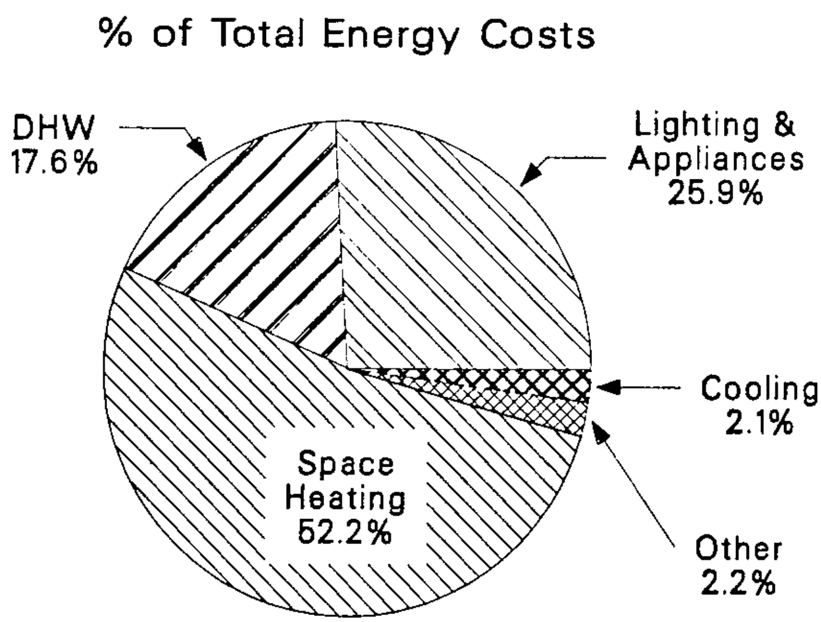


Figure 2. Charts showing energy end use in public housing as a function of site energy consumption and total energy costs.

ENERGY USE IN PUBLIC HOUSING BY FUEL TYPE

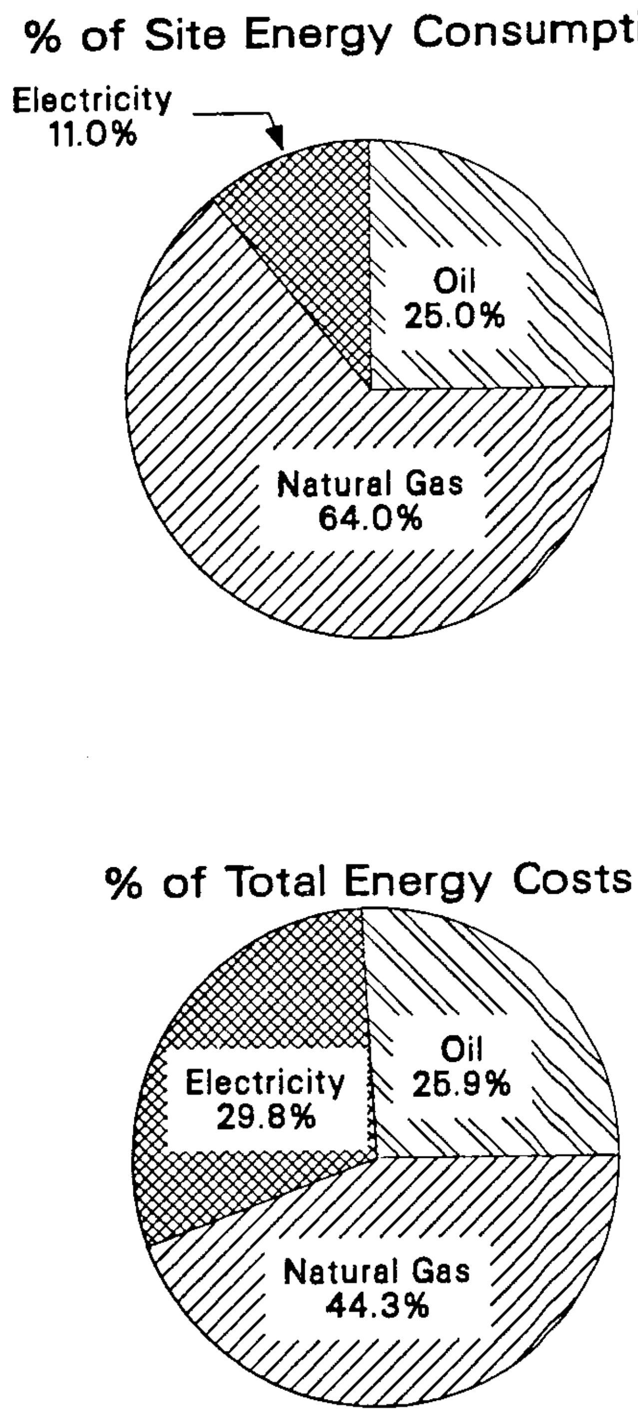


Figure 3. Charts showing energy use in public housing by fuel type as a function of site energy consumption and total energy costs.

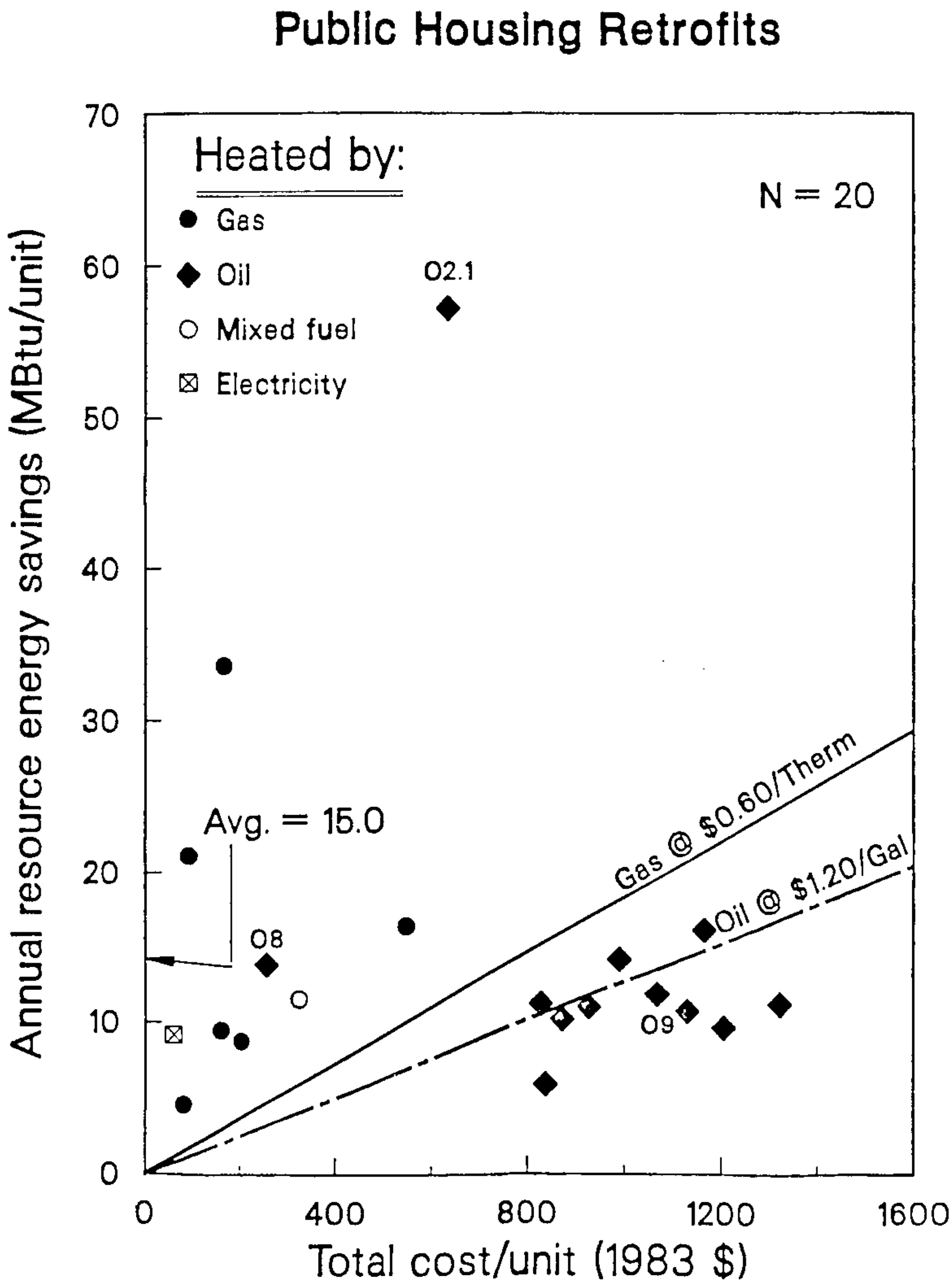


Figure 4. Graphic summary of public housing retrofits at selected sites. (02.1 is computerized boiler control system in Trenton, NJ; 08 is thermostatic radiator valve retrofits in New York City; and 09 is window retrofits in New York City.)

APPENDIX A: ENERGY CONSERVATION OPPORTUNITIES (ECOs)

This Appendix contains a list of 58 energy conservation opportunities (ECOs) considered in the Ehrenkrantz report. They were found to represent the significant energy savings modifications that can be made in the existing public housing stock. The ECOs are grouped into 12 major categories.

Architectural & Envelope

Door Weatherstripping
Window Weatherstripping
Attic Insulation
Floor Insulation
Roof Insulation
Storm Window Retrofit
Insulating Glass
Storm Doors
Wall Insulation
Vestibules

Space Heating

*Reduce Temperature
Night-time Setback Thermostat
Automatic Flue Damper
Flue Heat Recovery
Electric Automatic Pilots

Space Domestic Hot Water

*Reduce Temperature
Flow Restrictors
New Hot Water Heaters
Refurbish/Replace Fixtures

Space Lighting

Delamping
*Reduce Lighting Levels
Automatic Time Control
Incandescent to Fluorescent
High Efficiency Ballasts

Space Cooling

*Clean Condensors & Evaporators
*Require High EER Units

Central Radiation/Convector System

Individual Room Control
Zone Control Retrofit
Radiation Pump Control
Hot Water Reset Control
Radiation Part Load Pump

Central Air Handling Systems

*Reduce Outdoor Air Intake
Reduce Supply Air Quantities
Reduce Outdoor Air Damper Leakage
Automatic Start and Stop
Warm-up Cycle
Zone Reset Control
Heat Recovery

Central Heating Boiler

*Boiler Water Maintenance
*Burner Adjustment
*Boiler Control Adjustment
Automatic Cycling
Lead/lag Control
Reduce Burner Size
Modulating Burner
Part Load Boiler
Automatic Breeching Damper
Flue Gas Heat Recovery
Fuel Conversion

Central Heating Distribution

*Refurbish Steam Traps

Central Domestic Water Supply

Hydro-pneumatic System
Variable Speed Pumping
Separate Domestic Hot Water Heater

Central Cooling

*Chiller Control Adjustment
Ambient Control
Timed Control

Exterior Lighting

Timed Switching
Photocell Switching
Sodium Vapor Conversion

*Operation and Maintenance Items

Source: Perkins & Will and Ehrenkrantz Group, 1980. "An Evaluation of the Physical Condition of Public Housing Stock. Volume 4: Energy Conservation. HUD Report H2850, Washington, D.C.

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APPENDIX B: REVIEW OF MEASURED DATA ON RETROFIT ACTIVITY

In this Appendix, we summarize documented energy savings from retrofit efforts undertaken by 8 public housing authorities. Three housing authorities (Trenton, St. Paul, and Greeneville) undertook retrofit projects as part of a 1980-81 HUD Innovative Energy Conservation Demonstration Program (a total of 61 housing authorities received grants). These results are predominantly for family housing projects, the one exception being the senior project at Lumley Homes. A much more comprehensive analysis of retrofit performance is necessary to build on the following case studies.

Trenton (NJ) Housing Authority[1]

Bumblebee Energy Systems received a HUD Innovative Energy Conservation Demonstration grant to install a temperature control system in Page Homes, an urban multifamily housing complex. Indoor temperature sensors were placed in one-third of the units, transmitting periodic readings to a micro-processor. Using this information, the computer adjusts the hot water temperature for the boiler. The hot water heat distribution system was also rebalanced and a separate gas-fired boiler was installed to meet domestic hot water requirements. Fuel savings in the complex were an impressive 44%. The pre-retrofit energy consumption was comparable to that found in other buildings operated by the housing authority, yet it would be considered an "energy guzzler" in comparison to the overall residential housing stock. The retrofit was very cost-effective with a payback time under one year and a calculated cost of conserved energy around $1/MBtu (at 14.2% capital recovery rate). Annual operation and maintenance costs were estimated at $4000/year or $25/apt., based on Bumblebee System's service contract charges. Eight other similar apartment complexes, used as a control group, showed almost 16% savings. Therefore, net savings were 28% for the complex.

New York City (NY) Housing Authority[2]

In the winter of 1976-77, the NYC Housing Authority undertook a demonstration study program to determine the energy savings resulting from the installation of non-electric thermostatic modulating radiator valves (TRV) in 8 steam-heated buildings controlled as a single zone. The measure was installed in multi-unit dwellings at 4 sites and changes in consumption were compared against 4 similar control buildings at the same site. Daily pre and post-retrofit space heat energy consumption values were obtained from condensate meters at the 8 buildings. A conversion factor of 980 Btu/lb (assuming low pressure steam at 10 psi, 240 °F minus saturated water at atmospheric pressure) and NYC Housing Authority's estimate of 70% boiler efficiency were used in calculating annual energy consumption.

Significant reductions in energy usage occurred in 7 of the 8 buildings. Causal attribution was difficult because of such factors as the experiment's short time period (the pre and post-retrofit consumption data were collected during the same heating season) and likelihood of "independent" occupant retrofit measures and practices (i.e., apart from the study) occurring at the time of retrofit. Tenants did report increased levels of occupant comfort (e.g., more even distribution of heat in buildings). The study authors estimated energy savings of 6.8% specifically attributable to the TRV retrofit, obtained by calculating the percentage savings of the difference between 3 of the 4 study and control buildings weighted by the number of valves installed in each building. The authors ignored the results from one site because the control building had a greater reduction in consumption than the study building.

New York City (NY) Housing Authority[3]

The New York City Housing Authority has an on-going program for replacement of steel casement windows with double-hung, double-glazed thermal break aluminum windows in order to save fuel and reduce maintenance costs. The original windows were vulnerable to air infiltration, required substantial amounts of maintenance, and were frequently subject to glass breakage during windy weather. Pre and post-retrofit, weather-adjusted fuel oil consumption were available for 9 housing projects. The window replacement retrofit achieved average savings of roughly 18% with a 15-year simple payback time for the 9 buildings. The Housing Authority also estimated that the retrofit reduced operation and maintenance costs by $30/dwelling unit or $30,000/year for a typical 1000-unit complex. This lowers the payback time to roughly 11 years (assuming a 20 year lifetime and 7% real discount rate).

St. Paul (MN) Housing Authority[4]

The St. Paul Housing Authority received a HUD Innovative Energy Conservation Grant to install a computerized energy management system in 3 high-rise properties inhabited by elderly tenants. Many existing controls were tied into the computer. The system's main functions included issuing preventative mantenance orders, reducing electrical demand charges by minimizing peak usage, malfunction alarms, and lighting and temperature control in public areas. Prior to this retrofit, the Housing Authority had a rather extensive conservation program in operation and had undertaken many low-cost/no-cost retrofits (showerflow restrictors, reduced hot water temperature to 120 °F, insulated pipe ducts, etc.), plus various retrofits designed to improve heating system efficiencies (e.g., new burners on boilers). The system went into operation during the 1980-81 heating season. We compared fuel consumption from the 1978-79 heating season (before) to 1981-82 usage, normalizing the raw consumption and heating degree-day data to the long-term average value. According to the Housing Authority, the system also provided 404,000 kWh electricity savings in all 3 buildings which the staff converted to fuel-equivalent units and added to the pre-retrofit usage (thus increasing the overall savings). The electricity savings substantially reduced the simple payback time for the investment to roughly 4 years.

Newark (NJ) Housing Authority[5]

A computerized energy management system was installed by Bumblebee Energy Systems in a 530-unit family apartment complex operated by the Newark Housing Authority. The system monitors indoor apartment temperatures, and supplies heat by opening and closing motorized valves dependent on the average apartment temperatures in each building. Determination of energy savings attributable to the energy management system was complicated by the fact that the central heating plant was totally refurbished during the same time period. This included installation of new boilers, underground piping, control valves, and a separate gas-fired hot water generator. Based on an analysis of several years' consumption data at 4 other projects, Bumblebee Management concluded that the heating plant modernization did not yield significant savings. Any potential efficiency improvements were overshadowed by impacts stemming from the proper or improper operation and maintenance of the heating plant and control systems. They apportioned the 26% total annual savings as follows: one-half to replacement of the condensate lines (part of the modernization) and one-half to the Bumblebee energy management system. We used the 13% savings allocated to the energy management control system and the associated cost in estimating savings and cost-effectiveness (disregarding changes in consumption attributable to the refurbishment of the heating plant). An annual operating and maintenance cost of $25,000/year or $40/apartment (Bumblebee's estimated cost for a service contract for the control system) was factored in to the economic calculations. The non-space heating fraction of total consumption was subtracted out using the average of the summer months usage. In addition, we normalized monthly energy usage data to a 'typical' heating season. The retrofit had a simple payback period of approximately 3 years.

San Francisco (CA) Housing Authority[6]

In 1982, the San Francisco Housing Authority began trying to reduce rapidly increasing energy expenses by installing attic insulation, exterior door weatherstripping, low-flow showerheads, and water heater blankets in the buildings that it manages. The conservation measures were financed by the local utility's zero-interest loan program (ZIP). We analyze utility billing data for 3 years, including one post-retrofit year, at 5 multifamily housing projects (totalling 1822 units). Weather-normalized annual natural gas consumption declined by 13% after the retrofit at the five projects; net savings relative to a comparison group were 8%. We determined that most of the energy savings resulted from reduced base level usage. We found that the retrofit program was cost-effective, with a net present value of $399,000 or $220/unit. The Housing Authority's careful efforts to control retrofit costs, which averaged only $150/unit, contributed to the program's success.

Greeneville (TN) Housing Authority[7]

HUD and the Tennessee Valley Authority (TVA) initiated a demonstration project to test several passive solar retrofits. HUD provided $500,000 in funding to the Greeneville Housing Authority to install one of 3 passive solar designs in 275 single-family units. These strategies consisted of movable insulation, wall heaters, or sunspaces. Detailed monitoring occurred in 24 of the units. Data were gathered on indoor and outdoor temperature, solar radiation, electrical use for space and water heating, and operational status of the retrofit. Aggregate data on all 275 units were collected from the fall of 1978 through spring 1983, encompassing 5 heating seasons. Prior to installation of passive solar retrofits, the units had received various conservation retrofits (storm windows, R-30 attic insulation, and weatherstripping). Actual savings from the passive solar retrofits were far less than predicted estimates; analysis of the units that had detailed monitoring revealed that, in many cases, the tenants were not operating the solar retrofits properly or in an optimal fashion. Annual savings ranged from 425 kWh/unit for movable insulation to 1350 kWh/unit for the sunspaces. All 3 designs had long simple payback periods (i.e., greater than 20 years).

Asbury Park (NJ) Housing Authority[8]

Princeton University researchers studied two years of gas consumption data at Lumley homes, a six-story 60-unit apartment complex for senior citizens. Approximately 75 senior citizens live in the 60 units, which range in size from 280 to 540 ft^2. Pre and post-retrofit data were analyzed after the installation of a separate boiler for summertime domestic hot water heating. Consumption patterns were characterized by the Princeton energy scorekeeping model (PRISM); the study found that overheating (indoor temperatures estimated to average 77 °F during the heating season) was the principal factor contributing to high levels of gas consumption.

APPENDIX C: REVIEW OF BEHAVIORAL AND INSTITUTIONAL ISSUES

We have reviewed material on public housing in general and on retrofits in public housing and multifamily units. We present a summary of the available literature on behavioral and institutional issues in public housing.

New York City Housing Authority[1]

In New York City Housing Authority's "Radiator Valve Demonstration Study," complaints of overheating or lack of adequate heat were reduced after installing non-electric thermostatic modulating radiator valves in steam or hot water heated apartment buildings controlled as a single zone. However, it was discovered that tenants sometimes overrode the controls because "the heating system did not function properly." Two examples of this behavioral intervention were: (1) loosening valve heads so that the valves were continuously open; and (2) placing ice on the temperature sensing element so that the valves were continuously open. The installers of the equipment were aware of the importance of tenant education: tenants were advised on the optimal arrangement of furniture so that the air flow to the radiator was enhanced in order to prevent local "hot spots" from occurring.

Greeneville (Tennessee) Housing Authority[2]

In Tennessee Valley Authority's (TVA) "Greeneville Passive Solar Retrofit Demonstration," "performance shortfalls" occurred for each of the three passive solar designs (movable insulation, wall air heaters, and sunspaces) installed in 275 single-family units. Actual savings from the passive solar retrofits varied from a low of 30% to a high of 80% of predicted savings, and these shortfalls were attributed by TVA to "lack of occupant use." TVA suggested some design changes and recommended that incentives may be necessary (e.g., reduced electric allowances) and that educating the occupants on the use of retrofits was necessary in order to optimize the value of the retrofits. In fact, initially, the monitoring data (which included indoor and outdoor temperatures, solar radiation, total electric use, space heating and water heating energy use, and the operational status and/or temperatures of the passive solar retrofit devices) indicated poor participation by the occupants and led to the initiation of a significant educational effort by the housing authority.

Movable insulation devices were monitored by placing a magnetic switch at the bottom of each movable insulation shade to record whether the shade was closed or open. The disadvantage of using this "status sensor" is that one does not know how much the shade is open. TVA had estimated that the movable insulation should be closed 77% of the time to achieve optimum performance. However, actual data showed a range of 0 to 44%, and that the average percent time the shades were closed was 23% of the optimum. They also discovered that the shades were used most in bedrooms where privacy was desired, and least in kitchens where window views were important.

In the case of wall air heaters (air-cooled solar collectors mounted vertically on the outside of a wall), occupants often unplugged the fans connected to the heaters on very warm days or throughout the summer, and they forgot to install the plugs during cooler days or in the winter. TVA suggested two possible remedies: (1) hardwire the fans or (2) have maintenance people disconnect and connect the fans seasonally. The cost of these remedies would then have to be included in the economic analysis of these features.

The third passive solar design—sunspaces—requires the opening and closing of doors and windows and the installation of wall vents and roof vent fans which must be turned on and off, therefore, needing motivated users. (All these devices were monitored with status sensors.)

Finally, it is interesting to note that thermostat-limiting devices (maximum allowable setting was 75 °F) were initially put in some units and were effective; however, the housing authority received many complaints that the units were too cold, and they were eventually removed.

Philadelphia Housing Authority[3]

In the Bumblebee Energy Systems report: "Philadelphia Housing Authority: Modernization Program Recommendations," the authors noted that modernization improvements were only as good and as long-lived as the people who were responsible for them: "A well-designed enhancement, in the hands of people who do not know how to operate it, will lose its effectiveness in as little as a year, and may again require total replacement in as little as five years." The lack of training is seen as a major problem, and because the primary responsibility of most building supervisors is the provision of heat (or excess heat) to reduce the number of complaints of lack of heat, "substantial waste of fuel is the rule rather than the exception."

Housing Authority of Balitimore City[4]

In "NASA's Housing Authority of Baltimore City: Public Housing Energy Workshop," "management/staff/maintenance training" was cited as one of the most important issues to address in public housing for optimizing energy conservation investments. This training would include basic energy conservation training and special sensitivity training to raise tenant acceptance and understanding of energy conservation programs. In addition, tenant education and participation in the energy conservation process were also noted as being very important.

Mitchell-Lama Housing (New York City)[5]

According to the New York State Energy Research and Development Authority's "Institutional Barriers to Energy Conservation in Mitchell-Lama Housing," creating a climate in which energy-saving measures could be effective was believed to be of the utmost importance. Because building owners do not like to replace anything that could still function ("fix it when it breaks"), the institutional nexus deserves to be the focus of attention for stimulating investment in energy conservation designs and technologies and for achieving optimal performance of these measures. While the focus of this report is on Mitchell-Lama housing (state-assisted housing for middle-income households), the analysis is also useful for public housing (state-aided housing for low-income households). In this report, the following entities were perceived to be important role players:

Public agencies and authorities
- Public utilities commissions
- Public benefit corporations
- Federal agencies (DOE, EPA, HUD, IRS)

Investor-owners
- Limited partnerships
  (These people are primarily interested in housing projects as tax shelters and do not want to invest in energy conservation.)

Tenants

Tenant-cooperators
(These people own shares in a housing corporation that owns the building and receive little equity initially; therefore, they are reluctant to maintain the building.)

Managing agents
(Often "first-cost conscious" and have a minimal amount of training in energy conservation.)

Building superintendents
(Control the heating plant and are responsible for its management.)

Financial institutions

Utility companies
(Lower block rates for large users create disincentives to energy conservation and represent an obstacle to conversions from master-metering.)

Equipment vendors and service personnel
(Vendors are skeptical of contingency contracts and distrust managing agents (who are slow payers) and building superintendents (who want kickbacks).

Because of the large number of actors involved in the institutional process, there is a significant problem of diffuse accountability. This problem will affect proposed retrofit projects and effectiveness in public housing.

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