An Evaluation of the Physical Condition of Public Housing Stock: Final Report

Volume 1

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H-2850 Volume 1

An Evaluation of the Physical Condition of Public Housing Stock

Final Report

March 31, 1980

Prepared by

Perkins & Will
The Ehrenkrantz Group

For the

U.S. Department of Housing
and Urban Development
Office of Policy Development
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Errata Page	
3	"<u>Level II</u> ...." should read "<u>Level II</u>, which includes the cost of correcting all Level I deficiencies as well as those which do not comply with HUD Minimum Property Standards ....".
9	"minimum property standard" should read "Minimum Property Standards".
9	Delete "of which 61.0% are minorities".
16	Delete "which is in the process of being developed by HUD and the project team".
33	"Building Officials and Code Administered" should read "Administrators".
48	Column heading "R" should read "R^2".
60	Add footnote: "Level II costs included Level I cost estimates as well; Level III estimates are only for that level".
62	Add footnote: ""Regional" indicates the U.S. Department of Housing and Urban Development Regional Offices".
71	Add footnote #1 found on page 78.
90	"PHA's under the private acquisition program" eliminate the word "private".
113	"in a report ...... states," should read "in a report by the National Center for Health Statistics (National Center for Health Statistics, <u>Incidence of Acute Disabilities</u>, Washington D.C., 1972)".
	Delete" As to the overall ...... observation".
116	"$500,000" should read "$5,000,000".
116-122	References to "ANSI A117.1-1980" should read "ANSI A117.1-1979" in all cases.
130	"a. The program ....." should read. "The program shall be made accessible within three years from the date of publication of Section 504 by HUD."

Errata

Page	
	"c. The percentage ..... assumed" add "for planning purposes and in the absence of data."
131	Delete: "(October 1, 1980 through September 31, 1983)."
155	"Based upon ..... classifications" should read: "classifications (see chapter nine for more detailed explanation of those classifications) were ...."
157	Add footnote: "These numbers are exclusive of Hawaii, Puerto Rico and U.S. Virgin Islands."
238	For fourth entry in column under "Total", ".46%" should read "46%".
272	Reference to "Health Code ...." should read: "New York City Board of Health, New York City Health Code, New York, 1973."
273	Between second and third references insert reference: "American National Standards Institute, Stadard A117.1: Specifications for Making Buildings and Facilities Accessible to, and Usable by, the Physically Handicapped, Washington, D.C., 1961."
275	Add reference: "U.S. Office of Technology Assessment, Residential Energy Conservation, Volume I. Washington D.C.: U.S. Government Printing Office, 1979".

Abstract

The joint venture of Perkins & Will/The Ehrenkrantz Group completed a contract for the Department of Housing and Urban Development, Office of Policy Development and Research entitled, H-2850 A Physical Evaluation of Public Housing Stock. The study estimated 1) the costs of modernizing public housing for three levels of compliance, 2) the costs of making public housing accessible to the handicapped and a manual detailing guidelines to accomplish accessibility in public housing authorities as required by the Rehabilitation Act of 1973, Section 504, 3) the cost and benefits of retrofitting public housing to implement energy conservation measures. The cost estimates for each area of the study are based on a national survey from which results were extrapolated to the total public housing stock.

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Executive Summary

The following report summarizes a two-year study titled "An Evaluation of the Physical Condition of Public Housing Stock". This report was prepared in accordance with the terms of the U.S. Department of Housing and Urban Development - Office of Policy Development and Research Contract H-2850. The objectives, approach and conclusions for this study are summarized in this first volume. Three other volumes provide supporting documentation.

The following summary describes the central questions that were examined in this study and the proposed solutions/conclusions.

2.0 Modernization

To develop the cost estimates to upgrade public housing to three levels of modernization:

- <u>Level I</u>, which requires the correction of all violations of basic health and safety standards. The national estimates (in 1980 dollars) for the 1.17 million units of public housing was approximately $260 million.
- <u>Level II</u>, which includes the cost of correcting all Level I violations as well as all violations of HUD Minimum Property Standards modified to reflect the special conditions of modernization. The national estimate for this is $1.506 billion.
- <u>Level III</u>, which covers the cost of selected modernization improvements to make projects more habitable, easier to maintain, or more attractive. The national estimate was $6.791 billion.

Most public housing is in basically sound condition and little more than routine expenditures per dwelling unit will maintain it as a viable housing resource. There are, however, a limited number (6.1 percent of the projects and 7.4 percent of the units) of "chronic problem" projects which account for a disproportionate amount (41.2 percent of the Level II estimate) of the total estimated cost. Since modernization is exceptionally important to the future HUD policy it is vital that projects continue to be well maintained. These "chronic problem" projects will require a more creative and comprehensive response to keep them viable.

3.0 Accessibility

To develop the cost estimates to upgrade public housing to fulfill the national barrier-free legislation requirements. The estimates for the major category of disability to modify 58,650 units are as follows:

Disability	Required # of Units	Total Cost
Chairbound and Mobility Impaired	35,190	$275.9 million
Sight Impaired	11,730	19.4 million
Hearing Impaired	5,865	3.8 million
Hand/Arm Impaired	5,865	7.7 million
Total	58,650	$306.8 million

4.0 Energy Conservation

To develop estimates of the costs and benefits (expressed in terms of discounted payback periods) required to implement a comprehensive list of energy conservation measures in public housing. The capital cost for all measures with payback periods of less than 15 years was estimated to be $1.5 billion for installation costs only, $2.2 billion when all A/E fees, construction management fees and contingency are included. This investment would save aproximately $328 million annually in energy costs at 1980 price levels.

These conclusions and the many other findings of the study, are presented and documented in the following volumes.

This document is the first volume of the final report on the topic "An Evaluation of the Physical Condition of Public Housing Stock". This report was prepared in accordance with the terms of The U. S. Department of Housing and Urban Development - Office of Policy Development and Research contract H-2850. The objectives, approach and conclusions of the study are summarized in this first volume. Subsequent volumes provide the supporting documentation for both the approach and conclusions of this document.

1.1 Scope of Work

This project was commissioned by the U.S. Department of Housing and Urban Development - Office of Policy Development and Research to accomplish the following primary objectives:

- To develop national, regional and state estimates of the cost for three levels of modernization in public housing:

  Level I, which requires the correction of all violations of basic health and safety standards;

  Level II, which includes the cost of correcting all Level I violations as well as all violations of HUD Minimum Property Standards modified to reflect the special conditions of modernization; and

  Level III, which covers the cost of selected modernization improvements to make projects more habitable, easier to maintain, or more attractive.

- To develop national, regional, and state estimates of the cost to upgrade public housing to comply with the national barrier-free legislation requirements.

- To develop a manual to assist public housing authorities (PHAs) to implement the changes necessary to comply with the national barrier-free legislation.

- To develop national and building type estimates of the costs and benefits (expressed in terms of discounted payback periods) to implement a comprehensive list of energy conservation measures in public housing.

A work plan was approved in December, 1978, which outlined the steps that were taken to answer the primary objectives outlined above. This work plan was detailed because the questions required detailed and accurate answers within the technical limits of statistics and the state of the art of cost estimating.

The approved work plan, procedure, and material developed are covered in detail in the later sections and supporting volumes of this final report. In summary, however, the organization is different for each of the three major parts of the study. Specifically:

1.1.1 Modernization

In the modernization estimates, the approach required eight steps:

1. A modified version of Minimum Property Standards for Multi-family Housing (MPS) was created which reflected the special conditions of modernization. This document was reviewed with HUD, public housing authorities, the National Association of Housing and Redevelopment Officials and other housing industry groups. The final draft was divided into Levels I, II and III standards in accordance with the study objectives.

2. Each standard, potential violation, or basis for substandard designation, was defined.

3. A field survey document was designed to pick up quantities of substandard conditions in each surveyed project. The survey form and procedures were, in accordance with the approved work plan, limited to readily observable violations of the standards.

4. A sample of 400 projects was selected for the survey. The first 200 projects were a random cross section of the total stock. The second 200 projects were statistically selected expansions of particular subgroups within the public housing stock in order to refine key aspects of the estimate. Some 350 projects were used in the final analysis.

5. A re-survey of 60 randomly selected and stratified projects was conducted to document the statistical bias of the unit-selection technique used during the survey. Overall, an independent statistical review found that the modernization cost estimates vary by plus or minus 11 percent. The in-unit sample selection contributed only one percent to the standard error of the estimate.

6. The quantities of substandard conditions found in the field surveys conducted by trained personnel were expanded into quantity surveys for the entire project. Unit costs reflecting mid-1980 Washington, D.C. price levels were then applied to the quantities. The resulting costs were combined into project totals using normal construction cost estimating methods.

7. Seventeen key variables (e.g., building height, size, unit mix, vacancy, fuel, etc.) were collected for 2600 projects in order to provide a statistically reliable base for extrapolating the survey results to national, regional and state totals. This same national data base was also used for the energy and accessibility extrapolations.

8. The project cost estimates were extrapolated to national, regional and state totals using the 2600 sample as a 30% sample estimate of the universe. The state totals, due to the small samples in some states, were created by adjusting the regional estimates to reflect statewide public housing profiles. (Puerto Rico, U.S. Virgin Islands, Hawaii and Alaska are presented separately because the extrapolation process based on building type was not as valid in these locations.)

1.1.2 Accessibility

For the accessibility estimates the approach involved six steps:

1. A document based on the latest available draft of the American National Standard Specifications for Making Buildings and Facilities Accessible to and Usable by Physically Handicapped People (ANSI standards) was prepared, which detailed the requirements and conditions necessary to meet the intent of Section 504 of the Rehabilitation Act of 1973.

2. Based on the analysis of requirements, a field survey form was prepared.

3. The personnel conducting the modernization surveys also collected copies of plans and field data on existing project barriers to the handicapped. This was done for virtually all projects in the modernization survey.

4. Based on a review of the plans and field data, nine typical units (i.e., high-rise one bedroom, low-rise three bedroom, etc.) were selected for detailed redesign and costing. These nine unit types represent every significant unit variable. Each unit type was redesigned for five different disabilities, (wheelchair users, mobility impaired, blind, deaf, and hand or arm impaired).

5. A representative number of the project surveys were compared against the prototypes, and the prototype estimates were modified to reflect particular site or building conditions such as curb cuts, level changes and other variables in public areas and site conditions.

6. The modified estimates were then extrapolated to national, regional and state totals using the 2600 project data base described under "Modernization" above and target percentages were made for each modified unit type in each authority supplied by HUD's Office of Independent Living.

1.1.3 Energy Conservation

There were nine steps involved in this aspect of the study:

1. Research was conducted on the range of energy-using systems in public housing. Based on this research a comprehensive list of 77 potential energy conservation opportunities (ECO's) was prepared. These included virtually all actions (flow restrictors, automatic flue dampers, etc.) relevant to the generally simple systems found in public housing. Subsequent analysis found several of these to be irrelevant in public housing and the final list of ECO's was reduced to 58.

2. Further research and the results of the initial surveys identified five climatic zones and twelve building types (low-rise buildings with individual gas space heaters, high-rise central oil heat, etc.). As the national totals were analyzed the 60 possible combinations were reduced to 22, each of which had at least one percent of the national housing stock.

3. During the field surveys the data required for detailed analysis for each of the 22 climate/ building type cells was collected. Eventually over 96 detailed project energy analyses were made from the survey data.

4. Due to variations in energy usage data, the data was normalized using American Society of Heating, Refrigerating and Air Conditioning Engineers' (ASHRAE) equations applied to the details of each building type and each project analyzed.

5. Each energy conservation opportunity was then analyzed for the selected projects. Most of the ECO list were eliminated as irrelevant to the climatic zone and/or building type, but typically, ten to twenty-five ECOs were found applicable to a given project.

6. Using equations developed for each ECO as well as combinations of ECO's, potential energy savings were translated into dollar savings. The method used was to convert site and source BTUs and kilowats saved into dollar savings based on a calculated weighted-average and first-half of 1979 utility rates for each climate/building type cell.

7. A unit cost file was used to create detailed implementation cost estimates for each ECO. These costs are also early 1979 costs. However, they have been adjusted in this report to reflect mid-1980 costs.

8. Using escalation figures supplied by HUD and DOE, the implementation cost and savings were compared on a discounted payback basis. The results of the calculations were divided into payback periods of under five, under ten, and under fifteen years. ECO's with paybacks over 15 years were not considered.

9. Again using the 2600 project data base, these detailed estimates were extrapolated into national, building type/climate zone estimates.

1.2 Dimensions of the Problem

There are many misconceptions about public housing. The general public has a picture of deteriorating, largely vacant, crime-ridden, high-rise structures. There are some projects which fit this profile, but the majority do not.

One of the results of this study is the creation of an accurate picture of public housing. Some of the major characteristics of public housing and the essential services it provides can be summarized as follows:

- The projects are distributed in reasonably close approximation to the nation's population. There are 9904 projects managed by more than 2700 different authorities in as many localities.

- Since the total number of projects contain approximately 1,173,000 units, the average single project size is 119 units.

- The relatively modest average size is also a reflection of the typical building type used by PHAs. The national distribution of units by building type is predominantly low-rise as shown on Table 1.1.

- Many of the projects conform to the key points in the minimum property standards and are well built. They are also expensive to build, with an average project development cost today of $50-55,000 per unit in the current market.

- The average project age is 17 years. Table 1.1 shows how age is distributed among projects, units and building type.

- Some 893,000 units designated for families house over 3,000,000 persons of which 61.0% are minorities. The remaining 280,000 units are designated specifically for the elderly and house 307,000 persons or have 50% or more elderly tenants as part of a family project.

- No precise figures exist, but it is probable that a slightly higher than average number of handicapped individuals live in public housing than those represented in the nation as a whole. Assuming this to be the case, at least five percent of the tenants have a serious physical handicap.

- As will be discussed again later, most projects are 100% occupied, with waiting lists. Nationally, only 23,460 units (2.0 %) are vacant. Many of the vacancies are concentrated in the problem projects but even the national average would be considered less than normal for a well run private sector rental project.

- Public housing has many of the financial problems that face private market rental housing. The most significant of these problems is the presence of operating deficits due to the inability of project revenues to keep pace with rapidly escalating energy costs and the sociological problems of increased vandalism and crime associated with high density multi-family living.

- In 1968 public housing required $12.6 million in HUD subsidy to accommodate operating deficits. In 1978 the subsidy requirement was $685 million. This substantial increase over a ten-year period is in large part due to tenant income and rent limits imposed by the Brooke Amendments as well as the sharp increase in the cost of providing energy.

Therefore, contrary to assumption, public housing is typically modest in size, almost fully occupied and serves a large number of this nation's most needy citizens. There are projects which fit the popular stereotype, but they are a distinct minority.

Table 1.1

National Public Housing Selected Characteristics

	Projects:		Units		
Project Type	#	% of Total	#	% of Total	Avg Age
Family Hi-Rise ≥ 200 units	493	5.0	200,810	17.1	20
Family Hi-Rise < 200 units	815	8.2	23,254	2.0	14
Family Lo-Rise ≥ 200 units	826	8.3	361,240	30.8	23
Family Lo-Rise < 200 units	4589	46.3	307,524	26.2	18
Elderly	3181	32.1	279,656	23.8	12
Total	9904	100.0	1,172,486	100.0	17

Notes:

1. Elderly projects are those having 50% or more of their units designated for the elderly.

2. Hi-Rise projects are those having buildings predominantly five or more stories and those having combinations of hi and low-rise buildings.

3. Lo-Rise projects are those having buildings predominantly four or fewer stories.

1.3 Summary of Results

This summary presents answers to each of the questions raised in the original research proposal. Some of the facts reveal the inaccurate public perception of public housing. All of the major findings have significant policy implications and are summarized below.

1.3.1 Modernization

The major finding of the modernization portion of this study is the following:

The vast majority of the housing stock is in good condition. While some of it is not attractive, these units appear to successfully comply with the MPS physical standards. Rehabilitation is required largely due to the aging of structures and systems, to the normal wear and tear of building components, minor vandalism and changes in state and local codes. A sound and adequately funded routine maintenance program as well as routine modernization is needed to improve upon and preserve the generally good condition of public housing.

There is, however, a second group of projects which is differentiated from the first group by their serious, and in many cases, chronic problems. The nature of these problems varies from constant vandalism of the public areas in otherwise relatively sound projects, to projects suffering from massive vandalism and/or deterioration in both public areas and in the units. The key factor in this group of projects is the chronic nature of the problem - whether due to vandalism, age, poor management, deferred maintenance or some other cause.

The cost estimates for both groups excluding Alaska, Hawaii, Puerto Rico and the U.S. Virgin Islands are summarized in Table 1.2.

The distinction between the sound and chronic problem groups cannot be defined in exact dollar terms. Based on a review of the survey data as well as the cost estimates, a cutoff of $2500 per unit has been used as a reasonable approximation. With this rationale, the results are very striking. As is illustrated in Section 2.0, the "chronic problem" projects are 6.1 percent of the projects, 7.4 percent of the units, and 41.2 percent of the total modernization cost estimate for Level II .

Table 1.2

Nat'l. Modernization Cost Estimates for Basically Sound And Chronic Problem Projects

Category	Basically Sound	Chronic Problem	Total
Inventory Characteristics			
Projects	8908	604	9512
% of Total	89.9	6.1	96.0
Units	1,025,857	86,386	1,112,243
% of Total	87.5	7.4	94.9
Cost Estimates			
Level I Cost/Unit	$140	$1343	
Level I Total	$143,235,662	$116,016,398	$259,252,060
Level I % of Total	55.2	44.8	100.0
Level II Cost/Unit	$863	$7188	
Level II Total	$884,734,402	$620,942,568	$1,505,676,970
Level II % of Total	58.8	41.2	100.0

Notes:

1. It should be noted that many variables in projects make the general estimate of Level III not as specific as Levels I and II. While some items defined in Level III may have been present in a project, if it was damaged, in need of repair, and had health and safety implications, it became a Level I or Level II item. Consequently, the following Level III total estimate should be used as only a comparative magnitude number:

Level III Cost/Unit	$6209	$5508	
Level III Total	$6,314,887,122	$475,814,088	$6,790,701,210
Level III % of Total	92.0	7.0	100.0

2. All inventory characteristic totals and cost estimate totals exclude Alaska, Hawaii, Puerto Rico, U.S. Virgin Islands due to a limited sampling in those areas. Preliminary findings, however, suggest that projects in these areas are basically in sound condition.

3. Level II costs include Level I cost estimates as well; Level III estimates are only for that level.

In the majority of the basically sound projects, the typical substandard conditions found were roofs which were functionally obsolete or poorly maintained, graffiti and minor vandalism in the public areas, site erosion, broken doors, in-unit features such as open cabinets that no longer meet current MPS, and a small number of poorly maintained units due to poor tenant housekeeping. Most units, however, were in good condition.

In the chronic problem projects, the problems were much more extensive in both the public areas and the units. Vacant units were rapidly vandalized, site furniture (playgrounds, street lamps, etc.) were repeatedly broken, and public areas constantly vandalized. Hardware, gutters, fire hoses and extinguishers, mailboxes, exterior doors, windows and other vulnerable features were repeatedly damaged, destroyed or stolen. Elevators were often inoperable as well. However, the problems of these projects go beyond their physical deterioration. They also suffer from inadequate maintenance, poor management, security and other service needs. When these conditions exist they actually minimize the long term benefit of any improvements made to the physical stock.

In addition to the above summary, several other points should be made.

The current value of the Federal investment is substantial. The replacement cost today would be in excess of $65 billion for the buildings alone. This figure is a rough approximation based on a conservative estimate of a total development cost (construction, fees, administrative overhead, etc.) for a publicly enabled unit of $55,000 in 1980-81. Without an effective modernization program, a significant portion of this investment could be jeopardized.

The limitation in modernization funding prevented the most effective response to the deficiencies identified in the study. Because modernization needs far exceed available funding, HUD has pursued a strategy of funding the most critical work items first, such as those related to health and safety and structural integrity. Under this piecemeal approach, not all work items funded were of the highest priority (i.e., Levels I and II) as defined by the study.

The survey revealed many examples and symptoms of this approach. Typical were:

- Examples of funding of Level III amenity type actions while other PHAs were unable to receive funding for Level I serious health and safety problems.

- Premature replacement of toilets or kitchen appliances in a project even though most fixtures were sound. The sound ones were be replaced, as required by procedure, and stockpiled as a reserve for other projects in the PHA. Since a PHA is more likely to receive modernization money rather than an increased maintenance budget, this system was a solution to the inequity between routine maintenance and modernization funding.

- Most of the high modernization estimates received in applications for Urban Initiatives money contained extensive Level III changes or even major project restructurings. The actual Level I and II deficiencies were often relatively small fractions of the total.

- Examples of wholesale roof replacement even though only a minority had worn out, a result of the uncertainty of receiving funding for the remainder when needed.

- Projects where changes were made without regard to sequence. In one project the heating plant was replaced in spite of the fact that over 30 percent of the windows were broken.

All of these problems could be avoided in a restructured modernization program which is in the process of being developed by HUD and the project team.

1.3.2 Accessibility

To date very little has been done at the project level to fulfill Section 504 of the Rehabilitation Act. To comply with Section 504 requirements, the study has assumed the following:

- A total of 58,620 dwelling units is used as the target figure for the barrier-free compliance effort. This is approximately five percent of the current total of 1,172,486 units and reflects both the continuing attrition in the total stock as well as those units already adapted for the handicapped.

- The target for units adapted for the mobility-impaired and the chairbound is three percent of the total, the target for the hearing-impaired is 0.5 percent, for the sight-impaired is 1.0 percent; and for the arm and hand-impaired is 0.5 percent.

- All units for the chairbound and the mobility-impaired will have the same physical modifications.

- It is assumed that no more than ten percent of the units in an individual project would be adapted to avoid ghettoization of the handicapped.

- It is also assumed that if site or other factors in individual projects required unusually high costs, the local authority would use new construction or lease units which can be adapted for the average costs noted below.

Based on the assumptions above and the survey, the following have been major findings:

- Field surveys suggest that there are more handicapped people living in public housing than many local authorities assume. Moreover, they live there despite the fact that almost none of the family projects and many of the elderly projects have adequate adaptations for their disabilities. Special modifications, such as plywood ramps, are installed by project maintenance staff as needed or requested. Field surveys revealed several examples where disabled tenants were mobile only within their own units.

- The cost of complying, if properly planned and implemented, can be held to a total lower than many have assumed. This total and the cost estimate for the provision of accessible units for the disabled by type of disability is illustrated in Table 1.3.

Table 1.3

National Accessibility Cost Estimates for Dwelling Units for the Disabled

Disability	Req #	Units %	Cost/Unit	Total Cost $	%
Chairbouund and Mobility Impaired	35,190	60.0	$7840	$275,889,600	89.9
Sight Impaired	11,730	20.0	1650	19,354,500	6.3
Hearing Impaired	5,865	10.0	655	3,841,575	1.3
Hand/Arm Impaired	5,865	10.0	1310	7,683,150	2.5
Total	58,650	100.0	$5231	$306,768,825	100.0

Notes:

1. Total number of required units, 58,650 is 5.0% of the total public housing stock.

2. It is assumed that all accessible units also conform to Level II modernization standards once they are made accessible.

1.3.3 Energy Conservation

Energy cost escalation has been one of the major contributors to the alarming growth in the subsidy requirements. Fuel costs are expected to continue to rise significantly faster than both rents and inflation, thus aggravating an already severe problem.

However, because so little has been done to date, the potential for savings is substantial. Specifically, this study has found:

- Public housing uses an estimated 146 million BTUs per dwelling unit or 162 trillion BTUs per year for the public housing stock as a whole. In 1980 costs this translates into $673 per dwelling unit or $749 million for the entire stock.

- The major categories of energy use a percent of total dollars expended on energy:

Heating	52%
Domestic Hot Water	18%
Lights and Appliances	26%
Miscellaneous	4%

- The range in usage between high energy-use project prototypes (ones in severe climates and high-usage building and system characteristics) and low energy-use projects is over five to one.

- Energy usage in public housing is higher than private sector housing. This can be accounted for in part by the older public housing stock; the lack of energy conservation measures to date; and the fact that project office space, site lighting and other public space energy use has been prorated to the dwelling units averages.

- Because of the relatively high energy usage by public housing, there is significant potential for savings. These potential savings are summarized in Table 1.4.

- As would be expected, there are many actions that can be taken with relatively low initial costs and short paybacks. On a marginal basis, however, the curve of payback and return decreases as investment increases. This is summarized in Table 1.4. The conclusion to be drawn from this table is that an average investment of $1347 per dwelling unit (1980 dollars) will yield an average annual savings of

$307 dollars. This would reduce average energy consumption to 68 million BTUs per dwelling unit, which is comparable to typical, private sector housing today adapted for energy conservation. Extrapolating this to national totals, the potential implementation cost is $2.2 billion (in 1980 dollars) including A/E fees, construction management fees and contingency with potential annual savings of $328 million (in 1980 dollars).

- In addition to the recommended investment level for energy conservation retrofit, selective solar energy retrofit systems are cost effective and are recommended for funding.

  These systems are primarily for domestic hot water only since active solar space heating retrofit systems were found to be only marginally economical. It was found that 5 percent of the public housing stock would have solar domestic hot water systems that payback in less than 15 years, and 17 percent would payback in 30 years.

Table 1.5 shows a summary of the cost estimates for all three areas of the study.

Table 1.4

National Energy Conservation Savings & Capital Cost Averages per Dwelling Unit

Payback Period	Total Source Energy Savings (MMBTU)	Total Savings	Dollar Savings	Capital Cost
1. No Capital Cost ECOs	27.57	$ 75.36	11.2%	($75.36)*
2. Less than 5 year payback ECOs	94.55	291.79	43.4	576.10
3. Less than 10 year payback ECOs	108.45	339.94	50.5	1068.90
4. Less than 15 year payback ECOs	120.16	376.50	56.0	1745.27

Notes:

1. *"No Capital Cost" ECOs cost is estimated to be first year savings to accommodate for training and increased maintenance efforts.

2. (MMBTU) in millions of BTUs.

Table 1.5

Summary National Cost Estimates

Study Area	Total Cost
Modernization	
Level I	$ 259,252,060
Level II	1,505,676,970
Level III	6,790,701,210
Accessibility	
Chairbound/Mobility Impaired	$ 275,889,600
Sight Impaired	19,354,500
Hearing Impaired	3,841,575
Hand/Arm Impaired	7,683,150
Energy Conservation	
Installation of Combined Energy Conservation Opportunities with Less than 15 year Payback	$ 1,500,240,000
A/E Fees, Const. Mgmt. Fees and Contingency	680,000,000
Total Capital Cost	2,180,000,000
Total Dollar Savings per Year	328,000,000

1.3.4 Emerging Implementation Strategies

HUD should develop comprehensive plan which establishes the policies and procedures for future use of the funding made available for physical improvements in the public housing stock. Three categories of actions are treated separately, however they are all considered to be modernization in the general sense and need to be coordinated in terms of priorities. Recommended strategies are outlined below:

Modernization

The first step must be to separate the projects with modernization needs into the two categories. The "basically sound" group's needs can be met by providing adequate funding. Current fiscal year 1981 appropriations are projected to be $110 million which equals only 42% of the Level I total cost estimates and 7.2% of the total Level II estimates. The provision of adequate funding is no small matter. The "distressed" group's modernization needs, however, should be funded as part of a creative, comprehensive approach to modernization, management and other means of reversing the chronic nature of their problems. Often some Level III actions such as better security devices, are more important than many Level II changes in problem projects.

- In addition to the basic division into the "basically sound" and "chronic problem" groups, funding must be prioritized by level. Level I (health and safety problems) must be rectified immediately for all projects. Not to do so is dangerous for both the tenants and the continuing value of the public's investment in the housing stock.

- If funding continues to be less than the estimated costs for achieving modernization, efforts should be prioritized in the following areas of need:

    - All of the Level I problems for all projects
    - All of the Level II needs of the "basically sound" housing stock
    - Comprehensive action funding of Levels I, II and III where combining actions achieve significant economies of scale
    - Funding of a manageable group of the problem projects each year as carefully tailored project-by-project plans are developed.

- The remainder of the "distressed" projects should receive the minimum funding necessary to keep them habitable, but full funding should be held back until a tested set of actions are developed on the initial pilot projects.

- The funding for all of the above actions should be done on a multi-year comprehensive basis so that a predictable level of funds continues to be available throughout the modernization period (which will inevitably require several years in large, chronically-problematic projects). The implementation of multi-year funding should make it possible to reduce the time lag between identification of needs and funding for corrective action.

- The multi-year funding should be done on the basis of a multi-year modernization plan that incorporates all funding for physical improvements defined in annual joint reviews conducted by HUD and PHA personnel.

- As a means of disciplining the process so that each PHA correctly defines its needs within the confines of the modernization program and gives HUD the information necessary to prioritize fund allocations, a new budgeting and monitoring procedure should be implemented. This would include:

  - A new set of standards for modernization based on the work in this effort
  - A new set of budget forms, based (but significantly simplified) on the survey and cost-estimating procedures used in this study, to develop uniform, verifiable definitions of funding need
  - A processing system at HUD headquarters and field offices, which would review the uniform budget requests, highlight for further review unusual areas of cost, and rank approved actions into their appropriate categories

If adopted, it is felt that this strategy, currently under development by HUD and the project team, can be turned into detailed procedures, tested and implemented in time to guide next year's modernization funding.

Accessibility

A detailed guide for implementation of a Section 504 compliance program has been prepared as part of this contract. In addition to the recommendations already included in that manual, the following general strategies should be noted:

- Accessibility funding should be coordinated with other modernization funding even if the actual actions are carried out separately from other modernization efforts.

- Implementation changes should be made to meet actual or demonstrated potential need. Units should only be modified to meet the actual needs of current or potential tenants. Moreover, this should be done only in units which can be easily converted. The cost estimate in this study assumes that PHAs and HUD will select appropriate units for retrofit actions in their compliance efforts.

Energy Conservation

The energy conservation actions are unique because there are quantifiable benefits associated with the costs. Again, it is recommended that the funding be coordinated with a multi-year modernization master plan, but the priorities should be set on the basis of a uniform energy cost/benefit analysis procedure. Currently, this strategy and several others noted above are being developed by the project team and HUD as a task entitled "Preparation of a Standardized Modernization Application and Review Procedure" of which a Public Housing Energy Conservation Handbook is a component.

1.4 Organization of Final Report

The remainder of this first volume expands on the material summarized in this introduction. Specifically, it is divided into four sections.

- Modernization

  Section 2.0 provides a detailed expansion on the analysis and results of the modernization cost estimating aspect of the study.

- Accessibility

  Section 3.0 reviews the current status of public housing's compliance with Section 504 as well as a detailed expansion of the analysis and results of this aspect of the study.

- Energy Conservation

  Section 5.0 contains a detailed review of the analysis and results of this aspect of the study.

- Appendices

  Section 5.0 and 6.0 contain detailed explanations as to the methodologies, statistical analyses and data base developed for the execution of this report. The original work plan assumed that the study would be able to use the data on Form 1885 to construct a comprehensive profile of the entire housing stock. In fact, Form 1885 only yielded a profile of 5600 projects and this data base was determined to be statistically invalid. Therefore, a second effort designed to obtain seventeen key data elements in a statistically selected sample of 2600 projects was initiated. This section discusses the statistical basis for this sample of 2600 as well as some of the subgroups or strata created within it for use in the various cost estimates.

  Sections 7.0 - 9.0 contain detailed discussions of the background materials, sample survey results and estimating procedures and other supplementary information for each of the three study areas.

- Appendix Volumes II, III and IV.

Three supplementary Appendix volumes are also part of this report, they are:

- Volume II, which contains the standards and design criteria, survey instrument, and unit cost file used in the modernization surveys and estimates.
- Volume III, which contains the accessibility design criteria, survey instrument, unit cost file and Accessibility manual.
- Volume IV, which is a self-contained complete report of the energy study, survey instrument and a separate study outlining the feasibility of solar retrofit in public housing as well as supporting material.

The Department of Housing and Urban Development currently administers 1.17 million low-income public housing dwelling units housing 3.4 million people throughout the nation. Although the building of public housing began in 1937, the majority of the current stock was built between 1955 and 1965, and consists primarily of duplex and row house low-rise units.

Operating costs have almost tripled over the past decade, while monthly rents have increased less than 50%. The ability of low-income tenants to pay rents and rising operating costs has had a serious affect on the maintenance and improvement activities of many public housing authorities. The Brooke Amendments of 1969-71 in which tenants are required to pay no more than 25% of their annual adjusted income, puts further strains on local operating budgets. Housing authorities have been forced to defer the repair or replacement of numerous building deficiencies which resulted in accelerated deterioration, major capital expenses in the future, and detracted from the general quality of living in the housing project.

Authorization to provide new units has been about 50,000 per year for approximately 4% of the existing public housing stock. The small number built or purchased within this authorization serves largely to replace existing units lost to deterioration, vandalism and age. This makes the retrofit goal and success of the public housing Modernization Program of utmost importance. Only a well conceived plan of restoration and preservation will extend and maintain the useful life of the public housing stock.

HUD defines its modernization efforts as the process by which the public housing stock is improved to achieve conformance with standards of health, safety and liveability. The Federal Government provides public housing authorities with funds to finance capital improvements to correct physical deficiencies, achieve operating efficiency and economy, and upgrade living conditions.

The expenditures of these modernization efforts are limited to capital improvements which are defined as follows:

"...alterations, betterments, additions, replacements or major repairs that appreciably extend the useful life of the property (site, structures or non-expendable equipment), increase its value or utility, or make it more suitable for its intended use."

Deferred routine maintenance is a major cause of the current condition of the public housing stock. Deferred routine maintenance is not eligible for modernization funding and is inadequately funded under the Performance Funding System (1975) which provides operating subsidies to PHAs. Therefore, there is a backlog of required work to be done to the stock, estimated at $400 million by HUD in 1976, which dramatically affects the quality and quantity of public housing in the United States.

In order to evaluate and quantify the extent to which the problems outlined above exist, the study designs and implements a method for evaluation of the physical condition of the national public housing stock. An estimate of the costs, time and impact of rehabilitating or renovating the housing for three distinct levels of modernization is defined.

To establish a reference point for evaluating the existing condition of public housing, the Modernization Standards (Volume 2) were developed. A corresponding survey instrument (Volume 2) was developed to ascertain non-compliance within these standards in those housing projects which were surveyed. The survey results were then analyzed and a cost estimate developed for the needed corrective actions required to bring projects to each of the three levels of modernization. The cost estimates for these representative projects were then extrapolated to the universe of public housing projects for a national cost estimate. Each step of this process is summarized below.

2.1 Overview

To evaluate the public housing stock and estimate reasonable costs for the required modernization, the following items were required:

1. Definition of the three levels of modernization;
2. Modernization standards to define conditions against which projects could be evaluated;
3. Data collection or survey instrument to record existing conditions and deficiencies; and
4. Cost methodology.

2.1.1 Modernization Levels

In order to prioritize modernization work items for an overall modernization plan, the following was developed:

Level I describes work required to comply with federal, state and various local laws relating to public and resident health and safety. Level I includes those items of priority and emergency work which:

1. Alleviate conditions adversely affecting the health and safety of building users;
2. Arrest deterioration of major building components and/or systems where there is an immediate or potential threat to health or safety; and
3. Correct major life, health and safety code violations.

Level II addresses non-emergency items required to preserve the basic integrity of building structures and systems as well as common practice items (such as closet and cabinet doors) not included in previous issues of the Minimum Property Standards. This level includes those items of rehabilitation required to:

1. Bring a project up to the standards intended by the Minimum Property Standards "Guidelines for New Construction" or equivalent standards
2. Remedy those conditions caused by deferred maintenance which affect a building's efficient use and satisfactory enjoyment
3. Prevent major capital expenditure in the future.

Level III includes additional rehabilitation work beyond that stated in Level II. Additional amenities, elements of good design and above-standard materials are to be considered for:

1. Improved health and safety of residents;
2. Greater durability and ease of maintenance;
3. Increased liveability and enjoyment of the project; and
4. Improved site, building and residential security.

Level III is defined to be consistent with the intent of 24 CFR 841.107(c), issued in 1977. This federal regulation suggests a level of construction above that specified by MPS for new construction. Level III of this study aims to establish a similar standard for the modernization of existing public housing where appropriate.

The Modernization Standards serve as an articulation and definition of each of these three levels. For compliance with Levels I and II, all standards within that level must be met; and the modernization cost for that level is defined as the cost of correcting all sub-standard conditions at the given project. In contrast, Level III modernization costs for a given project are dependent upon specific project needs, priorities and local market considerations.

2.1.2 Modernization Standards

The emphasis for all levels of modernization is on physical improvements. If recommendations are to produce net benefits over time, each proposal must be evaluated as it relates to needs, operating costs and project management.

The following Department of Housing and Urban Development documents, and various other sources were used to develop a set of comprehensive standards which address the modernization of public housing. These sources include:

The Department of Housing and Urban Development's Minimum Property Standards for Multifamily Housing (MPS) (Document 4910), which defines minimum acceptable levels of design and construction standards for low-income public and federal housing mortgage insurance purposes. This document is used as the primary source for new construction. The basic issues of rehabilitation are not addressed, because many of the specified standards for new construction are costly and unwarranted in project modernization.

HUD standards for rehabilitation, Minimum Design Standards for Rehabilitation for Residential Properties ies (Document 4940.4), were issued as an aid in carrying out the objectives of the Federal Government in local programs. Although these standards define basic objectives for rehabilitation and modernization, they are performance based and conceptual in nature to allow maximum flexibility for local use. The HUD objectives presented in this document were incorporated into these standards. However, their non-specific nature prevented their use for field inspection of public housing in this study.

1. National Codes. Various codes such as the Building Officials and Code Administered (BOCA) Basic Building Code and the National Fire Protection Association Code which are widely accepted in the construction industry, were incorporated in mandatory Level I items and advisory Level III items, especially when the stringency of the code was known to be desirable, compared to local codes applicable to multi-family housing.

2. Department of Housing and Urban Development documents or handbooks. In addition to Documents 4910 and 4940.4 discussed above, other key HUD documents were reviewed to insure that these Modernization Standards reflect the intent of the HUD Modernization Program. These documents include the "Public Housing Development Handbook", "Low Income Public Housing Modernization Program Processing Handbook", and "Guidelines for Rehabilitating Old Buildings".

3. Security Specialists. Since security has become a major aspect of residential rehabilitation, various sources dealing with problems encountered in public housing were reviewed for incorporation in these standards. Security measures which had already been implemented in some public housing projects were added to this body of knowledge prior to incorporation in these standards. Other sources included the studies of Oscar Newman, Design Guidelines for Creating Defensible Space; A Design Guide for Improving Residential Security and the HUD Urban Initiatives Anti-Crime Program for Public Housing Agencies.

4. Site Planning Specialists. In the initial construction of a large portion of public housing, site work and site development were not major concerns. As a result, site deficiencies, misuse (vandalism and crime) and underutilization can be seen throughout the nation. Numerous residential site planning and development sources were incorporated into these standards, particularly as Level III items, to effect environmental, social and physical improvements.

5. Perkins & Will/The Ehrenkrantz Group. Numerous standards were developed by the Contractor specifically for use in public housing.

6. Experience of Housing Authorities. Many of the most responsible studies, while appearing sound and at many times promising in print, proved invalid or irrelevant when implemented due to the unique characteristics of public housing. The experience of housing authorities and their documented successes and failures were used as additional checks on all research sources for standards.

A full bibliography is included in the Modernization Standards and the specific source of each item within the book is noted. These standards are meant to reflect the intent of the HUD Modernization Programs as described by HUD personnel and their key documents.

The Modernization Standards are organized into seven distinct categories, representing major building/site elements as follows:

1.0 General Considerations
2.0 Site
3.0 Structure and Mechanical Systems
4.0 Exterior
5.0 Interior
6.0 Specialties
7.0 Equipment

Each category is further divided into distinct components with individual sets of standards, i.e., Section 2.0 Site, is composed of various components which include "Parking Areas", "Steps and Ramps", "Outdoor Lighting", etc. Those standards which apply to all components within a category provide a general performance understanding for that level.

The three compliance levels are noted separately on succeeding pages within each component to promote a clear understanding of compliance requirements for a given level. This organization provides for ease of comparison of modernization levels for a given element, and for direct reference to the survey instrument. Compliance with any level of modernization also includes those items in all preceeding levels.

Each item within the Modernization Standards consists of two parts: the modernization standard and a corresponding basis for substandard designation which is an observable condition. The basis for substandard designation for each reference standard, identifies the physical components, which when not present or in disrepair, results in non-compliance for a given modernization level. It is these physical components of the standards that are directly trans- lated to the survey instrument for identifying non-compliance.

Items within all three levels of the Modernization Standards may be categorized as:

1. Major repairs
2. Deferred maintenance items
3. Security items
4. Amenities
5. Performance specifications
6. Comments

Major repairs, which comprise the majority of these standards, form the basis for expenditures under the HUD Modernization Programs. As defined by HUD, major repairs are work items that are usually:

1. Non-recurrent;
2. Substantial in scope;
3. Involve expenditures that would otherwise materially distort the trend of maintenance expense;
4. Not the result of public housing authority failure to perform adequate maintenance during a period after April 1, 1975; and
5. May include replacement of structural elements due to normal wear and tear.

This category of standards involves both emergency work such as gas line leakage which would be a Level I item, and non-emergency work such as missing roof coping which is a Level II item.

Deferred maintenance items are defined as work needed at the present time for which funds are not available in current public housing authority operating budgets. Although these items are not eligible for modernization funds, it is this type of small deficiency which when left unattended becomes a major capital expense. An example of this problem is the case of an exterior brick wall which needs repointing. Left unattended, water can penetrate the building, leak to more than one floor, and damage large amounts of gypsum board and flooring that were otherwise in sound condition. Overall costs to the public housing authority would dramatically decrease if these deferred maintenance items were remedied in a timely manner.

In addition, many of these deferred maintenance items are highly visible, such as exterior painting, cracked plaster and substandard cabinetry. Their obvious deterioration potentially threatens the overall condition of the housing project, and also affects the morale of residents, which adds to the difficulty of attracting or maintaining a more stable population.

As mentioned above, site, building and dwelling unit security have been a growing concern in all communities throughout the country. Most building construction standards deal with issues of structure and materials and do not address sociological and psychological issues. Vandalism and security problems must be addressed to insure that public housing provides for the health and safety of residents, as well as the protection of public property. Security items are included in all three modernization levels as mandatory standards, and as further recommendations where applicable. For example, items affecting life safety such as lighting and exterior doors are Level I items, whereas relocating parking fields from secluded, unpatrolled areas to more visible areas are Level III items.

Standards included for greater liveability or for the conformance with regional norms are limited to Level III of the Modernization Standards. All of these items are meant to remedy the limits of housing built 30 and 40 years ago when different standards of living were the norm, and to provide living environments that are more comparable to equivalent private housing. Examples of these work items include provision of entry porches when they are standard in the area, or developing project sites for public and private recreation. Items of this nature are never mandatory and should be implemented according to project location, need and resident requirements.

It should be noted however, that several items herein classified as Level III amenities may occur in public housing projects acquired under the acquisition program. If such items were used and maintained by the PHA and were found deficient or damaged, they would become Level I or II items, e.g. insulated glass, exterior seating, circuit breakers, air-conditioning, etc.

Also included with each section are various performance standards that serve as general provisions. Although these standards do not translate into directly observable conditions, their inclusion was meant to amplify other more specific standards and identify the intent of that category.

Also included in the standards are comments on various items. This elaboration is meant to clarify the intent of the standard, guide implementation, and offer alternatives to the noted standard. Recommendations noted in the comments offer alternatives when need might suggest their use and additional funding is available.

The Modernization Standards are intended exclusively for existing buildings. There are, therefore, a number of limiting factors that would not be present in standards for new construction. Among the more important of these factors are certain design, planning and dimensional considerations; performance standards for mechanical systems other than readily observable conditions and the greater stringency of local codes. Examples of such limitations can be found in Appendix Section 7.0.

2.1.3 The Survey Instrument

The modernization survey instrument was used to record data from the architectural plan and field inspection of each project. It assessed the extent of substandard conditions (as defined by the three modernization levels) and provided the basis for the cost analysis. Each reference standard noted in the Modernization Standards was translated into a basis for substandard designation which in turn became a question on the survey instrument.

In content and form, the survey instrument was designed to obtain objective information. Existing conditions which have readily observable factors were recorded by the survey team and required no awareness as to which standard was being violated nor what the remedial action should be. The desired corrective action is determined in the cost estimating analysis and by the degree, quantity and location of the deficiency. This assures a uniform cost estimating process for all surveyed housing projects and avoids subjectivity.

To obtain cost estimates, the following information had to be obtained from the site visit to each housing project:

1. Existing building systems and materials
2. Building types
3. Presence or absence of public and private amenities and the possibility for provision of same
4. Existing physical conditions
5. The degree and quantity of each deficiency
6. Location of each deficiency.

The survey instrument provided an efficient and orderly means to provide these data. An example of this instrument is contained in Volume 2.

2.1.4 Cost Estimation Methodology

Cost estimates were made for each of the 350 projects surveyed based upon identified deficiencies recorded on the modernization survey instrument. Detailed surveys were performed on the site, interior and public spaces, on 5 dwelling units for projects under 50 units and on 10 dwelling units for projects over 50 dwelling units. Brief surveys were performed on 15 dwelling units for projects under 50 units and 30 units for projects over 50 units. Each detailed survey also included a brief survey. The concept of brief surveys was included to provide a determination of general condition. Units were selected in an unbiased manner but always included those units subject to greater structural and physical stress. This method was further validated by a re-survey of 60 projects, in which units were randomly selected. The 60 projects were selected on a stratified basis and modernization costs generated from the original survey were used as the basis for measuring any variances that might have occurred. Negligible variance occurred. Further discussion on results of the resample are presented in Appendix 5.0 Methodology.

Each response recorded on the survey reflected a substandard or noncompliance condition with the appropriate quantity noted. Furthermore, each response also referred to specific levels of modernization, as developed in the Modernization Standards (see Volume 2). The responses were then translated to specific work items to correct the deficiencies and appropriate materials and labor for same. When these summaries were completed, each survey was reduced to a series of work items by modernization level and then costed.

The Unit Cost File was created specifically for this project by the authors of the Building Cost File. All costs are indexed to Washington, D.C., mid-1980. The prices combine the latest value for materials, current trade wages and contractor mark-up. Once a project was costed, a twenty-five percent contingency was added to account for administrative problems experienced by contractors on public housing projects.

The entire cost estimating procedure is shown as Illustration 2.1, Modernization Cost Evaluation Process.

Illustration 2.1

Modernization Cost Evaluation Process

An Evaluation of
The Physical Condition of
Public Housing Stock
H-2850

PAGE 1

Modernization Standards **5383**

Category:	Interior/Dwelling Unit
Component:	Bathrooms
Level:	II
Date:	1 November 1978

Reference Standard	Description
P&M/TEG	All Level I standards shall be met.
HUD 4940.4 (4-2f.1)	The arrangement of fixtures shall provide for the comfortable use of each fixture and permit at least a 90 degree door swing. Adequate wall space shall be provided for a mirror or medicine cabinet and towel bars.
	Equipment
MPS 401-4.2a	Bathrooms shall be provided with:
1	1. Grab-bar and soap dish at tub or shower. 2. Shower curtain rod or enclosure at shower. 3. Soap dish at lavatory (soap dishes may be integral with the fixture). 4. Toilet paper holder at water closet. 5. Mirror and medicine cabinet or equivalent enclosed storage. 6. One towel bar convenient to tub and lavatory.
MPS 401-4.2c	Each 1/2 bath shall be provided with Items 3, 4, 5 and 6 in MPS 401-4.2a.
MPS 401-4.2d	Stall showers shall have a minimum area of 1,024 sq.in. and a least dimension of 30 in.
MPS 401-4.2a	Each bathroom shall have a bathtub with a minimum outside width of 30 in.
P&M/TEC	For general finish requirements and standards see (Interior Finishes. Level II).
	Electricity and Lighting
MPS 616-4.2	Provide wall switch controlled permanent lighting fixture.
MPS 616-4.5	Bathroom fixtures shall be controlled by a grounded wall switch not readily accessible from the tub or shower. When installed, electric bathroom heaters and control switches shall be located as far as practical from plumbing and at least 30 in. from tub or shower.

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Basis for Sub-Standard Designation **5382**

Category:	Interior/Dwelling Unit
Component:	Bathrooms
Level:	II
Date:	1 November 1978

Item	Description
Medicine Cabinet or Equivalent Storage	1. Missing mirror. 2. Unenclosed, missing or askew door. 3. Missing shelves. 4. Inappropriate material. 5. Holes, cracks.
Towel Bar	1. Missing. 2. Broken, defective. 3. Inappropriate material. 4. Unstable, poorly secured.
Electricity and Lighting	1. Inoperable outlets or fixtures. 2. Missing or defective overhead light. 3. Inadequate outlets. 4. Outlet within 30 in. of bathtub or shower. 5. Missing outlet adjacent to mirror.
Lavatory	1. Missing or broken splashback. 2. Poor jointing to wall. 3. Poor water pressure. 4. Broken or improperly installed soap dish.
Bathtub or Shower 2	1. Missing or defective curtain rod. 2. Missing or broken soap dish. 3. Missing grab bar. 4. Poor caulking, needs regrouting. 5. Insecure, rocks or unhinged. 6. Missing safety glass in shower doors. 7. Inadequate size as required.
Water Closet	1. Unstable. 2. Askew. 3. Improperly installed. 4. Missing or defective toilet paper holder.

Modernization Cost File - Work Items

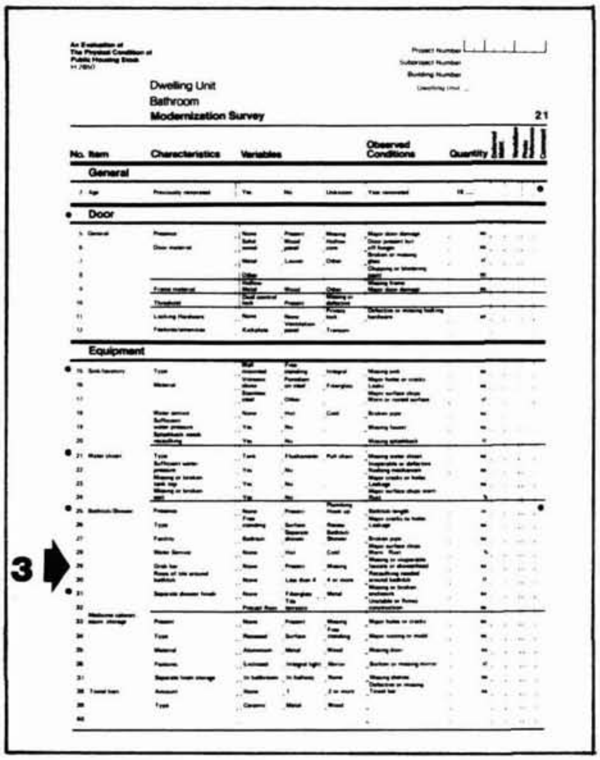
Toilets and Accessories (continued)

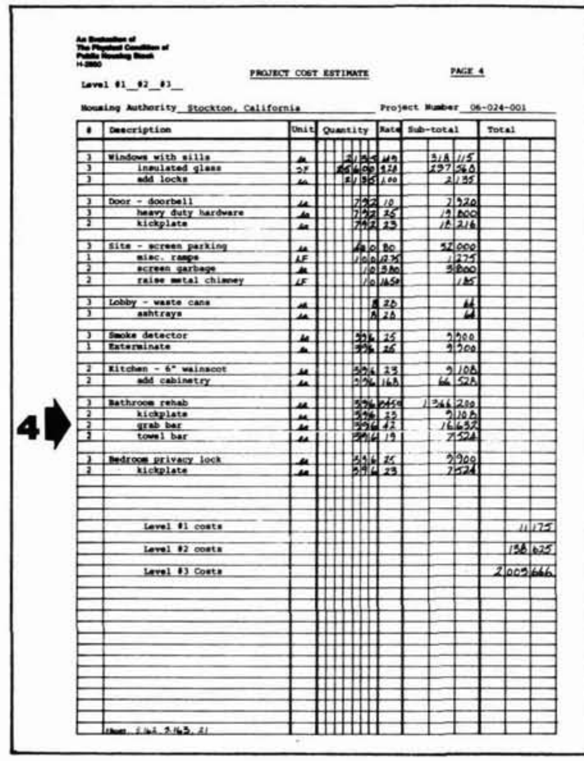
MATERIAL	ACTION	DESCRIPTION	UNITS	QTY	$	QTY	$	QTY	$
Towel Dispenser	Replace	Stainless Steel Wall Mounted, Paper	EA	1	82.00	15	80.00		
		Recessed, Paper	EA	1	106.00	15	101.00		
		Wall Mounted, Cloth Roll	EA	1	82.00	15	80.00		
Electric Hand Dryer	Replace	Wall Mounted	EA	1	190.00	10	180.00		
		Recessed	EA	1	196.00	10	185.00		
		Floor Mounted	EA	1	233.00	10	225.00		
Waste Receptacle	Replace	St. Steel Wall Mounted	EA	1	130.00	10	125.00		
		Recessed	EA	1	130.00	10	125.00		
		Floor Mounted	EA	1	130.00	10	125.00		
Sanitary Napkin Dispenser	Replace	St. Steel Wall Mounted	EA	1	212.00	10	200.00		
		Recessed	EA	1	212.00	10	200.00		
Utility Shelf	Replace	6X16" Stainless Steel	EA	1	31.00				
Medicine Cabinet	Replace	Recessed Baked Enamel, 18X24"	EA	1	55.00	10	45.00		
		St. Steel, 18X24"	EA	1	105.00	10	95.00		
		Wall Mounted Baked Enamel, 18X24"	EA	1	50.00	10	40.00		
		Stainless Steel 18X24"	EA	1	100.00	10	90.00		
5 Grab Bar	Replace	Stainless Steel Straight, 24"	EA	1	49.00	12	42.00		
		Angular, 24X36"	EA	1	80.00	12	73.00		
		Wall to Floor	EA	1	17.00	50	12.00		
		Straddle, Tub Mounted	EA	1	95.00	10	90.00		

M3.0 Modernization 65

Illustration 2.1 (continued)

Modernization Cost Evaluation Process





PROJECT COST ESTIMATE

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Level #1__ #2__ #3__

Housing Authority Stockton, California

Project Number 06-024-001

#	Description	Unit	Quantity	Rate	Sub-total	Total
3	Windows with sills	ea	[illegible]	49	318 115	
3	insulated glass	SF	[illegible]	128	297 568	
3	add locks	ea	[illegible]	1.00	2 135	
3	Door - doorbell	ea	792	10	7 920	
3	heavy duty hardware	ea	792	25	19 800	
2	kickplate	ea	792	23	18 216	
3	Site - screen parking	ea	650	80	52 000	
1	misc. ramps	LF	100	12.75	1 275	
2	screen garbage	ea	10	580	5 800	
2	raise metal chimney	LF	10	18.50	185	
3	Lobby - waste cans	ea	8	26	66	
3	ashtrays	ea	8	26	64	
3	Smoke detector	ea	396	25	9 900	
1	Exterminate	ea	396	25	9 900	
2	Kitchen - 6" wainscot	ea	396	23	9 108	
2	add cabinetry	ea	396	168	66 528	
3	Bathroom rehab	ea	396	3450	1 366 200	
2	kickplate	ea	396	23	9 108	
2	grab bar	ea	396	42	16 632	
2	towel bar	ea	396	19	7 524	
3	Bedroom privacy lock	ea	396	25	9 900	
2	kickplate	ea	396	23	7 524	
	Level #1 costs					11 175
	Level #2 costs					158 625
	Level #3 Costs					2 005 666

4

2.2 Analysis

The previous section provided an overview of the procedures leading up to the analytical phases of the modernization aspect of this study. This section describes the analytical process that enabled a quantification of the results of the field surveys and their subsequent extrapolation to the universe of public housing in the country.

Using the survey sample as the analytical data base, a series of statistical tests were performed to evaluate the relationship between the costs of modernization and the physical variables of the projects themselves. More specifically, the question being asked was, "Could costs per dwelling unit for modernization Levels I-III, be predicted by explaining the relationships among project size, age, room count, vacancy rate, density, building height, program type, construction type, and previous modernization fund allocation? And, if so, could a representative cost model be developed that would estimate costs in similar, unsurveyed projects, resulting in a national estimate?" The following sections describe this process.

2.2.1 General Analysis

The observations of the survey teams proved to be invaluable in this analysis. Their findings lent support to the stratification process described in Section 2.3 and also provided general views of the nature of public housing.

In most cases it was found that public housing was basically sound. Projects tended to be well built and in satisfactory condition. Photo references 1-11, pp. 75-81, show projects that were well-built and well-maintained. However, there were chronic problems. Roof replacement was typical due to age-related obsolescence or inadequate maintenance or both. Site erosion was common, usually due to either absence of ground cover or poor site selection. Elevator maintenance in large family high-rise projects varied especially where there was repeated vandalism. Typically, only one elevator was operable and tenants were reluctant to use it for lack of security and reliable operation.

Other common problems included deteriorated flat roofs, inadequate drainage in snow belt zones, poor or irregular trash collection procedures, poor quality door and window frame maintenance, and inadequate maintenance of circulation areas.

Problems of vandalism an^d graffiti were also prevalent in large, high-rise, family projects. Site-related vandalism often occurred to lighting fixtures, seating, and playground equipment. Vandalism was indicated by window breakage, squatters, destruction of roof hatches, removal of fire protection equipment, destruction of public restrooms, community rooms, heating systems in stairways, mailboxes, roof ventilators, and removal of copper flashing for illegal resale.

Small family projects were found to have very minor vandalism problems. However, similar to the large family projects, they were concerned with security.

Projects for the elderly were typically in good condition, especially if they were in high-rise buildings. However, those projects that were family-elderly combination sites frequently exhibited the same exterior/site problems as strictly family projects.

These findings gave support to the strata identified below for analysis.

2.2.2 Sample Stratification

As previously noted, the stratification process is different for each area of the study even though the same sample was used for all three areas. Stratification for analyzing the cost of providing accessibility was based upon structural and physical layout of units. Stratification for analyzing the cost of providing energy conservation, was based upon climatic zones, structural variables and energy resources. Both of these study areas allowed for physical generalizations without much emphasis upon physical condition, since the majority of public housing is neither accessible to the disabled nor energy efficient. Modernization posed a more difficult problem. Physical descriptions had to serve as a means of categorizing costs which respond to standards and specific levels of modernization. In addition, these descriptions had to define mutually exclusive subsets including the subset of "distressed" projects with chronic problems usually related to vandalism.

Some of these descriptors were easily selected based upon the surveyors' observations. For example, it was noted that elderly projects tended to be in better condition than family projects; that low-rise projects exhibited different site characteristics from high-rise, and that small, low-rise projects differed from the larger more dense high-rise projects. However, there were more specific characteristics of the distressed projects to be considered based upon a list submitted by HUD for inclusion in the sample.

This list contained 20 projects having a minimum of 200 dwelling units and vacancy rates, in most cases, in excess of 10%. In order to include most of these projects in the remaining 200 projects to be surveyed, a random selection was made among projects over 200 units with vacancy rates equal to or greater than 10%, both high-rise and low-rise. This created two strata. The control for these strata, since they would bias the sample in the extrapolation process, were projects 200 units and over with less than 10% vacancy rates, both high-rise and low-rise. It should be noted that the sample surveys validate the hypothesis that distressed projects fall into the two strata defined by high/low rise projects over 200 dwelling units, over 10% vacancy, in higher percentages than the remaining strata. However, these strata constitute only 1.7% of the units and 0.2% of the projects in the total housing stock. The project team definition of distressed projects, i.e. projects that have Level II modernization needs dwelling unit costs in excess of $2,500, shows that the majority of distressed projects are not large, high-rise projects, but rather, small, low-rise family projects. The sample was therefore stratified into eight categories or strata with characteristics as follow in Table 2.1. Appendix 7.0 contains a complete listing of the sample projects surveyed.

Table 2.1

Sample Stratum Characteristics

	Projects		Units			
Stratum	#	%	#	%	Avg Age	Avg Vac
Family High-Rise ≥ 200 Units, ≥ 10% Vacancy	12	3.4	10860	12.2	22	27.0%
Family Lo-Rise ≥ 200 Units, ≥ 10% Vacancy	29	8.3	15826	17.7	30	27.5%
Family High-Rise ≤ 200 Units, < 10% Vacancy	31	8.9	19135	21.5	27	1.6%
Family Low-Rise ≥ 200 Units, > 10% Vacancy	56	16.0	22358	25.1	28	1.5%
Family High-Rise > 200 Units	15	4.3	1353	1.5	24	1.8%
Family Low-Rise < 200 Units	110	31.4	7325	8.2	18	2.2%
Elderly High-Rise	46	13.1	8317	9.3	9	0.9%
Elderly Low-Rise	51	14.6	4049	4.5	10	0.8%

2.2.3 Regression Analyses

To estimate the cost per dwelling unit by modernization level, it was assumed that the dependent variable, cost (y') had a linear relationship with several independent variables describing physical attributes, X_1, $X_2 \ldots X_k$. The relationship and degree to which X affects Y is characterized by a partial regression coefficient b such that:

$$y' = a + b_1 x_1 + b_2 x_2 \ldots + b_k x_k$$

where:
y' = dependent variable
a = constant
b = partial regression coefficient for variables 1-k
X^{1-k}_{1-k} = independent variables 1-k

An example of one of the regression equations tested is:

$$\text{DUCOST} = a + b_1 \text{ (AGE)} + b_2 \text{ (DU)} + b_3 \text{ (AVERAGE ROOMS)} + b_4 \text{ (VACANCY RATE)} + \ldots + b_k X_k$$

By this means, if statistical significance were found, the relationships in the universe of public housing between physical variables and cost could be inferred.

Regresssion analysis was performed on each of the eight strata in the sample survey using the forward (stepwise) inclusion approach. This meant that independent variables were entered into the equation if they met certain statistical criteria (minimum F ratio of 0.1 acceptable, and up to 5 variables) with the highest contributing variable coming in first up to the fifth highest variable. In this approach, the regression coefficient b (unstandardized) could be evaluated for each variable's total influence upon the equation, through the F ratio.

The following table, 2.2 shows the variables brought into the regression equation by strata and the significance of the variables with cost as the dependent variable, indicated by a yes or no in the variable column. If a variable was not brought in, i.e. it did not meet the minimum F value for significance at 0.1, it is indicated by a (-). The R^2 column gives an estimate of the proportion (%) of projects wherein cost variances could be explained by the regression equation.

Table 2.2

Regression Analysis - Significance of Variables By Stratum

Stratum	Variables' Significance: Age	DU	Avg Rooms	Vac Rate	PHA City Pop 000	PHA Size	R
1. Family Hi-Rise ≥ 200 units, ≥ 10% Vac.							
Level I	Yes	-	Yes	Yes	Yes	Yes	.69
Level II	-	-	-	Yes	-	Yes	.58
2. Family Lo-Rise ≥ 200 units, ≥ 10% Vac.							
Level I	No	Yes	No	No	Yes	Yes	.36
Level II	No	Yes	Yes	No	No	No	.24
3. Family Hi-Rise ≥ 200 units, < 10% Vac.							
Level I	-	No	No	No	-	-	.06
Level II	No	-	No	No	-	-	.14
4. Family Lo-Rise ≥ 200 units, < 10% Vac.							
Level I	Yes	No	No	Yes	No	No	.18
Level II	Yes	-	-	-	No	No	.07
5. Family Hi-Rise >200 units							
Level I	No	Yes	Yes	-	Yes	Yes	.71
Level II	-	No	Yes	No	-	No	.38
6. Family Lo-Rise <200 units							
Level I	No	Yes	No	No	Yes	-	.06
Level II	No	Yes	No	Yes	No	-	.16
7. Elderly Hi-Rise							
Level I	Yes	No	No	No	-	-	.14
Level II	Yes	No	No	No	No	-	.16
8. Elderly Lo-Rise							
Level I	No	No	-	-	-	No	.05
Level II	No	No	No	-	No	-	.07

It can be seen through a review of the R^2 column that the given values show only one equation of possible significance, Stratum 1 Family High-Rise Projects, $\geq$200 units and $\geq$10% vacancy rate. Since this stratum represents only 0.39% of the total units in the universe, it was not used. Subsequent regressions were run using the log (base 10) of cost, the insertion of dummy variables to test location (regional) significance, and logs of cost with dummy variables. Even though the use of dummy variables improved the equations, all regression equations were subsequently rejected since the selected physical project descriptors in the aggregate were not necessarily predictive of dwelling unit cost. However, the dummy variables supported the use of regional cost means by stratum for the final cost estimates presented in this report.

2.2.4 Final Analysis

The original proposed analytical method assumed that after sample stratification and subsequent regression analyses of the independent variable, the total housing stock (universe) could be stratified using the same variables found to be suggestive of causality in the survey sample. This could only be done if the regression equations proved to be significant.

The previous section shows that there was very little significance among the selected variables. This is largely due to the fact that analysis was constrained by the data available which described the universe. While there were extensive data about the physical characteristics of the sample survey, these types of data were not available for the universe. Consequently, analysis was confined to those parameters which could be obtained about the total housing stock. A more detailed discussion of the development of the data base is in Appendix 5.0 - 6.0.

This exercise does not exclude the viability of regression equations, because it is very likely that the sample survey could have generated better R^2s using different sets of combinations of available data. However, in order to arrive at a point where national extrapolations could be made it was decided to use only that information which could readily be obtained in the field about the total housing stock.

As discussed in the previous section and in Appendices 5.0 - 6.0, the universe was stratified into eight strata based upon tenant type - family or elderly, total dwelling units - 200 units and over or under 200 units, building height - low-rise or high-rise, and vacancy rates - over 10% or under 10%, Average cost estimates for these types of projects within each of the ten Department of Housing and Urban Development regions as developed from the survey sample were then applied to the appropriate stratum. These regional estimates were further extrapolated to the state level.

Illustration 2.2 shows the process described above and Tables 2.4-2.5 show the inventory and stratum characteristics of the data base used for extrapolation.

The following sections illustrate and discuss the results of the above described process for Modernization Levels I-III at national, regional and state levels. Also included is a further discussion of the sub-stratum of distressed projects.

Illustration 2.2

Modernization Cost Extrapolation

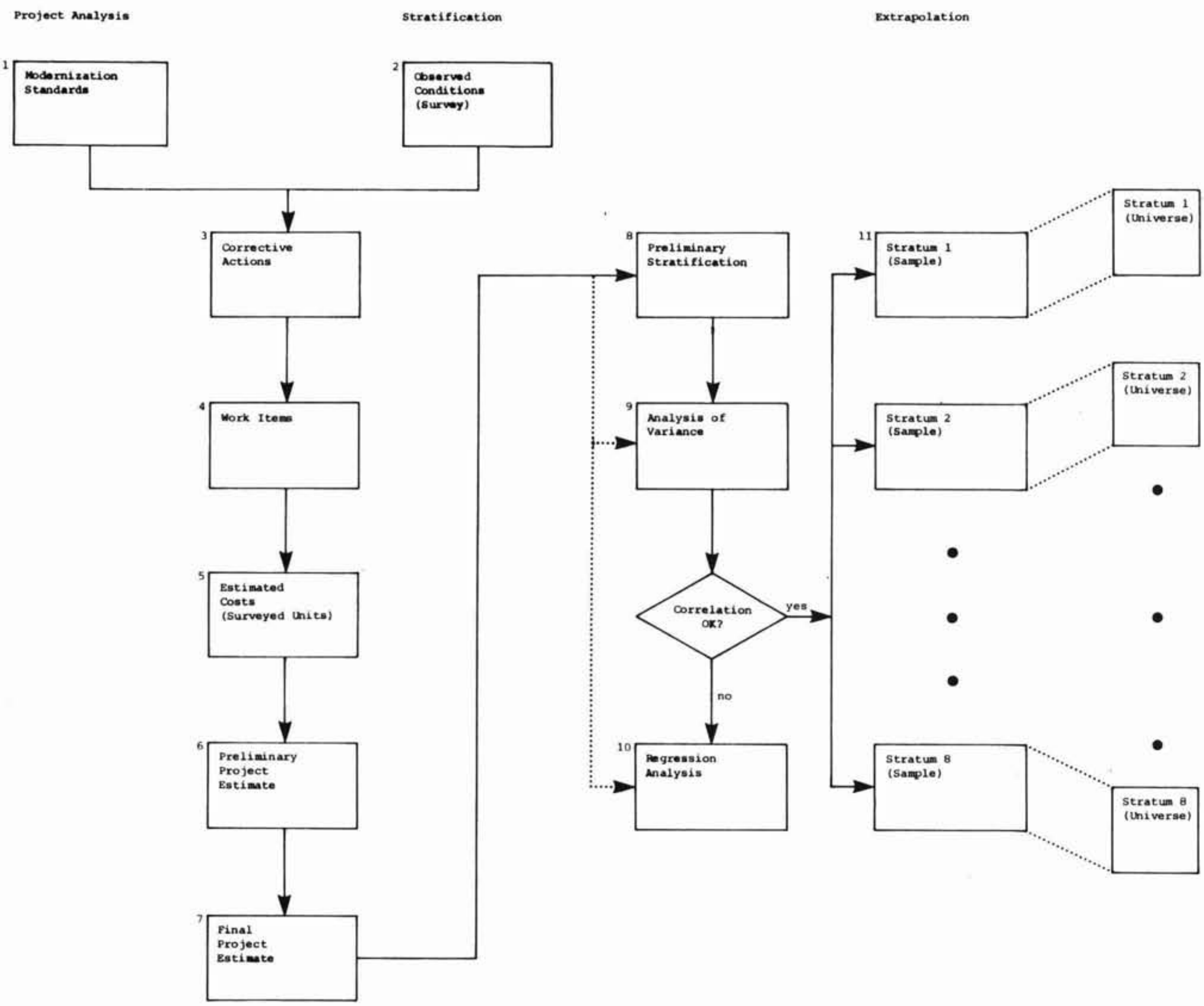

Table 2.3

Low Rent Public Housing Dwelling Units by HUD Region

Region	Dwelling 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	100.0

Table 2.4

Low Rent Public Housing Dwelling Units by State and Stratum

State	1	2	3	4	5
Alabama	0	4638	2699	11966	297
Alaska	0	0	0	0	0
Arizona	0	0	0	1782	0
Arkansas	0	0	0	0	1843
California	0	5718	0	26946	0
Colorado	0	0	0	1135	0
Connecticut	2719	0	6045	3167	1588
Delaware	0	0	0	1714	232
District of Columbia	0	0	0	7293	517
Florida	0	0	0	12926	0
Georgia	754	0	4033	14000	2202
Hawaii	0	0	0	1028	279
Idaho	0	0	0	0	0
Illinois	0	0	17706	20763	2176
Indiana	0	987	0	1205	0
Iowa	0	0	0	0	512
Kansas	0	0	1171	0	0
Kentucky	0	0	0	7325	0
Louisiana	0	803	3742	10999	0
Maine	0	0	0	0	0
Maryland	0	0	0	14100	1892
Massachusetts	4560	2729	2598	8972	548
Michigan	0	0	8577	5055	0
Minnesota	0	0	0	0	744
Mississippi	0	0	674	2797	0
Missouri	7921	2142	3536	1999	554
Montana	0	0	0	0	0
Nebraska	0	0	0	0	0
Nevada	0	0	0	0	0
New Hampshire	0	0	0	0	0
New Jersey	5197	0	7047	8953	913
New Mexico	0	0	0	0	0
New York	935	0	81392	17390	2432
North Carolina	0	0	0	12914	0
North Dakota	0	0	0	0	0
Ohio	0	4231	4767	19858	511
Oklahoma	0	4207	0	1859	1037
Oregon	0	0	0	2335	0
Pennsylvania	0	1198	16970	13491	447
Puerto Rico	0	0	11003	29654	1564
Rhode Island	0	1953	1218	5681	353
South Carolina	0	0	0	6129	0

Table 2.4 (continued)

Low Rent Public Housing Dwelling Units by State and Stratum

State	6	7	8	Total	%
Alabama	15326	1038	2508	38771	3.3
Alaska	1521	0	0	1521	-
Arizona	5027	377	632	7817	1.1
Arkansas	5945	1904	3118	12805	5.7
California	24754	3081	6008	66507	.6
Colorado	2255	2451	1610	7450	1.6
Connecticut	805	3588	557	18469	.3
Delaware	436	407	116	2005	1.0
District of Columbia	618	3459	0	11880	3.3
Florida	13368	10239	2585	39117	4.2
Georgia	22021	4253	1771	49033	.1
Hawaii	2554	0	959	4927	-
Idaho	0	973	0	973	1.5
Illinois	9361	17450	3662	71118	.3
Indiana	5517	7871	1521	17101	.6
Iowa	0	1239	1996	3746	1.8
Kansas	2711	1762	1909	7553	2.5
Kentucky	10312	2424	521	20585	.3
Louisiana	11085	0	2921	29550	2.1
Maine	904	1215	1584	3703	3.5
Maryland	3617	3430	1003	24041	2.2
Massachusetts	6292	7624	8276	41599	1.6
Michigan	6522	3676	2111	25941	1.1
Minnesota	1161	12289	4176	18370	1.9
Mississippi	8691	0	389	12550	.3
Missouri	2167	1905	1899	22121	.7
Montana	2088	0	952	3040	.3
Nebraska	458	1680	6318	8455	.4
Nevada	2932	0	638	3569	3.9
New Hampshire	1720	587	1815	4122	.6
New Jersey	5247	15805	2772	45934	10.6
New Mexico	6288	0	998	7474	3.1
New York	4929	15024	1633	123734	.3
North Carolina	19411	3018	465	35808	4.3
North Dakota	1820	0	2016	3835	1.6
Ohio	5120	11394	4258	50139	.8
Oklahoma	7216	1701	3141	19161	6.2
Oregon	2416	2759	1498	9008	.8
Pennsylvania	20578	14086	5537	72307	1.0
Puerto Rico	7124	0	0	49345	.4
Rhode Island	0	581	0	9785	3.0
South Carolina	5676	0	186	11990	4.6

Table 2.4 (continued)

Low Rent Public Housing Dwelling Units by State and Stratum

State	6	7	8	Total	%
South Dakota	0	0	0	0	0
Tennessee	0	1409	0	13661	548
Texas	0	12446	711	10270	548
Utah	0	0	0	0	0
Vermont	0	0	0	0	0
Virgin Islands	0	0	2395	0	0
Virginia	0	0	818	10703	262
Washington	0	5993	0	3679	415
West Virginia	0	0	1576	938	286
Wisconsin	0	0	0	0	198
Wyoming	0	0	0	0	350
Total	22,086	48,455	178,679	312,687	23,248

1. Family Hi-rise $\geq$200 units, $\geq$10% vacancy
2. Family Lo-rise $\geq$200 units, $\geq$10% vacancy
3. Family Hi-rise $\geq$200 units, <10% vacancy
4. Family Lo-rise $\geq$200 units, <10% vacancy
5. Family Hi-rise <200 units,
6. Family Lo-rise <200 units
7. Elderly Hi-rise
8. Elderly Lo-rise

Table 2.4 (continued)

Low Rent Public Housing Dwelling Units by State and Stratum

State	6	7	8	Total	%
South Dakota	4090	663	437	5190	.1
Tennessee	15311	1807	2858	35593	.2
Texas	18768	3414	7716	53872	1.5
Utah	227	1137	0	1364	1.4
Vermont	1439	359	313	2110	.5
Virgin Islands	2155	0	0	4550	1.0
Virginia	3532	851	1227	17394	.1
Washington	896	3990	1626	16598	.1
West Virginia	1516	1235	104	5654	.4
Wisconsin	3388	1493	6602	11680	4.2
Wyoming	152	181	0	694	.4
Total	307,466	174,421	105,236	1,172,486	100.1

2.0 Modernization

2.3 Summary of Results and Conclusions

The results presented in this section speak exclusively to the cost estimates for the modernization of Levels I-III for public housing at national, regional and state aggregations.

2.3.1 Unit Estimates

The following estimates shown in Table 2.5 are the average cost per dwelling unit in eight strata for each of the ten HUD regions by Levels I-III. As previously discussed, these costs were obtained from 350 field survey detailed estimates and form the basis for cost extrapolation.

It should be noted that due to the lack of available data about the universe at the time of field surveys, some strata were not found in the survey sample. Upon completion of the data base for extrapolation to the universe it was found that some units did occur in unsurveyed strata in certain regions. However, since comparable costs were not determined in the survey these strata by region are indicated by a blank (-) in Tables 2.6-2.8: Regional Average Modernization Costs Levels I-III by Stratum.

Table 2.5

National Average Modernization Cost Estimates Per Unit by Level by Stratum

Stratum	Level I	Level II	Level III
1. Family Hi-Rise Projects $\geq$ 200 units, $\geq$ 10% vacancy	$1589.64	$2677.04	$7254.25
2. Family Lo-Rise Projects $\geq$ 200 units, $\geq$ 10% vacancy	443.95	1756.16	5988.62
3. Family Hi-Rise Projects $\geq$ 200 units, < 10% vacancy	243.75	2333.32	6313.55
4. Family Lo-Rise Projects $\geq$ 200 units, < 10% vacancy	220.68	1318.44	6423.00
5. Family Hi-Rise Projects < 200 units	262.61	1280.99	8499.86
6. Family Lo-Rise Projects < 200 units	355.22	1267.81	8194.02
7. Elderly Hi-Rise Projects	56.75	462.48	3487.16
8. Elderly Lo-Rise Projects	70.04	613.29	5591.83
National Average Total	$ 287.46	$1255.99	$6544.80

Table 2.6

Regional Average Modernization Costs - Level I by Stratum

	Stratum	Boston	NY	Phila	Atlanta	Chicago
1.	Family Hi-rise $\geq$200 units, $\geq$10% Vac Cost/DU	4266.88	-	392.77	-	562.64
2.	Family Lo-Rise $\geq$200 units, $\geq$10% Vac Cost/DU	585.32	410.00	1117.33	-	49.38
3.	Family Hi-Rise $\geq$200 units, $\leq$10% Vac Cost/DU	170.46	191.23	313.47	121.23	45.65
4.	Family Lo-Rise $\geq$200 units, $\leq$10% Vac Cost/DU	295.72	171.03	275.43	245.29	99.68
5.	Family Hi-Rise <200 units, Cost/DU	16.25	-	277.52	318.05	270.85
6.	Family Lo-Rise <200 units, Cost/DU	205.35	89.11	344.17	317.09	167.19
7.	Elderly Hi-Rise Cost/DU	107.93	114.57	54.69	4.11	41.15
8.	Elderly Lo-Rise Cost/DU	19.52	2.96	58.88	51.69	33.85
	Total Cost					

Key: NY - New York
Phila - Philadelphia

Table 2.6 (continued)

Regional Average Modernization Costs - Level I by Stratum

	Stratum	Dallas	Ka City	Denver	San Fran	Seattle	National
1.	Family Hi-Rise $\geq$200 units, $\geq$10% Vac Cost/DU	99.00	15.78	-	137.00	-	1589.64
2.	Family Lo-Rise $\geq$200 units, $\geq$10% Vac Cost/DU	245.51	462.41	-	296.87	9.63	443.95
3.	Family Hi-Rise $\geq$200 units, $\leq$10% Vac Cost/DU	1001.07	-	53.00	97.00	-	243.75
4.	Family Lo-Rise $\geq$200 units, $\leq$10% Vac Cost/DU	199.58	844.73	-	289.03	-	220.68
5.	Family Hi-Rise <200 units, Cost/DU	359.24	-	-	-	-	262.61
6.	Family Lo-Rise <200 units, Cost/DU	418.39	75.39	91.09	944.04	567.27	355.22
7.	Elderly Hi-Rise Cost/DU	49.12	4.19	-	61.09	-	56.75
8.	Elderly Lo-Rise Cost/DU	135.98	34.90	-	43.77	13.65	70.04
Total Cost							287.46

Key: Ka City - Kansas City
San Fran - San Francisco

Table 2.7

Regional Average Modernization Costs - Level II by Stratum

Stratum	Boston	NY	Phila	Atlanta	Chicago
1. Family Hi-Rise $\geq$200 units, $\geq$10% Vac Cost/DU	5254.56	-	1291.51	-	5075.70
2. Family Lo-Rise $\geq$200 units, $\leq$10% Vac Cost/DU	2035.70	1499.39	2001.13	1030.81	768.84
3. Family Hi-Rise $\geq$200 units, $\leq$10% Vac Cost/DU	1151.81	3600.05	1165.89	435.07	1399.88
4. Family Lo-Rise $\geq$200 units, $\leq$10% Vac Cost/DU	1079.39	2535.39	2605.20	877.11	844.66
5. Family Hi-Rise <200 units, Cost/DU	896.12	-	1147.74	1938.78	957.37
6. Family Lo-Rise <200 units, Cost/DU	1400.92	2228.34	911.51	1216.25	697.66
7. Elderly Hi-Rise Cost/DU	530.58	569.21	573.07	1246.56	444.90
8. Elderly Lo-Rise Cost/DU	1020.32	359.86	778.75	533.97	671.77

Total Cost

Key: NY - New York
Phila - Philadelphia

Table 2.7 (continued)

Regional Average Modernization Costs - Level II by Stratum

	Stratum	Dallas	Ka City	Denver	San Fran	Seattle	National
1.	Family Hi-Rise ≥200 units, ≥10% Vac Cost/DU	421.00	663.52	-	408.00	-	2677.04
2.	Family Lo-Rise ≥200 units, ≥10% Vac Cost/DU	2552.19	957.85	-	2132.85	548.66	1757.16
3.	Family Hi-Rise ≥200 units ≤10% Vac Cost/DU	8618.06	-	882.00	431.00	-	2333.32
4.	Family Lo-Rise ≥200 units, ≤10% Vac Cost/DU	1505.79	884.73	-	1062.77	208.00	1318.44
5.	Family Hi-Rise <200 units, Cost/DU	1197.37	-	-	-	-	1280.99
6.	Family Lo-Rise <200 units, Cost/DU	1501.28	906.72	1072.54	1743.93	917.66	1267.81
7.	Elderly Hi-Rise Cost/DU	179.69	427.82	-	711.59	-	462.48
8.	Elderly Lo-Rise Cost/DU	712.97	358.83	-	304.89	500.40	613.23
Total Cost							1255.99

Key: Ka City - Kansas City
San Fran - San Francisco

Table 2.8

Regional Average Modernization Costs - Level III by Stratum

Stratum	Boston	NY	Phila	Atlanta	Chicago
1. Family Hi-Rise ≥200 units, ≥10% Vac Cost/DU	8656.06	-	10620.55	-	5124.38
2. Family Lo-Rise ≥200 units, ≥10% Vac Cost/DU	7197.88	10685.23	5602.11	2847.45	7207.76
3. Family Hi-Rise ≥200 units, ≤10% Vac Cost/DU	7480.67	5573.28	7289.31	6386.25	7483.97
4. Family Lo-Rise ≥200 units, ≤10% Vac Cost/DU	4731.28	4265.32	9257.97	4753.97	6336.59
5. Family Hi-Rise <200 units, Cost/DU	6070.95	-	9566.15	9534.30	6602.94
6. Family Lo-Rise <200 units, Cost/DU	9437.66	7200.85	5712.19	10149.63	6779.37
7. Elderly Hi-Rise Cost/DU	2852.75	1959.38	5567.20	1246.56	3382.56
8. Elderly Lo-Rise Cost/DU	4524.05	994.12	6498.26	7038.69	2840.99

Total Cost

Key: NY - New York
Phila - Philadelphia

Table 2.8 (continued)

Regional Average Modernization Costs - Level III by Stratum

	Stratum	Dallas	Ka City	Denver	San Fran	Seattle	National
1.	Family Hi-Rise ≥200 units, ≥10% Vac Cost/DU	10575.00	5315.46	-	2892.00	-	7254.25
2.	Family Lo-Rise ≥200 units, ≥10% Vac Cost/DU	5658.83	5039.13	-	4986.15	3818.00	5988.62
3.	Family Hi-Rise ≥200 units, <10% Vac Cost/DU	1898.81	-	1583.00	6329.00	-	6313.56
4.	Family Lo-Rise ≥200 units, <10% Vac Cost/DU	8643.36	5640.12	-	7838.76	2909.00	6423.00
5.	Family Hi-Rise <200 units, Cost/DU	10697.33	-	-	-	-	8449.86
6.	Family Lo-Rise <200 units Cost/DU	8917.09	4584.80	9528.36	6780.97	5956.19	8194.02
7.	Elderly Hi-Rise Cost/DU	4885.55	5842.91	-	1788.63	-	3487.16
8.	Elderly Lo-Rise Cost/DU	7607.26	4981.61	-	2434.87	5296.38	5591.83
Total Cost							6544.80

Key: Ka City - Kansas City
San Fran - San Francisco

2.3.2 Summary Cost Estimates

The product of the stratified estimate of the national public housing stock dwelling unit count applied to the regional cost estimates, results in a national cost estimate for each stratum by modernization level.

These estimates, shown in summary fashion as Table 2.9 by state and level of modernization, translate into the following contract authority amounts assuming a 6.625% loan interest rate for 25 years which has an amortization factor of .09166.

Level	Capital Cost Estimate	Contract Authority
I	$ 259,252,060	$ 23,763,044
II	1,505,676,970	138,010,351
III	6,970,701,210	622,435,673

Table 2.9

Summary National Modernization Costs - State Average - Costs by Level

State	Level 1	Avg Cost Per DU	Level 2	Avg Cost Per DU	Level 3	Avg Cost Per DU
Alabama	8365837	193	38459594	889	266771090	6167
Alaska						
Arizona	2065414	237	8484498	973	64414357	7384
Arkansas	3666355	257	13693800	958	105679861	7396
California	33367693	450	88027699	1186	427734710	5764
Colorado	205383	25	2418282	291	21483599	2584
Connecticut	14159321	687	29693115	1441	113739823	5519
Delaware	715771	221	5453775	1682	23604034	7231
Dist. of Col.	2553988	193	22137634	1669	95248317	7182
Florida	7585208	174	41739994	956	228090439	5226
Georgia	11714872	214	51333610	938	354574040	6481
Hawaii						
Idaho	0	0	0	0	0	0
Illinois	5874540	74	61162423	771	411343899	5184
Indiana	1466645	77	10149170	532	83098433	4335
Iowa	74848	18	1246072	298	17179624	4110
Kansas	278390	33	3902561	463	32236781	3825
Kentucky	5103363	222	22266577	970	146174085	6365
Louisiana	11173879	339	69588553	2111	227787649	6909
Maine	347679	84	3527236	854	19162997	4638
Maryland	5899987	220	44947173	1676	194905136	7266
Massachusetts	26436286	570	63989279	1379	242901904	5233
Michigan	2208605	76	23880881	825	158872548	5489
Minnesota	1042544	51	9794800	478	66213723	3230
Mississippi	3543679	253	13524692	966	108550969	7751
Missouri	3041900	123	12461177	505	94693882	3836
Montana	190220	56	2239751	660	19897562	5806
Nebraska	262023	28	3401414	361	43385067	4599
Nevada	2795560	702	5307188	1332	21433182	5381
New Hampshire	452069	98	4573573	994	26122363	5679
New Jersey	5165502	101	69756267	1361	148970796	2907
New Mexico	2766713	332	10152170	1217	63665687	7634
New York	20704135	150	357227563	2587	594347626	4305
North Carolina	9359140	234	38945852	975	265442640	6644
North Dakota	165754	39	1951678	456	17338366	4051
Ohio	4013535	72	38691069	692	280731091	5018
Oklahoma	5306234	248	28157066	1317	147502350	6899
Oregon	1390825	138	3452040	343	29114518	2897
Pennsylvania	17478756	217	88983984	1103	491534473	6092
Puerto Rico						

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Table 2.9 (continued)

Summary National Modernization Costs - State Average - Costs by Level

State	Level I	Avg Cost Per DU	Level II	Avg Cost Per DU	Level III	Avg Cost Per DU
Rhode Island	3098929	284	12134662	1111	53846851	4931
South Carolina	3312775	248	12378370	925	88053076	6581
South Dakota	372537	64	4386437	757	38968347	6729
Tennessee	8535118	215	36897049	929	251948485	6344
Texas	15083280	251	88304156	1469	409128245	6806
Utah	20709	14	243836	160	2166199	1423
Vermont	340350	145	2525471	1072	16019819	6802
Virgin Islands						
Virginia	4611688	238	33801895	1742	140450921	7237
Washington	588128	32	5688694	307	47527388	2566
West Virginia	1427041	226	6778882	1074	39115367	6200
Wisconsin	905014	69	7652354	587	48081170	3689
Wyoming	13840	18	162961	210	1447721	1868
Total	$259,252,060	$287	$1,505,676,970	$1256	$6,790,701,210	$6545

Notes:

1. Level II costs are inclusive of Level I costs, Level I and Level III costs exclusive.

2.3.3 Modernization Level I

Modernization Level I estimates represent the cost of complying with minimum federal, state and local health/ safety requirements. The national Level I estimate is $259,252,000.

Table 2.10, National Modernization Costs - by State by Stratum, shows Level I modernization cost estimates broken down by stratum in each state. California, New York and Massachusetts account for 12.9%, 10.2% and 8.0% respectively for 31.1% of total Level I estimates. This is due in large part to the higher proportion of projects being modernized in these states as well as the relatively older age of the housing stock.

Stratum 6, Family Low-Rise projects under 200 units, accounts for the highest percentage of Level I cost estimates with 40.6% of the total cost. The high percentage of Level I costs can be partially explained by the fact that these type projects account for 46.3% of the total units in the country; are on the average 18-24 years old and have an average project size of 60 units.

Table 2.11 shows the total costs aggregated into the ten HUD regions. Revion IV - Atlanta, accounts for 22.2% of the estimated modernization capital cost estimate. Small low-rise family projects are dominant in this region primarily because of the large number of small housing authorities.

Table 2.10

National Modernization Costs - Level I by State by Stratum

State	1	2	3	4	5
Alabama	0	0	327161	2935167	94320
Alaska					
Arizona	0	0	0	437053	0
Arkansas	0	0	0	0	662077
California	0	1697530	0	7788314	0
Colorado	0	0	0	0	0
Connecticut	11602970	0	1030417	936619	25807
Delaware	0	0	0	472169	64509
District of Columbia	0	0	0	2008579	143498
Florida	0	0	0	3170600	0
Georgia	0	0	488934	3434002	700370
Hawaii					
Idaho	0	0	0	0	0
Illinois	0	0	808293	2069695	589431
Indiana	0	48756	0	120072	0
Iowa	0	0	0	0	0
Kansas	0	0	0	0	0
Kentucky	0	0	0	1796664	0
Louisiana	0	197146	3746387	2195244	0
Maine	0	0	0	0	0
Maryland	0	0	0	3883440	524990
Massachusetts	19457234	1597607	442841	2653241	8906
Michigan	0	0	391555	503931	0
Minnesota	0	0	0	0	201394
Mississippi	0	0	81651	685969	0
Missouri	124987	990569	0	1688761	0
Montana	0	0	0	0	0
Nebraska	0	0	0	0	0
Nevada	0	0	0	0	0
New Hampshire	0	0	0	0	0
New Jersey	0	0	1347654	1531313	0
New Mexico	0	0	0	0	0
New York	0	0	15564610	2974169	0
North Carolina	0	0	0	3167757	0
North Dakota	0	0	0	0	0
Ohio	0	208925	217614	1979491	138522
Oklahoma	0	1032957	0	370997	372649
Oregon	0	0	0	0	0
Pennsylvania	0	140616	5319660	3715743	124170
Puerto Rico	0				
Rhode Island	0	1142865	207623	1679980	5741
South Carolina	0	0	0	1503403	0

Table 2.10 (continued)

National Modernization Costs - Level I by State by Stratum

State	6	7	8	Total	Level I%
Alabama	4859757	4266	145166	8365837	3.2
Alaska					
Arizona	1594152	1548	32661	2065414	.8
Arkansas	2487479	93545	423253	3666355	1.4
California	23369028	249867	262953	33367693	12.9
Colorado	205383	0	0	205383	.1
Connecticut	165386	387257	10863	14159321	5.5
Delaware	150003	22247	6843	715771	.3
District of Columbia	212735	189175	0	2553988	1.0
Florida	4238899	42081	133628	7585208	2.9
Georgia	6982557	17481	91528	11714872	4.5
Hawaii					
Idaho	0	0	0	0	-
Illinois	1565104	718072	123945	5874540	2.3
Indiana	922447	323901	51470	1466645	.6
Iowa	0	5189	69659	74848	.0
Kansas	204386	7385	66619	278390	.1
Kentucky	3269788	9963	26947	5103363	2.0
Louisiana	4637945	0	397157	11173879	4.3
Maine	185582	131175	30922	347679	.1
Maryland	1244909	187589	59058	5899987	2.3
Massachusetts	1292064	822842	161549	26436286	10.2
Michigan	1090402	151267	71448	2208605	.9
Minnesota	194071	505710	141369	1042544	.4
Mississippi	2755928	0	20132	3543679	1.4
Missouri	163335	7981	66267	3041900	1.2
Montana	190220	0	0	190220	.1
Nebraska	34494	7038	220491	262023	.1
Nevada	2767634	0	27926	2795560	1.1
New Hampshire	353254	63383	35432	452069	.2
New Jersey	467530	1810800	8206	5165502	2.0
New Mexico	2631023	0	135690	2766713	1.1
New York	439223	1721300	4833	20704135	8.0
North Carolina	6154927	12403	24053	9359140	3.6
North Dakota	165754	0	0	165754	.1
Ohio	855983	468855	144144	4013535	1.5
Oklahoma	3018951	83564	427116	5306234	2.0
Oregon	1370380	0	20444	1390825	.5
Pennsylvania	7082195	770360	326013	17478756	6.7
Puerto Rico					
Rhode Island	0	62720	0	3098929	1.2
South Carolina	1799772	0	9600	3312775	1.3

Table 2.10 (continued)

National Modernization Costs - Level I by State by Stratum

State	1	2	3	4	5
South Dakota	0	0	0	0	0
Tennessee	0	0	0	3350850	174164
Texas	0	3055574	711951	2049603	196726
Utah	0	0	0	0	0
Vermont	0	0	0	0	0
Virgin Islands	0				
Virginia	0	0	256509	2947990	72669
Washington	0	57709	0	0	0
West Virginia	0	0	493939	258247	79508
Wisconsin	0	0	0	0	53736
Wyoming	0	0	0	0	0
Total	31,185,191	10,170,254	31,436,799	62,309,063	42,233,187
% of Total	12.0	4.0	12.2	24.0	1.6

1. Family Hi-rise $\geq$200 units, $\geq$10% vacancy
2. Family Lo-rise $\geq$200 units, $\geq$10% vacancy
3. Family Hi-rise $\geq$200 units, $<$10% vacancy
4. Family Lo-rise $\geq$200 units, $<$10% vacancy
5. Family Hi-rise $<$200 units
6. Family Lo-rise $<$200 units
7. Elderly Hi-rise
8. Elderly Lo-rise

Table 2.10 (continued)

National Modernization Costs - Level I by State by Stratum

State	6	7	8	Total	Level I%
South Dakota	372537	0	0	372537	.1
Tennessee	4854923	7427	147754	8535118	3.2
Texas	7852468	167681	1049277	15083280	5.8
Utah	20709	0	0	20709	.0
Vermont	295512	38734	6104	340350	.1
Virgin Islands					
Virginia	1215706	46542	72271	4611688	1.8
Washington	508229	0	22191	588129	.2
West Virginia	521697	67516	6134	1427041	.6
Wisconsin	566377	61434	223466	905014	.3
Wyoming	13840	0	0	13840	.0
Total	104,344,678	9,268,298	5,304,590	259,252,060	
% of Total	40.6	3.6	2.0	100.0	100.0

Table 2.11

National Modernization Costs - Level I by Region

Region	Total Level I	%	Total Units	%
I - Boston	$ 44,834,634	17.3	79,792	7.2
II - New York	25,869,637	10.0	169,669	15.3
III - Philadelphia	32,687,231	12.6	134,190	12.1
IV - Atlanta	57,519,992	22.2	251,267	22.6
V - Chicago	15,510,883	6.0	194,352	17.5
VI - Dallas	37,996,461	14.7	122,865	11.0
VII - Kansas City	3,657,161	1.4	41,877	3.8
VIII - Denver	968,443	0.4	21,575	1.9
IX - San Francisco	38,228,667	14.7	70,077	6.3
X - Seattle	1,978,953	0.8	26,580	2.4
Total	$259,252,062	100.0	1,112,243	100.0

Notes:

1. Estimates exclude Alaska, Hawaii, Puerto Rico, U.S. Virgin Islands due to limited sampling at those locations. See Appendix 7.0 for further details.

2.3.4 Modernization Level II

Modernization Level II estimates deal with the correction of deficiencies of the Minimum Property Standards for Rehabilitation and all deficiencies defined as Level I items. It is the project team's opinion that this is the most representative and realistic level to which housing authorities should respond. The national estimate excluding the off-continent states and territories is $1,506,676,976.

Table 2.12 shows Level II Costs by State and Stratum, inclusive of the previously presented Level I estimates. Stratum 3, Family High-Rise Projects over 200 units and under 10% vacancy rate, accounts for 29.0% of the total cost estimate. These projects are concentrated in the larger more populous states and tend to have very large projects averaging 590 units. New York State alone accounts for 23.9% of the estimated Level II costs.

Table 2.13 shows Level II modernization estimates on a regional basis and as can be expected, Region II - New York, accounts for 28.4% of the total estimate.

Table 2.12

National Modernization Costs - Level II by State by Stratum

State	1	2	3	4	5
Alabama	0	4781067	1174113	10495596	574961
Alaska					
Arizona	0	0	0	1562816	0
Arkansas	0	0	0	0	2206745
California	0	12195835	0	28637810	9
Colorado	0	0	0	0	0
Connecticut	14288778	0	6962602	3418698	1423173
Delaware	0	0	0	4466090	266789
District of Columbia	0	0	0	18998479	593466
Florida	0	0	0	11337456	0
Georgia	0	0	1754687	12279332	4269337
Hawaii					
Idaho	0	0	0	0	0
Illinois	0	0	24786709	17538005	2083454
Indiana	0	759120	0	1017458	0
Iowa	0	0	0	0	0
Kansas	0	0	0	0	0
Kentucky	0	0	0	6424526	0
Louisiana	0	2049424	32252075	16562662	0
Maine	0	0	0	0	0
Maryland	0	0	0	36732153	2171203
Massachusetts	23961116	5556361	2992310	9684438	491149
Michigan	0	0	12007238	4270169	0
Minnesota	0	0	0	0	711864
Mississippi	0	0	293027	2452894	0
Missouri	5255589	2051895	0	1688761	0
Montana	0	0	0	0	0
Nebraska	0	0	0	0	0
Nevada	0	0	0	0	0
New Hampshire	0	0	0	0	0
New Jersey	0	0	25370602	22700194	0
New Mexico	0	0	0	0	0
New York	0	0	293015608	44089096	0
North Carolina	0	0	0	11327291	0
North Dakota	0	0	0	0	0
Ohio	0	3252935	6673249	16773648	489633
Oklahoma	0	10738068	0	2799095	1242063
Oregon	0	0	0	485726	0
Pennsylvania	0	2398280	19785427	35145965	513529
Puerto Rico					
Rhode Island	0	3974800	1402925	6131995	316615
South Carolina	0	0	0	5375880	0

Table 2.12 (continued)

National Modernization Costs - Level II by State by Stratum

State	6	7	8	Total	Level II%
Alabama	18640384	1293870	1499603	38459594	2.6
Alaska					
Arizona	6114627	469659	337397	8484498	.6
Arkansas	8925650	342206	2219198	13693800	.9
California	43169727	2192665	1831662	88027699	5.8
Colorado	2418282	0	0	2418282	.2
Connecticut	1128282	1903743	567840	29693115	2.0
Delaware	398271	233115	90509	5453775	.4
District of Columbia	563414	1982275	0	22137634	1.5
Florida	16258983	12763144	1380411	41739994	2.8
Georgia	26782728	5302020	945505	51333610	3.4
Hawaii					
Idaho	0	0	0	0	0
Illinois	6530995	7763556	2459745	61162423	4.1
Indiana	3849239	3501905	1021447	10149170	.7
Iowa	0	529862	716209	1246072	.1
Kansas	2463584	754022	684956	3902561	.3
Kentucky	12541800	3021878	278373	22266577	1.5
Louisiana	16642019	0	2082373	69588553	4.6
Maine	1266061	644850	1616324	3527236	.2
Maryland	3297055	1965654	781108	44947173	3.0
Massachusetts	8814599	4045064	8444234	63989279	4.2
Michigan	4550094	1635452	1417929	23880881	1.6
Minnesota	809832	5467565	2805539	9794800	.7
Mississippi	10570806	0	207965	13524692	.9
Missouri	1968770	814930	681331	12461177	.8
Montana	2239751	0	0	2239751	.1
Nebraska	415775	718623	2267016	3401414	.2
Nevada	5112666	0	194522	5307188	.3
New Hampshire	2409937	311588	1852048	4573573	.3
New Jersey	11691347	8996467	997657	69756267	4.6
New Mexico	9440720	0	711450	10152170	.7
New York	10983481	8551814	587564	357227563	23.7
North Carolina	23608218	3761866	248478	38945852	2.6
North Dakota	1951678	0	0	1951678	.1
Ohio	3571896	5069100	2860608	38691069	2.6
Oklahoma	10832694	305691	2239455	28157066	1.9
Oregon	2216833	0	749480	3452040	.2
Pennsylvania	18756696	8072226	4311860	88983984	5.9
Puerto Rico					.8
Rhode Island	0	308328	0	12134662	.8
South Carolina	6903316	0	99174	12378370	.3

Table 2.12 (continued)

National Modernization Costs - Level II by State by Stratum

State	1	2	3	4	5
South Dakota	0	0	0	0	0
Tennessee	0	1452571	0	11981997	1061674
Texas	0	31764100	6129076	15463831	655699
Utah	0	0	0	0	0
Vermont	0	0	0	0	0
Virgin Islands					
Virginia	0	0	954036	27884050	300539
Washington	0	3287888	0	765151	0
West Virginia	0	0	1837110	2442675	328820
Wisconsin	0	0	0	0	189939
Wyoming	0	0	0	0	0
Total	43,505,393	84,262,344	437,390,794	385,415,137	19,893,652
% of Total	2.9	5.6	29.0	26.0	1.3

1. Family Hi-rise $\geq$200 units, $\geq$10% vacancy
2. Family Lo-rise $\geq$200 units, $\geq$10% vacancy
3. Family Hi-rise $\geq$200 units, <10% vacancy
4. Family Lo-rise $\geq$200 units, <10% vacancy
5. Family Hi-rise <200 units
6. Family Lo-rise <200 units
7. Elderly Hi-rise
8. Elderly Lo rise

Table 2.12 (continued)

National Modernization Costs - Level II by State by Stratum

State	6	7	8	Total	Level II%
South Dakota	4386437	0	0	4386437	2.5
Tennessee	18621842	2252629	1526335	36897049	5.9
Texas	28176471	613410	5501568	88304156	.0
Utah	243836	0	0	243836	.2
Vermont	2016017	190414	319040	2525471	2.2
Virgin Islands					.4
Virginia	3219712	487695	955865	33801895	.5
Washington	822150	0	813505	5688694	.5
West Virginia	1381677	707470	81130	6778882	.0
Wisconsin	2363412	664208	4434795	7652354	.0
Wyoming	162961	0	0	162961	.0
Total	365,133,685	97,638,964	62,821,217	1,505,676,976	
% of Total	24.5	6.5	4.2	100.0	100.1

Table 2.13

National Modernization Costs - Level II By Region

Region	Total Level II	%	Total Units	%
I - Boston	$ 116,443,336	7.7	79,792	7.2
II - New York	426,983,830	28.4	169,669	15.3
III - Philadelphia	202,103,343	13.4	139,190	12.1
IV - Atlanta	255,545,738	17.0	251,267	22.6
V - Chicago	151,330,697	10.1	194,352	17.5
VI - Dallas	209,895,745	13.9	122,865	11.0
VII - Kansas City	21,011,224	1.4	41,877	3.8
VIII - Denver	11,402,945	0.8	21,575	1.9
IX - San Francisco	101,819,385	6.8	70,077	6.3
X - Seattle	9,140,742	.6	26,580	2.4
Total	$1,505,676,970	100.0	1,112,245	100.0

2.3.5 Modernization Level II - Chronic Problem Projects

Modernization Level II cost estimates also contained the best approximation of costs attributed to the sub-category of chronic problem projects. As previously noted, chronic problem projects for the purposes of this study are defined as projects requiring in excess of $2500 per unit for Level II modernization. Maximum Level II per unit costs were $17,000/unit, representing a total rehabilitation effort.

Distressed projects in the nation total $621,053,000 for 41.2% of the national Level II estimate. Table 2.14 shows these estimates by stratum. Illustration 2.3 shows the stratified relationships between the distressed and national projects, units and cost. This illustration is a frequency distribution of dwelling units in the universe by Modernization Level II costs. It shows costs in two ways 1) as a histogram of the number of dwelling units by cost per dwelling unit and 2) as a frequency polygon indicated by a detached line showing the distribution of total modernization costs distributed by cost per dwelling unit.

It can be seen that while only 86,386 or 7.4% of the dwelling units fall into the more expensive categories, these units account for 41.2% of the total Modernization Level II costs as noted above. These units are those left of the $2500 cut-off point and are shaded. This point was selected because at this dollar value the cause of deterioration in projects tend to shift away from problems attributable to age and normal wear, towards those problems due to vandalism.

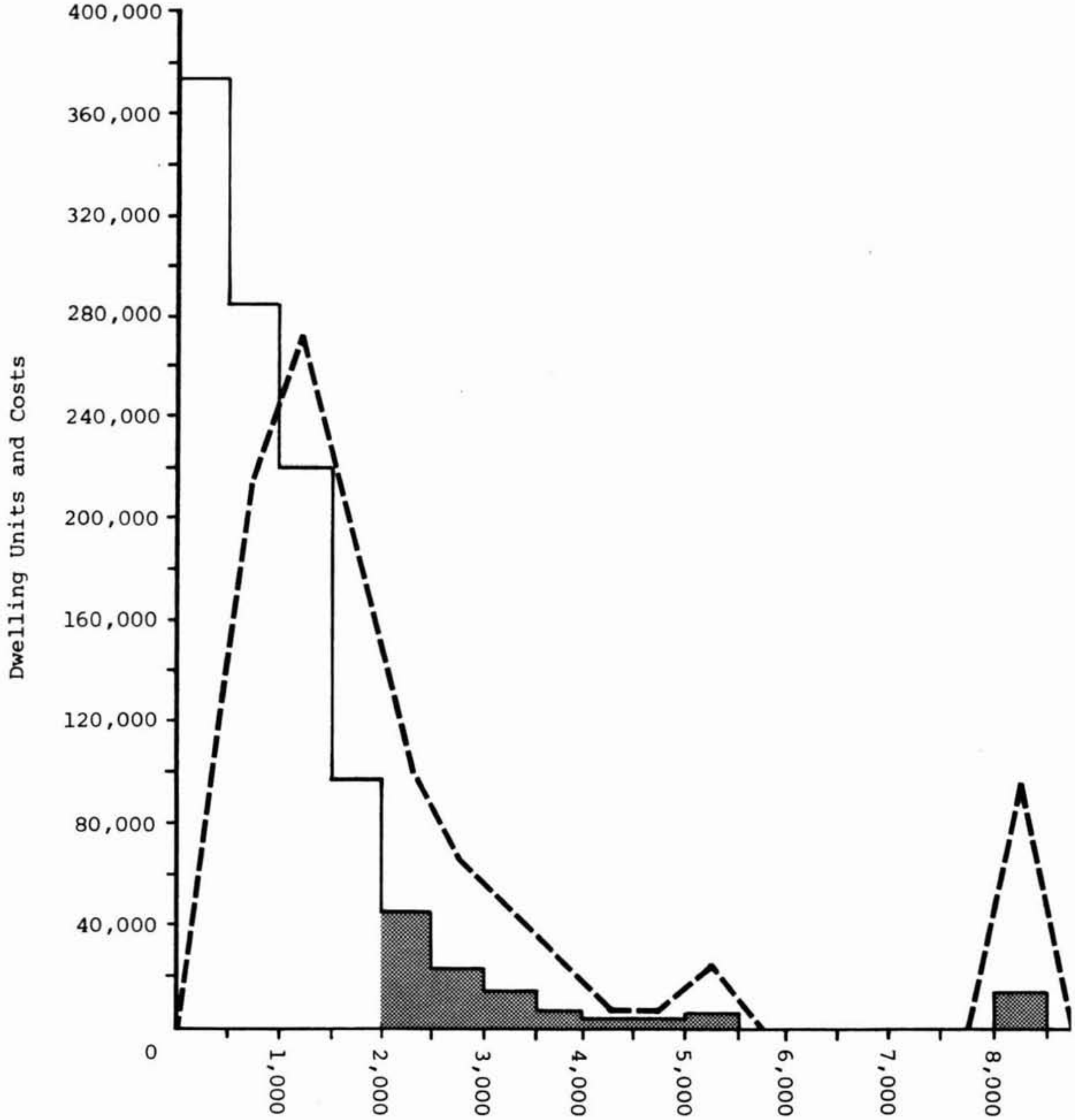
Table 2.14

Modernization Costs - Level II Chronic Problem Projects

Stratum		Projects	Units	Cost Unit	Total Cost	% Total
1	Family Hi-Rise ≥200 Units ≥10% occupancy	11	4,594	$12,300	$56,505,774	9.1
2	Family Lo-Rise ≥200 Units ≥10% occupancy	19	15,118	3,902	58,989,544	9.5
3	Family Hi-Rise ≥200 Units <10% Vacancy	43	18,945	14,848	281,286,983	45.3
4	Family Lo-Rise ≥200 Units <10% Vacancy	64	25,648	5,229	134,123,595	21.6
5	Family Hi-Rise <200 Units	55	512	2,557	1,241,885	0.2
6	Family Lo-Rise <200 Units	376	19,989	4,411	88,173,845	14.2
7	Elderly Hi-Rise	0	0	0	0	0.0
8	Elderly Lo-Rise	36	1,579	2,568	620,942	0.1
Total		604	86,386		$620,942,568	100.0

Illustration 2.3

Frequency Distribution of Modernization Cost Per Dwelling Unit (Level II)



Cost per Dwelling Unit (Level II)

Legend: ——— Number of Dwelling Units by Cost per D.U.
— — — Total Modernization Costs by Cost per D.U.

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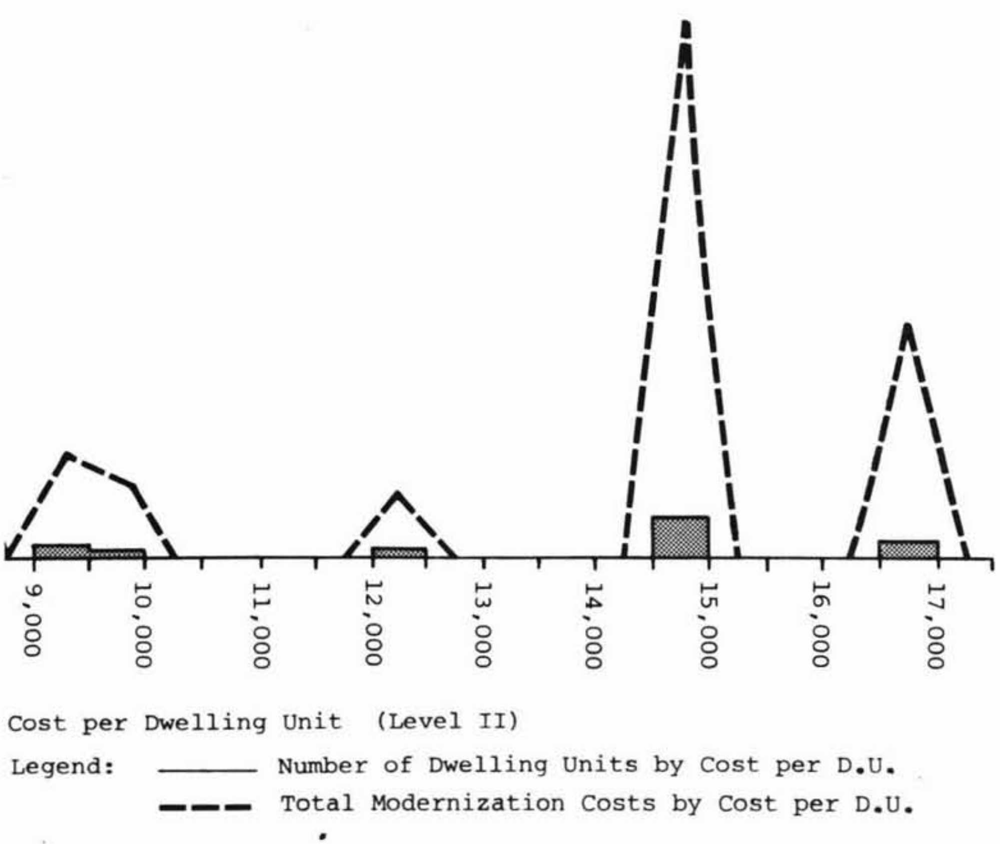
Illustration 2.3 (continued)

Frequency Distribution of Modernization Cost Per Dwelling Unit (Level II)



2.3.6 Modernization Level III

Modernization Level III estimates differ substantially from the other two levels. Level III estimates are unique to each project's particular circumstances and design. Level III responds to the utilization of above-standard materials, design innovations, additional amenities and other items that increase the liveability and other desired characteristics of public housing.

While some items defined in Level III may have been present in a project, if it was damaged or in need of repair it became a Level I or Level II item, depending upon its health and safety implications. It should be noted that the presence of Level III items in projects is often due to the fact that they were acquired by PHA's under the private acquisition program. Level III items are shown in Volume II - Modernization. The many varieties of projects make the general estimate of Level III not as specific as Levels I and II. Consequently, the total estimate of $6,790,701,210 should be used as only an order of magnitude number. Table 2.15 shows these estimates by state and by stratum. Table 2.16 shows Level III estimates by each of the ten HUD regions.

Table 2.15

National Modernization Costs - Level III By State By Stratum

State	1	2	3	4	5
Alabama	0	13206944	17234425	56886533	2827472
Alaska					
Arizona	0	0	0	8470523	0
Arkansas	0	0	0	0	19681935
California	0	28511271	0	211226249	0
Colorado	0	0	0	0	0
Connecticut	23538511	0	45220069	14985145	9641576
Delaware	0	0	0	15870924	2223625
District of Columbia	0	0	0	67513951	4946405
Florida	0	0	0	61449451	0
Georgia	0	0	25756475	66554450	20995236
Hawaii					
Idaho	0	0	0	0	0
Illinois	0	0	132513491	131569089	14369494
Indiana	0	7116640	0	7632909	0
Iowa	0	0	0	0	0
Kansas	0	0	0	0	0
Kentucky	0	0	0	34821180	0
Louisiana	0	4544075	7106073	95071058	0
Maine	0	0	0	0	0
Maryland	0	0	0	130533229	18096479
Massachusetts	39472164	19646324	19434179	42449705	3327392
Michigan	0	0	64192507	32034557	0
Minnesota	0	0	0	0	4909694
Mississippi	0	0	4301254	13294780	0
Missouri	42101733	10794764	0	11275574	0
Montana	0	0	0	0	0
Nebraska	0	0	0	0	0
Nevada	0	0	0	0	0
New Hampshire	0	0	0	0	0
New Jersey	0	0	39276529	38189437	0
New Mexico	0	0	0	0	0
New York	0	0	453630930	74172838	0
North Carolina	0	0	0	61394353	0
North Dakota	0	0	0	0	0
Ohio	0	30495783	35676199	125834926	3376977
Oklahoma	0	23808925	0	16067037	11077945
Oregon	0	0	0	6793158	0
Pennsylvania	0	6713921	123701303	124896474	4280146
Puerto Rico					
Rhode Island	0	14054198	9111586	26878315	2144976
South Carolina	0	0	0	29137476	0

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Table 2.15 (continued)

National Modernization Costs - Level III By State By Stratum

State	6	7	8	Total Level III	%
Alabama	155554366	1293870	19767480	266771090	3.9
Alaska					
Arizona	51026678	469659	4447497	64414357	1.9
Arkansas	53015313	9304171	23678442	105679861	1.6
California	167858012	5511412	14627766	427734710	6.3
Colorado	21483599	0	0	21483599	.3
Connecticut	7600963	10235785	2517774	113739823	1.7
Delaware	2489593	2264641	755251	23604084	.3
District of Columbia	3530768	19257194	0	95248317	1.4
Florida	135681531	12763144	18196313	228090439	3.4
Georgia	223502387	5302020	12463472	354574040	5.2
Hawaii					
Idaho	0	0	0	0	0
Illinois	63463235	59026057	10402534	411343899	6.1
Indiana	37404202	26624868	4319814	89098433	1.2
Iowa	0	7236544	9943080	17179624	.3
Kansas	12429613	10297977	9509191	32236731	.5
Kentucky	104661564	3021878	3669463	146174085	2.2
Louisiana	98847906	0	22218536	227787649	3.4
Maine	8529150	3467143	7166703	19162297	.3
Maryland	20661764	19095731	6517933	194905186	2.9
Massachusetts	59381829	21748945	37441367	242901904	3.6
Michigan	44214615	12434291	5996579	158872548	2.3
Minnesota	7869375	41569717	11864937	66213723	1.0
Mississippi	88213582	0	2741352	108550969	1.6
Missouri	9933112	11129829	9458870	94693882	1.3
Montana	19897562	0	0	19897562	.3
Nebraska	2097725	9814526	31472816	43385067	.6
Nevada	19879715	0	1553467	21433182	.3
New Hampshire	16235167	1675303	8211893	26122363	.4
New Jersey	37780426	30968356	2756047	148970796	2.2
New Mexico	56074651	0	7591037	63665687	.9
New York	35492969	29437734	1623157	594347626	8.8
North Carolina	197011038	3761866	3275383	265442640	3.9
North Dakota	17338366	0	0	17338366	.3
Ohio	34709179	38540197	12097830	280731091	4.1
Oklahoma	64342498	8311368	23894576	147502350	2.2
Oregon	14388641	0	7932710	29114518	.4
Pennsylvania	117543209	78419213	35980207	491534473	7.2
Puerto Rico					
Rhode Island	0	1657776	0	53846851	.8
South Carolina	57608306	0	1307294	88053076	1.3

Table 2.15 (continued)

National Modernization Costs - Level III By State By Stratum

State	1	2	3	4	5
South Dakota	0	0	0	0	0
Tennessee	0	4012498	0	64942886	5220973
Texas	0	70428786	1350414	88763681	5848173
Utah	0	0	0	0	0
Vermont	0	0	0	0	0
Virgin Islands					
Virginia	0	0	5964767	99090165	2504922
Washington	0	22879662	0	10701083	0
West Virginia	0	0	11485870	8680413	2740640
Wisconsin	0	0	0	0	1310003
Wyoming	0	0	0	0	0
Total	105,112,408	256,213,791	995,946,071	1,777,181,549	139,524,063
% of Total	1.5	3.8	14.7	26.2	2.1

1. Family Hi-rise ≥200 units, ≥10% vacancy
2. Family Lo-rise ≥200 units, ≥10% vacancy
3. Family Hi-rise ≥200 units, <10% vacancy
4. Family Lo-rise ≥200 units, <10% vacancy
5. Family Hi-rise <200 units
6. Family Lo-rise <200 units
7. Elderly Hi-rise
8. Elderly Lo-rise

Table 2.15 (continued)

National Modernization Costs - Level III By State By Stratum

State	6	7	8	Total Level III	%
South Dakota	38968347	0	0	38968347	.6
Tennessee	155399638	2252629	20119861	251948485	3.7
Texas	167358605	16677855	58700730	40918245	6.0
Utah	2166199	0	0	2166199	.0
Vermont	13581422	1023790	1414607	16019819	.2
Virgin Islands					
Virginia	20177074	4737805	7976188	140450921	2.0
Washington	5336270	0	8610374	47527388	.7
West Virginia	8658601	6872857	676985	39115367	.6
Wisconsin	22965978	5049948	18755241	48081170	.7
Wyoming	1447721	0	0	1447721	.0
Total	2,503,814,464	521,256,132	487,654,766	6,790,701,210	
% of Total	36.9	7.8	7.2	100.0	99.9

Table 2.16

National Modernization Costs - Level III By Region

Region	Total Level III	%	Total Units	%
I - Boston	$ 471,793,757	6.9	79,792	7.2
II - New York	743,318,422	10.9	169,669	15.3
III - Philadelphia	984,858,248	14.5	139,190	12.1
IV - Atlanta	1,709,604,824	25.1	251,267	22.6
V - Chicago	1,048,340,864	15.4	194,352	17.5
VI - Dallas	953,763,792	14.0	122,865	11.0
VII - Kansas City	187,495,354	2.8	41,877	3.8
VIII - Denver	101,301,794	1.5	21,575	1.9
IX - San Francisco	513,582,249	7.6	70,077	6.3
X - Seattle	76,641,906	1.1	26,580	2.4
Total	$6,790,701,210	100.0	1,112,245	100.0

2.3.7 Supplementary Observations

While the previous sections describe the quantitative elements and subsequent observations of this study, there are several areas of concern which must be presented to complete the picture. These findings relate to overall concerns of tenants and management, maintenance, and general project design.

Full-time project managers tend to have better knowledge of their projects and tenants than part-time managers. A few projects had very well organized tenant organizations with building coordinators responsible for collecting complaints, maintenance requests and providing tenant patrols during periods of non-surveillance by local security forces.

Activities in community rooms or centers located on project sites were seldom operated by the project or the public housing authority. In some cases these facilities were not used at all, and therefore subject to squatters and vandalism. Failure to provide a standard procedure of sealing vacant units also led to vandalism and/or illegal occupancy.

Most projects had a procedure for responding to maintenance work. In small projects tenants called the maintenance office and requests were responded to on a priority basis, e.g., a stopped-up toilet was a higher priority than a leaking faucet. In large projects tenants filled out a maintenance request form or called a central maintenance number for the entire PHA which responded to items within trades by priority. This proved to be a complicated process, particularly in projects where there was no full-time or 24-hour emergency on-site maintenance.

The most critical item however, is the fact that due to the lack of maintenance, many projects need modernization funds to correct what has become a major deficiency through neglect. This is particularly true of the building exterior, roofs, and heating plants.

In order to provide visual illustration of the conditions found during the field surveys, a series of representative photographs is included. They are divided into two groups: examples of the basically sound projects and examples of non-compliance conditions projects.

2.3.8 Photo References

Photo reference 1, shows a Midwestern public housing project of single-family homes in good condition owned and developed by the PHA. Shown is a demonstration solar house which takes advantage of an energy conservation opportunity while conforming to an attractive, varied design type.

Photo reference 2 shows a typical well-constructed low-rise project located in the Midwest.

Photo references 3 and 4, St. Thomas, Virgin Islands and Rio Piedras, Puerto Rico, show attractive structures suitable to the climate which use concrete to its material advantage.

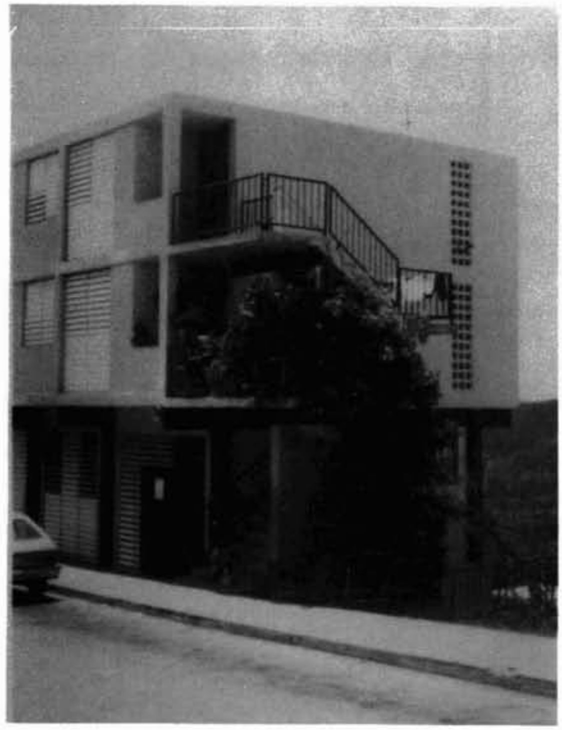

Photo reference 4A, Kansas City, Kansas, shows a low-rise elderly project in good condition.

Photo reference 5, Joliet, Illinois, shows an elderly high-rise of simple concrete construction. While Joliet multi-family construction is generally low-rise, in this instance, a high-rise was chosen for better building security and general accessibility.

Photo reference 6, Marin County, California, represents one of the most attractive and distinguished designs seen in public housing. This project is 20 years old and illustrates the use of durable construction materials in a responsible design framework.

Photo reference 7, North Carolina, shows a project where the use of varied housing profiles better integrate public housing into the surrounding community.

Photo reference 8, Los Angeles, California, shows a pleasant living room which could exist in the private market housing project. Contemporary finishes and ample natural light provide an attractive environment which acts as an incentive to maintain the unit.

Photo reference 9, Los Angeles, California, shows an accessible bath in a project designed for the elderly. The occupant of this unit however, is not disabled.

Photo reference 10, Bronx, New York, is a typical urban high-rise.

Photo reference 11, Chicago, Illinois, is another typical urban high-rise. It shows several design problems most notably: its height produces shaded areas throughout daylight hours; play areas are too remote from dwelling units; the brick facades are unrelieved and depressing; the site abuts a major expressway, and this is one project among several in this neighborhood, resulting in a community engulfed by a single housing type.

Photo reference 12, Lompoc, California, shows a well kept but antiquated kitchen. There are no work surfaces, open cabinets and old appliances. These represent Level II modernization items.

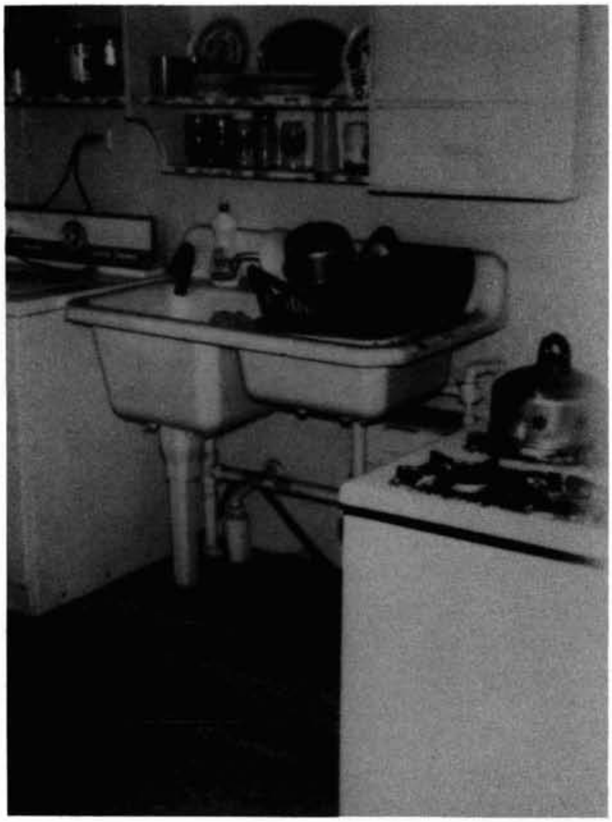

Photo reference 12A, Lompoc, California, shows a well-maintained kitchen; however, it does not meet MPS standards because the upper cabinetry is not enclosed.

Photo reference 13, in Akron, Ohio, is the oldest project in the city, and is an Urban Initiatives project. In spite of its 38 years it remains structurally sound and in generally fair condition.

Photo reference 14, Chicago, Illinois, shows a dumpster in poor condition unfortunately located in a pedestrian walkway.

Photo reference 15, Providence, Rhode Island, shows a "moth-balled" building which has been vandalized.

Photo reference 16, Sitka, Alaska, shows a scattered-site, single-family project integrated with conventional housing. Severe ground erosion is due to an inappropriate foundation in volcanic soil.

Photo reference 17, Akron, Ohio, shows erosion, concrete cracks, settling, and spalling on steps.

Photo reference 18, Jersey City, New Jersey, shows a vacated low-rise family project.

The second component of this study was to prepare cost estimates for making a percentage of low income public housing units accessible to and usable by physically handicapped tenants.

Handicapped accesibility in new or rehabilitated public housing has commanded more attention in recent years and is now mandated by federal legislation. As a result, public housing authorities require more information and a greater understanding of the history and progress of accessibility in public housing.

The public is generally not aware of the extent to which handicapped individuals populate this country. Estimates of the number of handicapped individuals in the total U.S. population vary widely. For example, it has been estimated that from 10 to 20 percent of the total population in the U.S has some kind of permanent disability that restricts activity. This does not include the temporary disabilities caused by pregnancy, illness or accident. An even higher estimate appears in a report to HUD that states,

> "As to the overall extent of persons with varying degrees of physical restrictions in the United States, the National Center for Health Statistics has made the following observation: 'At least 67,900,000 Americans suffer from limiting physical conditions and would benefit from a more accessible environment. An additional 20 million or more Americans over the age of 65 and limited in mobility as a result of the aging process are not included in this figure.'"

Clearly, such a large number of potentially handicapped persons have needs that can be met under the auspices of the Department of Housing and Urban Development and other federal agencies. These needs, however, have to be met according to the specific requirements of different categories of disability. This is because the blind person, for example, requires a completely different environment from that of a wheelchair-bound person to get around safely and as easily as possible.

A report from a group called the Work Committee on Recreation for the Handicapped has estimated this breakdown of disabilities by type as follows:

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1.2 million blind or severely visually impaired
7.6 million suffering from heart conditions
6.2 million (non-institutional) using orthopedic aids
1.8 million deaf
18.3 million hard of hearing
14.5 million respiratory ailments, i.e., pleurisy, emphysema
18.3 million arthritics

The number of handicapped persons in the U.S. is increasing at a faster rate than the rest of the population, due to improved life expectancy. Not only do handicapped persons live longer, but victims survive trauma more frequently in spite of acquiring a physical disability. In 1969, the National Center for Health Statistics estimated that there were 409,000 wheelchair users. HUD has estimated that today there are one and one-half million wheelchair users. This trend will probably increase, making it very important to begin providing more accessible housing as soon as possible.

An analysis of the data shows that eight large states -- California, New York, Pennsylvania, Texas, Illinois, Ohio, Florida and Michigan -- account for half of the handicapped people in the U.S., with a disproportionately high number living in the South.

<u>The Handicapped Population and Their Housing Needs</u> also notes that the Census study shows that "...compared to the non-disabled, the disabled have less education, lower incomes, and fewer members in the labor force. Strikingly, almost twice as many handicapped fall under .75 of poverty level; (they are) the poorest of the poor. Fifteen percent of the handicapped are in this category compared with eight percent of the general population. The average income for the totally disabled is half that of the non-disabled; roughly $6,600 compared with $12,000 in 1970."

One can assume then, that the percentage of disabled people needing public housing is greater than the percentage of disabled people in the total population.

It is recommended that the PHA staff involved with the implementation of proposed HUD regulations, or those merely interested, refer to the literature listed in the bibliography section of the Accessibility Appendix (Section 8.0). These articles and books can aid in an understanding of the various disabilities.

3.1 Overview

The mandate for the proposed three-year transition plan came as a result of several key pieces of federal legislation. Public Law 90-480 (the Architectural Barriers Act of 1968) required that any facility built or supported by federal funds be made barrier free. The impetus for this legislation came as a result of many factors, including a report by the National Commission on Architectural Barriers to Rehabilitation of the Handicapped entitled Design For All Americans.

Specifically, the Architectural Barriers Act of 1968 states that: "...any building constructed in whole or in part with federal funds must be made accessible to and usable by the physically handicapped." ANSI Standard A117.1 (1961) was used as the measure of "accessibility" at this time.

Because of problems with the interpretation and implementation of the Architectural Barriers Act of 1968, P.L. 93-112 was passed. This law, known as the Rehabilitation Act of 1973, proved to be a much more effective tool for removing the barriers existing for the disabled.

Three sections comprise the heart of the Rehabilitation Act of 1973. Section 502 established an Architectural and Transportation Barriers Compliance Board. In 1974 amendments were added as P.L. 93-516. These amendments acted to strengthen some previously weak areas in the legislation. Sections 503 and 504 apply to organizations doing business with the federal government. Specifically, Section 503 is administered by the Department of Labor and covers federal contracts. It requires affirmative action by any business holding a contract or subcontract over $2500, including construction contracts. It should be noted that the handicapped here include both physically and mentally handicapped, and that an employer must actively recruit and advance the handicapped equally with others. The key phrase in Section 503 is "reasonable accommodation". Section 504 involves those groups holding federal grants or federally-assisted contracts. It is administered by whatever agency is handling the grant or providing the contract, be it HEW, HUD, DOE or any other department or federal agency.

Another Act of importance is the Urban Mass Transportation Act of 1964 (amended in 1970). This law mandated a barrier-free mass transportation system wherever federal monies were involved. Since a large proportion of mass transit is federally funded, this has a widespread effect. The states and cities are still trying to assess their responsibilities in this area.

The important point in this discussion of legislation is that the mandate for HUD to provide minimum facilities for the handicapped in public housing is Section 504 of the Rehabilitation Act of 1973.

3.1.1 ANSI A117.1

The document that has been used for years by various groups, from legislators to building code officials, is Standard A117.1 of the American National Standards Institute. This standard, in a publication titled Specifications for Making Buildings and Facilities Accessible To, and Usable by, the Physically Handicapped, was first published in 1961. The original document, and the subsequent revisions in 1971, were for many years considered incomplete by handicapped groups. As the first document of its kind, however, it was a step forward. Applying to buildings and facilities "used by the public", its scope and definition of "public" have been changed over the years.

These changes came about largely through the development of a new and more comprehensive ANSI A117.1 Standard involving many concerned groups and a two-year project undertaken at Syracuse University. Housing and exterior spaces, to mention two major areas, have been added. This new standard, ANSI A117.1 - 1980 is used in this report as the minimum criteria for accessible buildings and facilities.

3.1.2 Barrier Free Demonstration Project

In an effort to assess the potential problems in creating accessible buildings and facilities in public housing projects, HUD implemented a "Barrier Free Demonstration Program" in 1978. Thirty-one PHA's were asked to submit transition plans. Nine were approved and funding was granted to effect the alteration of approximately $500,000 worth of facilities. The results will provide valuable experience and well documented information for other PHA's. The regional HUD representative should be contacted for information on these "barrier free demonstration projects."

3.1.3 Needs of the Handicapped

Aside from the physical and legislative constraints imposed upon the implementation of accessibility in public housing, there are two programmatic concepts that also must be addressed: independent living and mainstreaming.

The concept of "independent living" for the handicapped has as its basic premise that all the disabled should be as physically and psychologically independent in their daily lives as is possible. This implies the removal of all barriers that a physically handicapped person might encounter in his or her normal travels. In addition, there is a psychological component. The handicapped do not want to feel as if they are a burden to their family or society. In order for the concept of "independent living" to be realized, all aspects of public and some private spaces would be affected, including public transportation, office buildings, museums, restaurants, and housing, to mention only a few. Public housing offers one area where the handicapped can make another step towards achieving independence.

The concept of "mainstreaming" has evolved from that of "independent living". "Mainstreaming" is the integration of the handicapped with other people in all facets of normal daily life. This is radically opposed to past theories that the handicapped should live together. Draft HUD regulations presently propose limiting handicapped population to twenty-five percent in any project or building within that project. This has evolved in an attempt to promote "mainstreaming".

It has been found that, with the exception of the elderly handicapped, those handicapped persons in public housing prefer to live among all other tenants. They enjoy the same facilities and activities as the able bodied. This should be kept in mind when designing for the HUD minimum requirements in this report.

De-institutionalization is another part of "mainstreaming". Many handicapped persons who presently live in institutions because housing or facilities are not available elsewhere would greatly benefit from increased accessibility in public housing. This would allow them to join the community.

By reading as much as possible on the disabled and handicapped accessibility, as well as thinking of personal encounters with the disabled, sensitivity can be developed to aid in an understanding of the mandate for this report and the subsequent changes that will be required in the public housing stock.

It is also recommended that any of the following groups be contacted as outlined in HUD's Accessibility Manual for Public Housing Authorities to understand the specific needs of the physically handicapped. These include local chapters of:

Alexander Graham Bell Association for the Deaf
American Association of Workers for the Blind, Inc.
American Coalition of Citizens with Disabilities
American Foundation for the Blind
American Occupational Therapy Association, Inc.
Council for Exceptional Children
Disabled American Veterans
Gerontological Society
Goodwill Industries
March of Dimes National Foundation
Muscular Dystrophy Association, Inc.
National Association for the Physically Handicapped
National Easter Seal Society for Crippled Children and Adults
National Multiple Sclerosis Society
National Paraplegic Foundation
Paralyzed Victims of America
United Cerebral Palsy Association, Inc.

3.1.4 Current Status of Accessibility in Public Housing

The general status of accessibility in public housing indicates that there is little formal accommodation for the handicapped. Sine 1969, new public housing has had to meet ANSI A117.1 (1961), which deals primarily with entrances to public buildings. Housing for the elderly built since 1973 must provide dwelling units for the handicapped (10% of the total stock with accessible bathrooms and half of these units also with accessible kitchens). This means that the most accessible buildings are new, and their tenants are elderly. Even these buildings, however, have problems.

The "Summary of Results and Conclusion" following later in this section will indicate more specifically the problems and general status of the public housing stock with respect to accessibility for the handicapped.

3.2 Analysis

The accessibility component of this "Evaluation of the Physical Condition of the Public Housing Stock" estimated the extent to which sites, public interior spaces and dwelling units were accessible to the physically handicapped at the time of the survey.

In addition, a method for providing accessibility was developed to provide the highest degree of accessibility while realizing that cost is an important issue.

This methodology began with the development of design criteria, at first divided into two levels of compliance as in modernization, and eventually using only one, the ANSI A117.1-1980 Standard as the basis for defining handicapped accessibility.

Data were collected from a final random sample of 350 public housing projects across the country. The accessibility portion of the survey ascertained the extent to which project site, public interior spaces and dwelling units were accessible to the physically handicapped individual. This required the collection of information about existing physical conditions, and the presence or lack of specific items. These data were then translated into a work item list according to categories of disability with associated costs appended to arrive at a cost by disability for each project surveyed.

Unlike modernization where the cost of compliance was defined as the cost to upgrade all units and public spaces to meet a given level, draft HUD regulations propose that five percent of all dwelling units in the PHAs assisted housing inventory be accessible to the handicapped by the end of a three-year period. In addition, those site and public spaces listed in the previous section must be accessible.

Five disability types have been identified by HUD. They are as follows:

1. Wheelchair user: those individuals who are unable to move about except by the use of a wheelchair.

2. Mobility impaired: those individuals who cannot move about without the aid of walkers, crutches or a cane. They include those who lack the stamina to walk long distances or climb stairs or demonstrate a prevalance of fainting or poor balance.

3. Blind: those individuals who are unable to read ordinary newspaper print with the aid of eyeglasses (legal blindness = 20/200 or field defect of 10% or less) and those individuals who have total loss of vision (totally blind).

4. Deaf: those individuals who are unable to interpret speech either with or without amplification.

5. Hand or arm impaired: those individuals who are limited in their ability to use their hand or arm, such as those missing a limb or with lack of coordination or strength.

HUD is proposing to separate the five percent dwelling unit requirement listed above into two percent for wheelchair users and three percent for the other four categories. The project team recommends the following percentages by disability type, including HUD's mandated two percent for wheelchair users:

1.	Wheelchair users:	2%
2.	Mobility impaired:.	1%
3.	Blind:.	1%
4.	Deaf:	.5%
5.	Hand or arm-impaired:	.5%

Categories 2 - 5 are only suggested as a breakdown of the three percent. This separation will be helpful because of the requirement by HUD to tailor the dwelling unit to the disability type. It should be noted that these requirements can be met through new construction, incorporation of accessible units in ongoing modernization programs or specific changes to make an existing unit accessible. The draft regulations refer to any construction changes as "alterations".

The following sections detail the data required, the survey and costing methodology, the analysis of the data, summarized results and recommendations for the implementation of accessibility programs.

3.2.1 Data Requirements

The data originally collected for the accessibility cost estimate consisted of:

1. Definition of accessibility standards using ANSI A117.1 - 1980 and recommended supplementary design criteria
2. A survey instrument that assessed the degree of compliance within these criteria.

The survey instrument was the source of data by which a comparison was made to ANSI A117.1-1980. Items that did not comply with ANSI A117.1-1980 were costed, with some assumptions as noted later in this text.

It should be noted that the survey instrument did not follow the order of the ANSI Standard, which is organized by building component, but was made specifically for ease in collecting data and ultimately projecting the costs to make 5% of public housing accessible.

Accessible Route Concept

The "accessible route", also known as the "accessible path" concept provides the greatest understanding of the logic behind the survey process and the barriers the disabled encounter in a given public housing project.

ANSI defines the "accessible route" as:

> "A continuous unobstructed path connecting all accessible elements and spaces in a building or facility that can be negotiated by a severely disabled person using a wheelchair and that is also safe for and usable by people with other disabilities. Interior accessible routes may include corridors, floors, ramps, elevators, lifts, and clear floor space at fixtures. Exterior accessible routes may include parking access aisles, curb ramps, walks, ramps, and lifts."

Accessibility Assumptions Based on ANSI A117.1-1980

At least one accessible path of travel was assumed to be provided:

A. From the site arrival points for public transportation, passenger drop-off/loading and parking to an accessible entrance of all buildings with accessible dwelling units.

B. Connecting all accessible buildings and facilities on a site.

C. From each accessible entrance to each accessible part of a building or facility.

This applied in particular to each dwelling unit intended for use by the chairbound, and each common resident area intended for use by the chairbound.

Access to any facilities provided for public housing tenants cannot be denied the handicapped. At least a portion of these facilities, such as postal services and laundry rooms must be located on an accessible path.

An accessible path was assumed to be specifically provided from the accessible dwelling unit to a public facility. This implied that the accessible path is linear, going from point to point.

At least part of each of the following facilities was assumed to be made accessible, based on the requirements in ANSI A117.1-1980. That part included whatever was necessary to permit an individual access to all listed activities, and the design or designation of that part could not segregate handicapped individuals from others.

A. Spaces and facilities serving all residents in common (e.g. playgrounds, parking structures, building entrances, rental offices, lobbies, etc.) (ANSI 4.1.1, 4.1.2)

B. Spaces and facilities serving a group of dwelling units or sleeping accommodations of which one or more is accessible (e.g. mailbox areas, terraces, patios, parking areas, halls, corridors, laundry rooms, floor lounges, bulk storage areas, etc.) (ANSI 4.1.1, 4.1.2)

C. Spaces and facilities serving individual accessible dwelling units (e.g. entry walks, assigned parking spaces, patios, balconies, mailboxes, etc.). (ANSI 4.1.1, 4.1.2)

In addition, the following parts of a building intended for use by the handicapped were assumed to be made accessible for this cost estimate:

A. At least one principal entrance
B. All stairways connecting levels not served by elevators and those located directly in a path of travel, and stairways
C. Public toilet rooms, if provided or required
D. At least one publicly-used passenger elevator if provided
E. A portion of each service line area or counter area provided
F. Public telephones and drinking fountains
G. Places of assembly.

These requirements applied to all public or community buildings on a public housing site, with some exceptions. They did not apply to buildings containing only dwelling units unless one or more dwelling units was intended for occupancy by a handicapped person. (ANSI 4.1.2)

The following parts of the dwelling unit were assumed to be accessible and be connected by at least one accessible path of travel:

A. A principal entrance
B. A kitchen
C. One full bathroom (including a toilet, lavatory, and a tub or shower)
D. The living area
E. Dining area
F. One bedroom or sleeping area (efficiency apartments)
G. A laundry area (if provided in individual dwelling units)
H. A family room, den or additional bedroom if the unit is intended for use by families
I. At least one telephone if installed in the dwelling unit
J. Patios, terraces, balconies.

Non-chairbound handicapped residents are not restricted to the accessible path and are likely to venture off it. Such persons will require access to equipment, such as telephones, seating, and water fountains, that is not located on the accessible path.

Every accessible space was assumed to be served by at least one accessible means of egress or place of refuge (a place that provided protection from fire and smoke in an emergency).

Additionally, it should be noted that each category of the design criteria was related to specific disabilities.

3.2.2 Survey Instrument

The data collection instrument for the accessibility portion of this report consisted of recording descriptive information, dimensions, and construction materials for each project surveyed The survey instrument indicated where appropriate retrofit measures or structural renovations could be made to each project and/or unit to allow for accessible sites, public interior spaces and dwelling units by disability type.

For example, each variable or line in the survey implied compliance or non-compliance of a whole condition. This condition suggests a work item for a specific disability that was provided for in the design criteria. These disabilities were based at that time upon the expanded draft ANSI A117.1 (1979) definition of the handicapped which were:

1. Severe loss of sight, blindness. This category includes those individuals who are unable to read ordinary newspaper print with the aid of eyeglasses (legal blindness = 20/200 or field defect of 10% or less) and those individuals who have total loss of vision (totally blind).

2. Severe loss of hearing. This category defines persons who are unable to interpret speech, either with or without amplification.

3. Lack of coordination/limitations of stamina. Persons in this category include those demonstrating difficulty in controlling and directing their extremeties; individuals who become short of breath and/or who experience abnormal elevations in blood pressure as a result of walking long distances or climbing stairs; and individuals demonstrating prevalence of fainting, dizziness, or poor balance.

4. Difficulty in moving head, lifting and reaching, bending, turning, sitting or kneeling. This category includes individuals limited in their ability to move the head either up or down or from side to side; and/or individuals with decreased mobility and range of motion of upper extremeties as well as those confined to wheelchairs; and/or those with severe arthritis of the spine of those in back braces and plaster body casts.

5. Difficulty in handling or fingering. These are individuals who have difficulty performing functional activities with the hands.

6. Inability to perform upper extremity skills. Individuals in this category, unlike those in 4 and 5, have "complete" paralysis, lack of coordination or absence of both upper extremities.

7. Reliance on walking aids. Individuals in this group are those needing crutches, canes, or walkers. They are also referred to as "semi-ambulant".

8. Inability to use lower extremities. This category consists of persons who are unable to move about except by the use of a wheelchair.

These disabilty categories were later grouped by HUD as follows:

1. Wheelchair users (former categories 6 and 8)
2. Mobility-impaired (former categories 3, 4 and 7)
3. Blind (former category 1)
4. Deaf (former category 2)
5. Hand or arm impaired (former category 5).

A complete copy of the survey instrument is contained in Volume III Accessibility.

3.2.3 Cost Estimation Methodology

The cost of providing accessibility to the disabled in the current public housing stock is estimated at $320 million dollars at current (second quarter 1980) Washington, D.C. prices.

The steps in producing the cost estimate for accessibility are listed below and shown in Illustration 3.1.

1. Standards were developed, by disability, for the provision of accessibility. These standards, which conformed generally to draft ANSI A 117.1 (1978), were submitted and approved by HUD as the basis for conducting the accessibility survey.

2. A survey instrument was designed to measure the degree of non-conformance within a housing project with the standards and supplementary design criteria discussed in 1 above.

3. Four hundred (400) projects were selected and 350 surveyed for the final analysis.

4. Work items required to achieve conformance with 1. above were developed and unit costs collected for each work item.

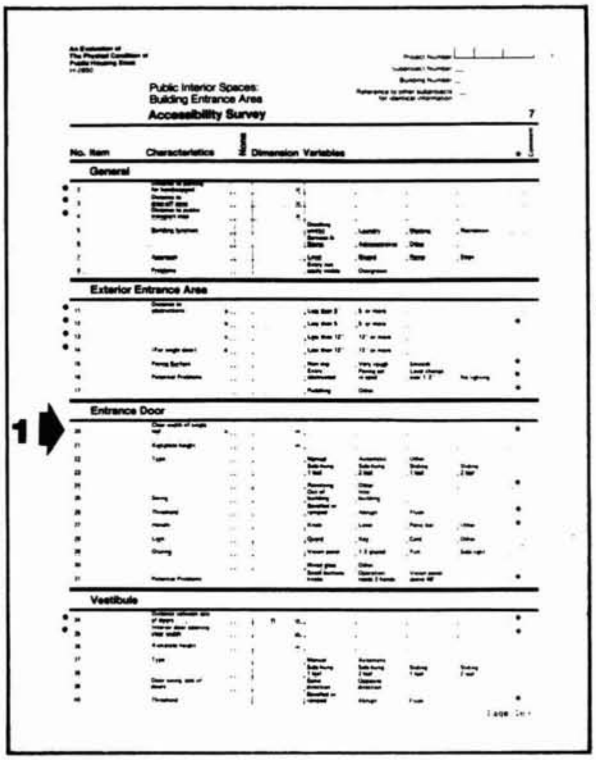
5. Nine prototypical dwelling units, i.e., units that presented typical accessibility problems, were selected from the surveyed projects and detailed design studies were conducted to produce "least-cost" solutions for each disability within each prototypical unit. This approach avoided inflated cost estimates that might have developed from item-by-item costing. The prototypes and unit costs are presented in Volume III Accessibility of this report.

6. Each surveved dwelling unit was assigned to its closest prototype and all differences (added or deducted work items) required to achieve accessibility between the given dwelling unit and its assigned prototype were noted and costed.

7. The cost of added or deducted work items was then used to adjust the cost estimate for the prototype to produce a cost estimate for the surveyed project.

Illustration 3.1

Accessibility Cost Evaluation Process



1

Public Interior Spaces:
Building Entrance Area
Accessibility Survey 7

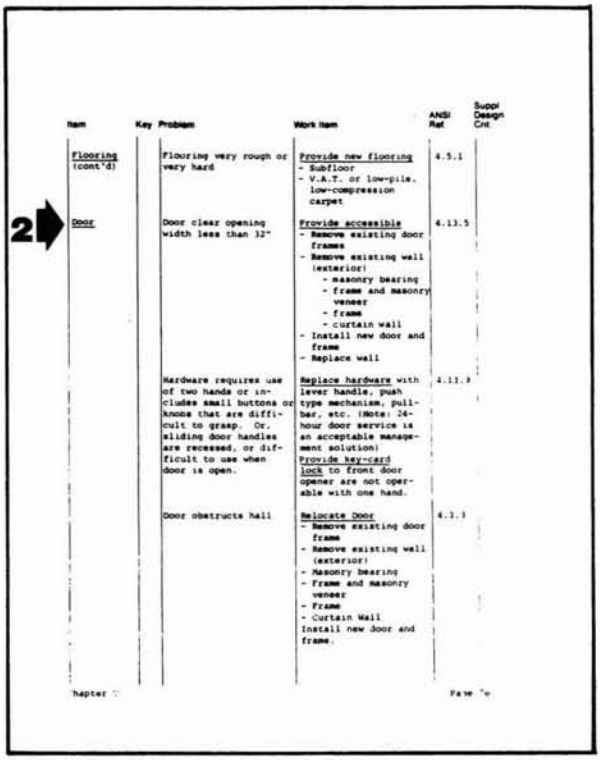
No.	Item	Characteristics	Dimension Variables

General

Exterior Entrance Area

Entrance Door

Vestibule



2

Item	Key	Problem	Work Item	ANSI Ref	Suppl Design Crit
Flooring (cont'd)		Flooring very rough or very hard	Provide new flooring - Subfloor - V.A.T. or low-pile, low-compression carpet	4.5.1	
Door		Door clear opening width less than 32"	Provide accessible - Remove existing door frames - Remove existing wall (exterior) - masonry bearing - frame and masonry veneer - frame - curtain wall - Install new door and frame - Replace wall	4.13.5	
		Hardware requires use of two hands or includes small buttons or knobs that are difficult to grasp. Or, sliding door handles are recessed, or difficult to use when door is open.	Replace hardware with lever handle, push type mechanism, pull-bar, etc. (Note: 24-hour door service is an acceptable management solution) Provide key-card lock to front door opener are not operable with one hand.	4.13.9	
		Door obstructs hall	Relocate Door - Remove existing door frame - Remove existing wall (exterior) - Masonry bearing - Frame and masonry veneer - Frame - Curtain Wall Install new door and frame.	4.3.3	

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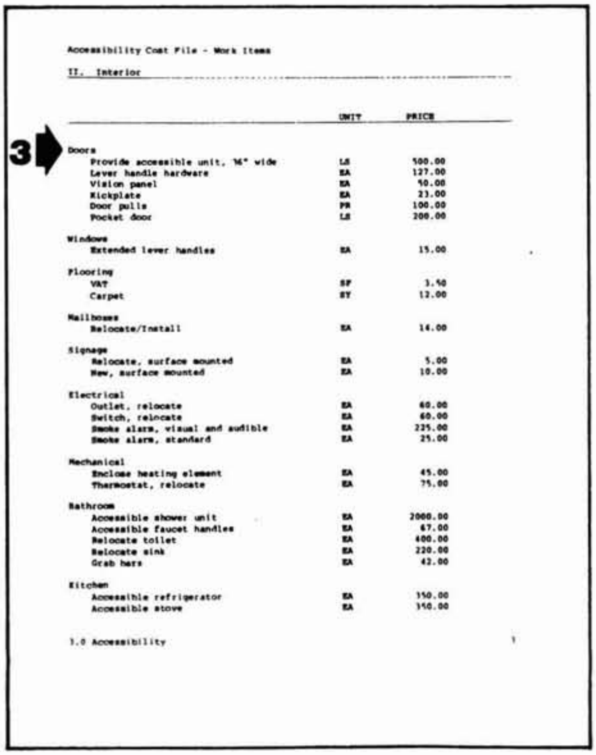


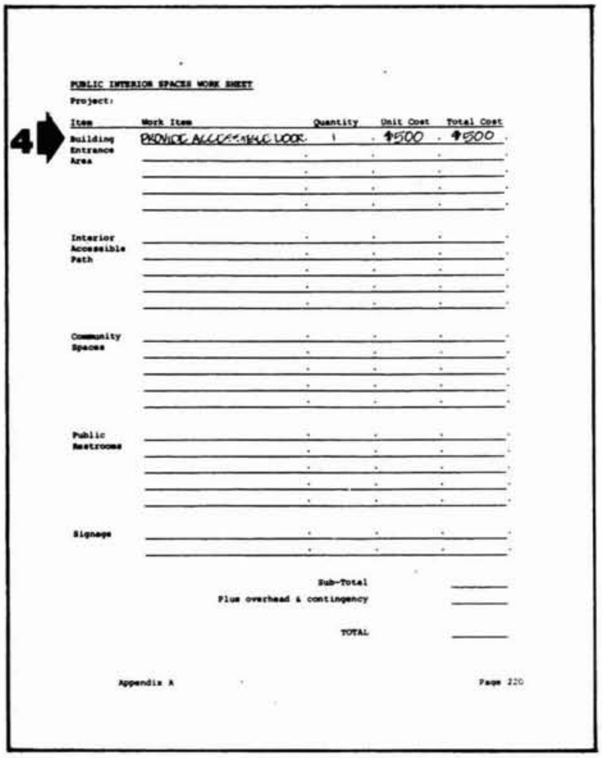
3

Accessibility Cost File - Work Items

II. Interior

	UNIT	PRICE
Doors		
Provide accessible unit, 36" wide	LS	500.00
Lever handle hardware	EA	127.00
Vision panel	EA	50.00
Kickplate	EA	23.00
Door pulls	PR	100.00
Pocket door	LS	200.00
Windows		
Extended lever handles	EA	15.00
Flooring		
VAT	SF	3.50
Carpet	SY	12.00
Mailboxes		
Relocate/Install	EA	14.00
Signage		
Relocate, surface mounted	EA	5.00
New, surface mounted	EA	10.00
Electrical		
Outlet, relocate	EA	60.00
Switch, relocate	EA	60.00
Smoke alarm, visual and audible	EA	225.00
Smoke alarm, standard	EA	25.00
Mechanical		
Enclose heating element	EA	45.00
Thermostat, relocate	EA	75.00
Bathroom		
Accessible shower unit	EA	2000.00
Accessible faucet handles	EA	67.00
Relocate toilet	EA	400.00
Relocate sink	EA	220.00
Grab bars	EA	42.00
Kitchen		
Accessible refrigerator	EA	350.00
Accessible stove	EA	350.00

3.0 Accessibility 3



4

PUBLIC INTERIOR SPACES WORK SHEET

Project:

Item	Work Item	Quantity	Unit Cost	Total Cost
Building Entrance Area	PROVIDE ACCESSIBLE DOOR	1	$500	$500
Interior Accessible Path				
Community Spaces				
Public Restrooms				
Signage				

Sub-Total

Plus overhead & contingency

TOTAL

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3.3 Summary of Results and Conclusions

Some general conclusions were arrived at through the collection of data. They are noted below.

The sites often require substantial work. Many authorities try to build on land sloped less than 5%, but some of the older projects are hilly, banked with roads lower than housing entry level, or stepped. Parking is not usually a problem since at least some units on each site are located adjacent to parking. Specific problems vary widely -- from a site that needs only curb cuts or ramps to sites with walks generally under several inches of water.

The most common difficulties with building entrance areas included abrupt level changes, such as 6" high entry pads, or inadequate approach and maneuvering space, such as a 36" X 36" entry pad, where a 60" X 60" pad is normally needed.

Restrooms with multiple stalls in community areas were found to be almost always too small for the mobility impaired. Public kitchens and storage were usually accessible; laundries were often tight in floor space and equipment difficult to use. Many projects provided laundry hookups instead of facilities, but the handicapped were not able to afford the equipment or had no access to laundry facilities.

Dwelling units varied from being completely inaccessible to the chairbound (such as in three-story buildings with the first story four feet above the ground) to the easily-approached, entered and negotiated. Little provision has been made for activity limitations.

Housing units built for the elderly in the last seven or eight years have electric outlets and switches within reach and some lever handles, but many of the windows were hard to open and kitchen equipment hard to use. Virtually no provision had been made for the sight or hearing disabled in any units. All in all, very few projects had significant accommodation for the handicapped.

In order to provide the cost estimate there were policy issues identified and included here.

These eight policy issues were identified, and affected extrapolation of the cost of accessibility retrofit. Following is a brief discussion of these issues, along with the assumptions made regarding each one in the development of the national estimate.

1. Section 504 requires that public housing be made accessible to the disabled within three years of the date upon which HUD publishes its final regulations. Inasmuch as those regulations are still in unissued form, the Project Team has necessarily had to rely on goals and targets provided by HUD'S Office of Independent Living that may be altered in the regulations when they are finally published. The following goals and targets were assumed in creating the estimate of the cost of providing accessibility in public housing.

   a. The program shall be made accessible within three years commencing on October 1, 1980.

   b. For planning purposes, the number of dwelling units in the public housing stock as of October, 1980 was assumed to be 1,172,486 units, which reflected the net loss in units resulting from a higher rate of depreciation than the current rate of replenishment. Over the three years FY 1975 through FY 1977, only 12,000 units were constructed per year and only 7,000 units were made available in FY 1977.

   c. The percentage and number of units to be made accessible, by disability, were assumed to be as follows:

Disability	Percent	Total Units
1. Wheelchair users	2.0%	23,450*
2. Mobility-impaired	1.0%	11,725
3. Blind	1.0%	11,725
4. Deaf	0.5%	5,862
5. Hand or arm impaired	0.5%	5,862

* 2,100 of these units could be achieved via new construction (see 3. below). However, for the purposes of this estimate, all 23,460 were assumed to be achieved via retrofit of the existing stock.

2. Though a distinction is made between wheelchair-users and the mobility-impaired throughout the literature, great similarity appears in the work items required to provide accessibility for the two groups. Many of the mobility-impaired choose to

use wheelchairs within their dwelling units and further, many mobility-impairments are chronic in nature and degenerate to a state that requires wheelchairs. For cost estimating, we assumed the same retrofit actions and costs for the provision of an accessible unit for both groups.

3. Accessible units for the mobility-impaired and chairbound can be achieved via new construction for approximately one-fourth of the cost of achieving them via the retrofit of existing buildings. In contrast, accessible units for the activity-impaired and sensory-impaired do not cost significantly less to build than to achieve via retrofit. Cost savings would therefore result if all accessible units planned in new public housing were to be assigned to the mobility-impaired and chairbound.

   However, the concept of mainstreaming is still considered valid here. There is always a tradeoff between ideals and the reality of costs, and these were assumptions that were made in this cost estimate.

   It has been assumed that the current housing trend (FY 1978) will continue and that approximately 7,000 units will be constructed annually. If ten percent of these units (2100 units over 3 years) are made accessible to the disabled and <u>all</u> of these newly constructed accessible units are designed for the chairbound and mobility-impaired (resulting in a savings of $\pm$ \$13,000,000 when compared to providing the same units via the retrofit of existing units), only 8.75% of the total requirement for the mobility-impaired and chairbound could be met via new construction. To achieve the above will require immediate redesign of currently drawn projects scheduled for completion during the planning period (October 1, 1980 through September 31, 1983).

   As noted in item 1. above, the current estimate does not assume that <u>any</u> accessibility requirements will be met via new construction.

4. Once the site, public areas and community space have been made barrier-free on a given site, the cost per accessible unit on that site decreases as the number of accessible units increase. The former cost can be thought of as fixed while the latter are variable.

Upper limits must therefore be set for the number of accessible units "per project" and "per building" so that handicapped ghettos are not developed in an effort to reduce costs.

In addition to the undesirable social effects of high concentrations of the handicapped, serious safety problems occur as regards evacuation when the handicapped are clustered together and security problems are often exacerbated.

The recommended rules were as follows:

a. No more than one disabled tenant per fire exit. In high-rise structures this generally limited the number of accessible units to one or two per floor.

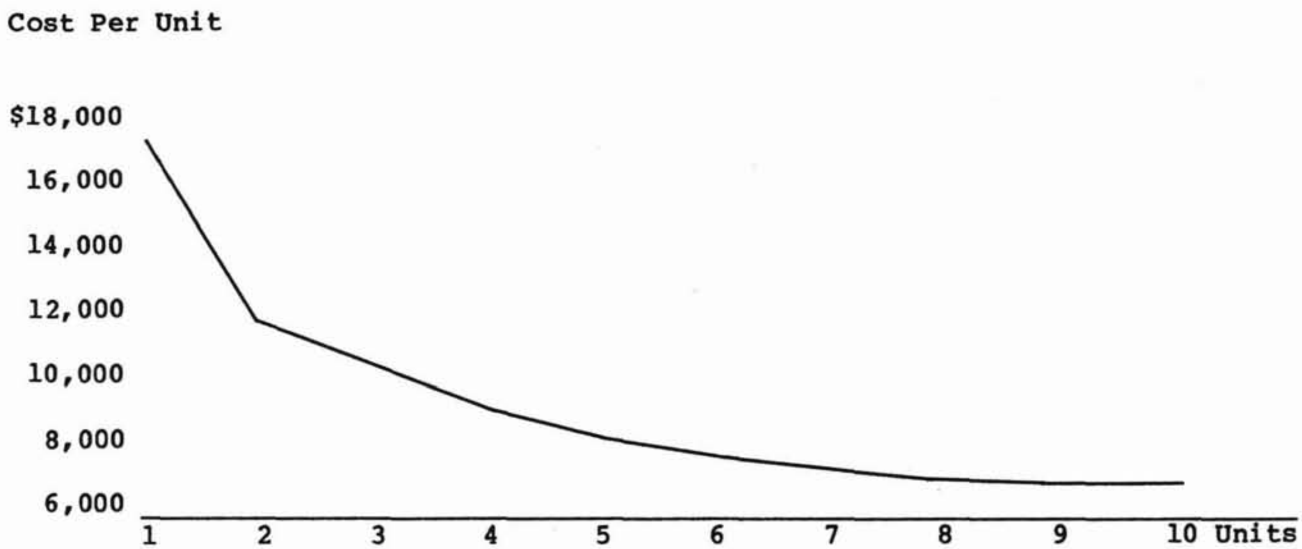
b. No more than 10% of the total units in a project, rounded up to the nearest integer, were assigned to the disabled. (New construction guidelines permit up to 25% of the units within a project to be assigned to the disabled.)

For the purposes of producing a national cost estimate, it has been assumed that any project selected for the mobility-impaired and chairbound will contain five accessible units and that one-fifth of the site work and public areas accessibility costs are therefore attributable to each unit.

As Illustration 3.2 indicates, the cost per unit could be further reduced if more than five units were provided at each selected project. It should be noted that the average size of a public housing project in the United States is 109 units so that an average of 10 units could be provided without violating the "10% rule". However, the marginal savings per unit drops to a negligible amount between 5 and 10 units.

Illustration 3.2

Cost Per Accessible Unit as a Function of the Number of Units



The preceeding graph assumes that an accessible unit for the mobility-impaired or chairbound costs $5,460 for "in unit" retrofit and that site work and public areas can be retrofitted for $11,900 per project.

5. Site, public space and community space retrofit to provide a barrier-free environment for the chairbound and mobility-impaired costs significantly more than to provide a barrier-free environment for the other disability categories.

   Once implemented at a given project, <u>all</u> accessible units within that project were usually assumed to be assigned to the chairbound and mobility-impaired in order to minimize the cost <u>per</u> unit of the site, public space and community space retrofit. This decision was made because of the high cost of alternate methods.

   Conversely, if accessible units were implemented for the blind, deaf or hand or arm impaired in a given project, units were not to be implemented for the mobility-impaired and chairbound at that project if any site work were required.

   In short, cost minimization implies the separation of sensory and hand or arm impaired disabilities from wheelchair and mobility disabilities between project, a necessary tradeoff if realistic costs were to be addressed.

6. If the disabled tenants were to have access to community space, thereby precluding the use of projects in which no community space exists, project selection for accessibility would have been severely limited in many PHA's. It was assumed that community space would be made accessible when it exists, but that its existence would not be a prerequisite for project selection. However, for purposes of developing a national estimate for accessibility, it was assumed that all projects other than single-family homes had community space that was to be made accessible.

7. The cost estimate for retrofit within dwelling units for the chairbound and mobility-impaired was $5,460 unless the unit was a duplex or required extraordinary items such as an entirely new kitchen or a new elevator. In every PHA surveyed, the required number of units for the chairbound and mobility-impaired could be achieved without incurring these extraordinary costs and it was

assumed that in those few instances where no reasonable unit existed within a PHA for retrofit, a new unit would be leased or purchased that could be made accessible at reasonable cost in order to fulfill the PHA's accessibility requirements.

8. The cost estimate assumed the inclusion of housing for the elderly which constituted approximately 21% of the total public housing in the nation. Housing for the elderly in turn is significantly more accessible than most multi-family housing. Most projects for the elderly were initially designed with grab bars in bathrooms, electric outlets at 18 inches above the floor, lower light switches, at least one accessible path, alarms in all public places and handicapped parking and drop-offs. Commonly missing were wheelchair-height counters, lever-handled doors and radiators and in-unit alarms. On average, costs for bringing housing units for the elderly up to the level called for in the design criteria for the chairbound averaged 42% of the amount required in multi-family units. This reduced amount was factored into the costs presented in this estimate.

3.3.1 Cost Estimates

All costs reflected second quarter 1980 Washington, D.C. prices and included an additional 30% of quoted prices to cover contingencies (5%) and contractor's mark-up (which is generally considered to be 25%) to compensate for the generally slow payments and additional paper work required of contractors on public housing jobs.

There was some overlapping of corrective action between modernization and the provision of accessibility for the disabled. Those items that were assumed to be corrected via modernization and therefore not attributable to the provision of accessibility are listed below along with some implementation decisions that significantly affected accessibility costs.

Site Work

Rough pavement was assumed to be corrected under modernization and shall not be considered a cost under accessibility.

Improper drainage was assumed to be corrected under modernization and was not to be considered a cost under accessibility in most cases.

Lack of handicapped parking stalls was to be corrected by making three standard parking spaces into two handicapped parking spaces in most cases without requiring the construction of a new stall. Inadequate lighting was assumed to be corrected under modernization and was not to be considered a cost under accessibility in most cases.

Public Interior Space

Inadequate lighting was assumed to be a maintenance procedure or modernization improvement and not an accessibility cost in most cases.

Slippery flooring was assumed to be considered a maintenance item and did not require new construction.

No elevators were to be replaced or installed for the purpose of providing accessibility in order to reduce costs.

If improved maintenance and/or minor retrofit of existing cabs was insufficient to provide an accessible elevator, alternative sites were assumed to be selected or new units leased or constructed.

Dwelling Units

In most cases a new shower unit was not required. Rather, modification of existing facilities was to be made to meet ANSI A 117.1 - 1980 minimum standards.

In most cases, an existing plumbing wall could be left and fixtures and/or the door rearranged or widened to permit accessibility to bathrooms.

3.3.2 Cost Summary

Average (mean) costs for providing accessible units are presented in the following table. All assumptions presented in the previous sections are included.

Disability	In Unit (per DU)	Public* Areas (per DU)	Site	Total
Chairbound Mobility-impaired	$5,460	$950	$1,430	$7,840
Blind	940	295	415	1,650
Deaf	585	45	25	655
Hand or Arm-Impaired	640	460	210	1,310

Using these costs, the required units by HUD Region were determined by applying the percentage of required units to the housing stock by HUD Region and by state. The total cost by disability was then produced by applying the above unit costs to the required number of accesible units. The results are provided in the following table.

*As previously noted, "Public Areas" and "Site Costs" are allocated at one-fifth of their total amount per project which assumes that five accessible units will be provided in each project that is made barrier-free.

Table 3.1

Total Costs by Region for the Provision of Accessible Units for the Disabled

Region	Chairbound/ Mobility Impaired	Blind	Deaf	Hand Or Arm Impaired
I. DU	2,284	798	399	399
$	$17,906,560	$1,316,700	$261,345	$ 522,690
II. DU	6,758	2,258	1,126	1,126
$	$52,982,720	$3,717,450	$737,530	$1,475,060
III. DU	4,026	1,342	671	671
$	$31,563,840	$2,224,300	$439,505	$879,010
IV. DU	7,538	2,513	1,256	1,256
$	$59,097,920	$4,146,450	$822,680	$1,645,360
V. DU	5,831	1,944	972	972
$	$45,715,040	$3,207,600	$617,010	$1,273,320
VI. DU	3,686	1,229	614	614
$	$28,898,240	$2,027,850	$402,170	$804,340
VII. DU	1,256	419	209	209
$	$9,847,040	$691,350	$136,895	$273,790
VIII. DU	647	216	108	108
$	$5,072,480	$356,400	$70,740	$141,480

Table 3.1 (continued)

Total Costs by Region for the Provision of Accessible Units for the Disabled

Region	Chairbound/ Mobility Impaired	Blind	Deaf	Hand Or Arm Impaired
IX. DU	2,248	749	375	375
$	$17,624,320	$1,235,850	$245,623	$491,250
X. DU	797	266	133	133
$	$6,248,840	$438,900	87,115	$174,230

Table 3.2

Total Units and Costs by State and Disability

State	Chairbound/ Mobility Impaired	Blind	Deaf	Hand Or Arm Impaired
Alabama DU	1,163	388	194	194
$	$9,117,920	$640,200	$127,070	$254,140
Alaska DU	46	15	8	8
$	$2 360,640	$24,750	$5,240	$10,480
Arizona DU	235	78	39	39
$	$1,842,400	$128,700	$22,545	$51,090
Arkansas DU	384	128	64	64
$	$3,010,560	$211,200	$ 41,920	$ 83,840
California DU	1,995	665	333	333
$	$15,640,800	$1,097,250	$218,115	$436,230
Colorado DU	224	75	37	37
$	$1,756,160	$123,750	$24,235	$48,470
Connecticut DU	554	185	92	92
$	$4,343,360	$305,250	$60,250	$120,520
Delaware DU	87	29	15	15
$	$682,080	$47,850	$9,825	$19,650

Table 3.2 (continued)

Total Units and Costs by State and Disability

State	Chairbound/ Mobility Impaired	Blind	Deaf	Hand Or Arm Impaired
District of Columbia DU	357	119	59	59
$	$2,798,880	$196,350	$38,645	$77,290
Florida DU	1,174	391	196	196
$	$9,204,160	$645,150	$128,380	$256,760
Georgia DU	1,471	490	245	245
$	$11,547,350	$808,500	$160,475	$320,950
Hawaii DU	145	48	24	24
$	$1,136,800	$79,200	$15,720	$31,440
Idaho DU	29	10	5	5
$	$227,360	$ 16,500	$3,275	$3,275
Illinois DU	2,134	711	356	356
$	$16,730,560	$1,173,150	$233,180	$466,360
Indiana DU	513	171	86	86
$	$4,021,920	$282,150	$56,330	$112,660
Iowa DU	112	37	19	19
$	$878,080	$61,050	$12,445	$24,895
Kansas DU	227	76	38	38
$	$1,779,680	$125,400	$24,890	$49,780

Table 3.2 (continued)

Total Units and Costs by State and Disabiltiy

State	Chairbound/ Mobility Impaired	Blind	Deaf	Hand Or Arm Impaired
Kentucky DU	617	206	103	103
$	$4,837,280	$339,900	$67,465	$134,930
Louisiana DU	887	296	148	148
$	$6,954,080	$488,400	$96,940	$193,880
Maine DU	111	37	19	19
$	$870,240	$61,050	$12,445	$24,890
Maryland DU	721	240	120	120
$	$5,652,640	$396,000	$78,600	$157,200
Massachusetts DU	1,248	416	208	208
$	$9,784,320	$686,400	$136,240	$272,480
Michigan	778	259	130	130
$	$6,099,520	$427,350	$85,150	$170,300
Minnesota DU	551	184	92	92
$	$4,319,840	$303,600	$60,260	$120,520
Mississipi DU	377	126	37	37
$	$2,955,680	$207,900	$41,265	$82,530
Missouri DU	664	221	111	111
$	$5,205,760	$364,650	$72,705	$145,410

Table 3.2 (continued)

Total Units and Costs by State and Disability

State	Chairbound/ Mobility Impaired	Blind	Deaf	Hand Or Arm Impaired
Montana DU	91	30	15	15
$	$713,440	$49,500	$9,285	$19,650
Nebraska DU	254	85	42	42
$	$1,991,360	$140,250	$27,510	$55,020
Nevada DU	107	36	18	18
$	$838,880	$59,400	$11,790	$23,580
New Hampshire DU	124	41	21	21
$	$972,160	$67,650	$13,755	$27,510
New Jersey DU	1,378	$459	230	230
$	$10,803,520	$757,350	$150,650	$301,300
New Mexico DU	224	75	37	37
$	$1,756,160	$123,750	$24,235	$48,470
New York DU	3,712	1,237	619	619
$	$29,102,236	$2,041,050	$405,445	$810,890
North Carolina DU	1,074	358	179	179
$	$8,420,160	$590,700	$117,245	$$234,490
North Dakota	115	38	19	19
$	$901,600	62,700	12.445	$24.890

Table 3.2 (continued)

Total Units and Costs by State and Disability

State	Chairbound/ Mobility Impaired	Blind	Deaf	Hand Or Arm Impaired
Ohio DU	1,504	501	251	251
$	$11,791,360	$826,650	$164,405	$328,810
Oklahoma DU	575	192	96	96
$	$4,508,000	$316,800	$62,880	$125,760
Oregon	270	90	45	45
$	$2,116,800	$148,500	$29,475	$58,950
Pennsylvania DU	2,169	723	362	362
$	$17,004,960	$1,192,90	$227,110	474,220
Rhode Island DU	294	98	49	49
$	$2,304,960	$161,700	$32,695	$64,190
South Carolina DU	360	120	60	60
$	$2,822,400	$198,000	$39,300	$78,600
South Dakota DU	156	52	26	26
$	$1,223,040	$85,800	$17,030	$34,060
Tennessee DU	1,068	356	178	178
$	$8,373,120	$587,400	$116,590	$233,180
Texas DU	1,616	539	269	269
$	$12,669,440	$889,350	$176,195	$352,390

Table 3.2 (continued)

Total Units and Costs by State and Disability

State	Chairbound/ Mobility Impaired	Blind	Deaf	Hand Or Arm Impaired
Utah DU	41	14	7	7
$	$321,440	$$23,100	$4,585	$9,170
Vermont DU	63	21	11	11
$	$493,920	$34,650	$7,205	$14,410
Virginia DU	522	174	87	87
$	$4,092,480	$287,100	$56,985	$113,970
Washington DU	498	166	83	83
$	$3,904,320	$273,900	$54,365	$108,730
West Virginia DU	170	56	29	29
$	$1,322,800	$92,400	$18,995	$37,990
Wisconsin DU	350	117	58	58
$	$2,744,000	$193,050	$37,990	$78,980
Wyoming DU	21	7	4	4
$	$164,640	$11,550	$2,620	$5,240
Puerto Rico DU	1,485	495	248	248
$	$11,642,400	$816,750	$162,440	$324,880
Virgin Islands DU	137	46	23	23
$	$1,074,080	$75,900	$15,065	$30,130

Due in large part to the rapid escalation of energy costs during the past several years, more than 2700 Public Housing Authorities thoughout the country are confronted with the problem of an ever-widening gap between income and operating expenses.

The largest factor contributing to the overall operating cost of PHAs has been energy. Energy costs now average over $670 per dwelling unit per year. The dramatic energy price increase over the past 10 years can be seen in Illustration 4.1, as the cost of fuel has almost tripled.

Based on these historic price trends it can be estimated that energy costs in public housing have risen some 400 percent since 1970 -- from $185 million spent for energy in 1970 to $740 million estimated to be spent in 1980. Most of this increase has ocurred during the last few years and fuel costs are expected to increase over general inflation for many years to come.

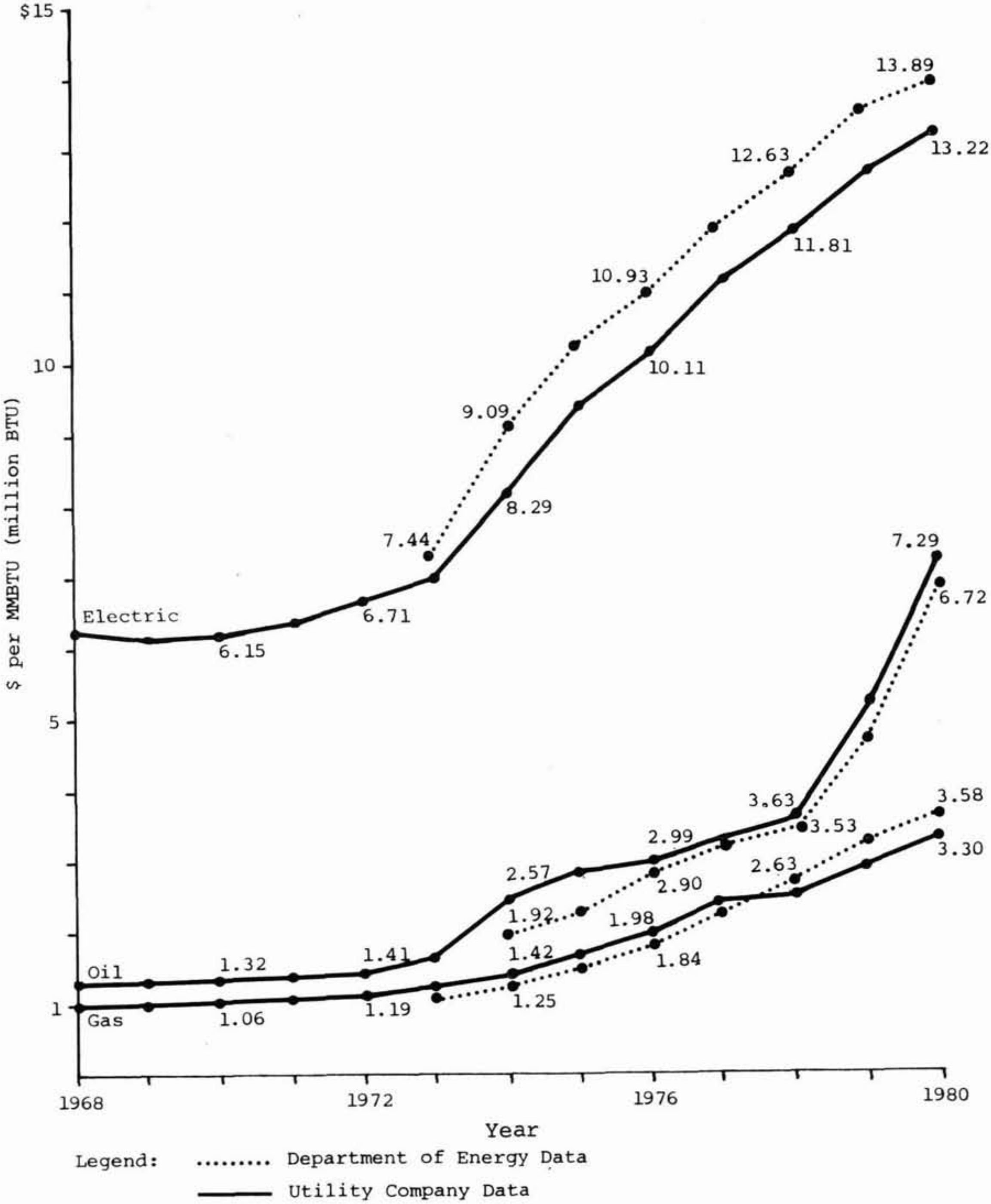
The projects vary from single-family wood frame homes to steel and concrete high-rise structures. Since the inception of Public Housing in 1937, almost $20 billion have been spent on the development of these projects. The design of most buildings, which were constructed during the late 1940's through the 1960's, however, reflects the low energy costs of that time.

In recent years, attention has focused increasingly on the nation's energy problems and efforts to reduce energy consumption and costs. Given the magnitude of these costs many actions that could reduce energy consumption by only a small percentage would yield significant energy cost savings. In addition, any energy savings would reduce dependence on foreign sources of fuel and reduce the demand for new power generation plants. Unfortunately, there are few incentives for PHA tenants to conserve energy; significant energy savings can, therefore, be accomplished only with energy conservation retrofit at substantial cost, effort and time.

This aspect of the study has been prepared to assess the existing energy consumption and energy conservation potential in the United States Public Housing Stock. It presents recommended levels of energy saving investment costs based on a cost/benefit analysis.

Illustration 4.1

Average National Residential Fuel Purchase Price



4.1 Overview

The analysis of the total Public Housing stock for existing energy use and potential energy savings was completed in two phases. Phase I was the survey process and Phase II the analysis process. The following overview of these two phases is diagrammed in Illustration 4.2.

During the survey phase three major tasks were completed before the actual survey could begin. The first was to research energy use factors and criteria applicable to public housing. This analysis was then applied to create the survey instruments. The survey instruments were used to record utility data and significant features of a project in order to calculate energy use. A classification system for projects was also developed to create a manageable number of housing prototypes for detailed analysis. When the survey instruments were completed and tested, 350 randomly selected projects were surveyed.

From project data gathered in the field, building types were analyzed for distribution of dwelling units and physical characteristics. Ninety-five projects were selected to represent the public housing stock based on dwelling unit distribution and representative physical characteristics. The data on these projects were entered in the computer for detailed energy analysis.

A set of algorithms were developed to determine existing energy use. Following this, potential energy conservation opportunities (ECOs) were analyzed and refined. Energy savings, cost and discounted payback were estimated for each ECO for all ninety-five projects producing over 5000 results.

Based on the results of this analysis, ECOs were ranked according to greatest benefit-to-cost ratios and grouped into the following four categories:

1. Operation and maintenance ECOs (No cost ECOs)
2. Less than five-year payback ECOs
3. Less than ten-year payback ECOs
4. Less than fifteen-year payback ECOs.

Since some ECOs are mutually exclusive and others are interdependent, each payback category was reanalyzed as a group to show diminishing returns of combined ECOs. The results are four final totals of energy savings and cost, corresponding to the three payback categories and the "No Capital Cost" maintenance ECOs category. These results were then extrapolated to the total Public Housing stock for each building type and the United States as a whole.

A more detailed discussion of the approach can be found in Appendix 9.0.

In addition to this energy conservation analysis, a separate but coordinated solar analysis to assess potential solar retrofit in public housing was also completed.

Illustration 4.2

Project Methodology Flow Chart

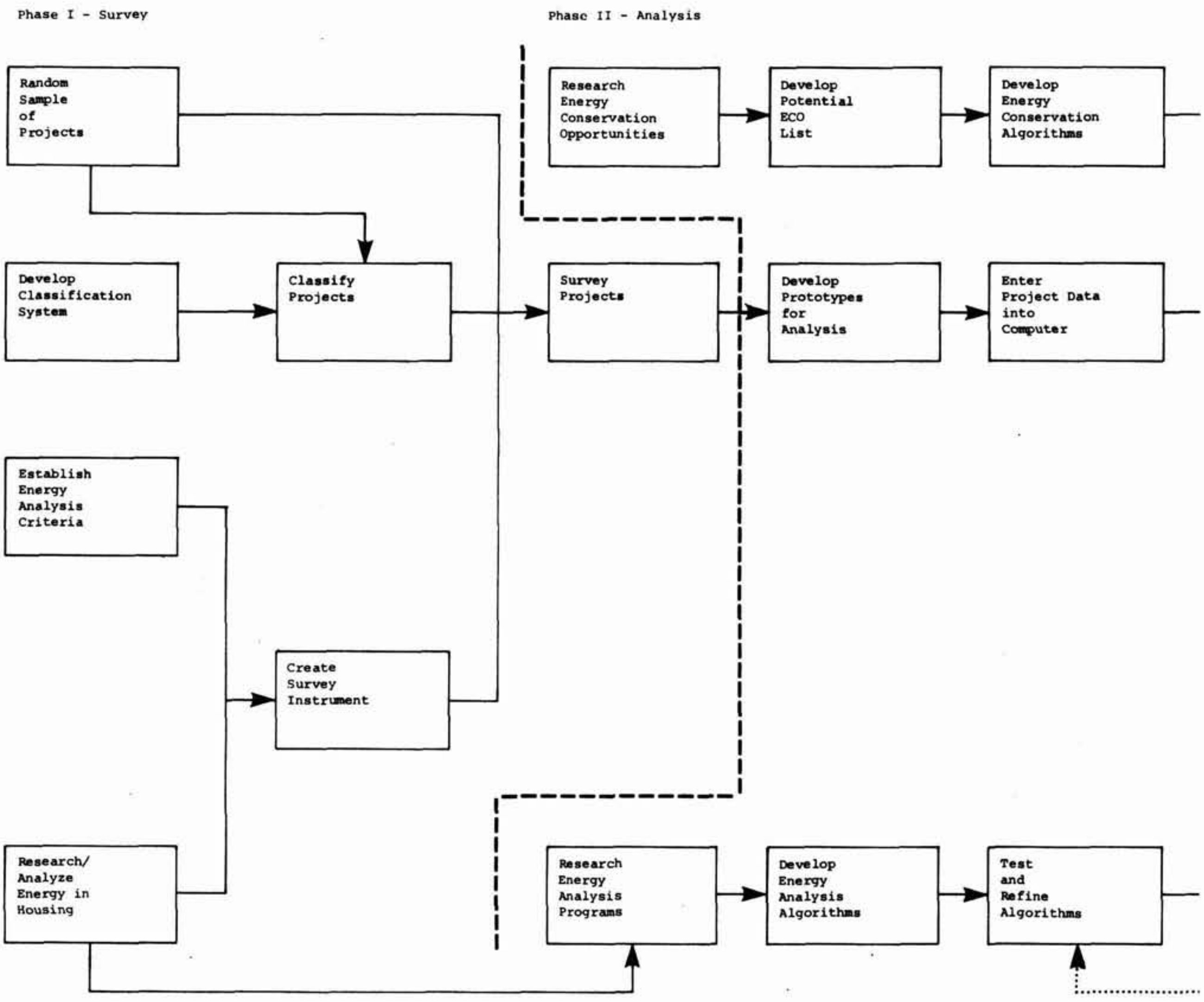
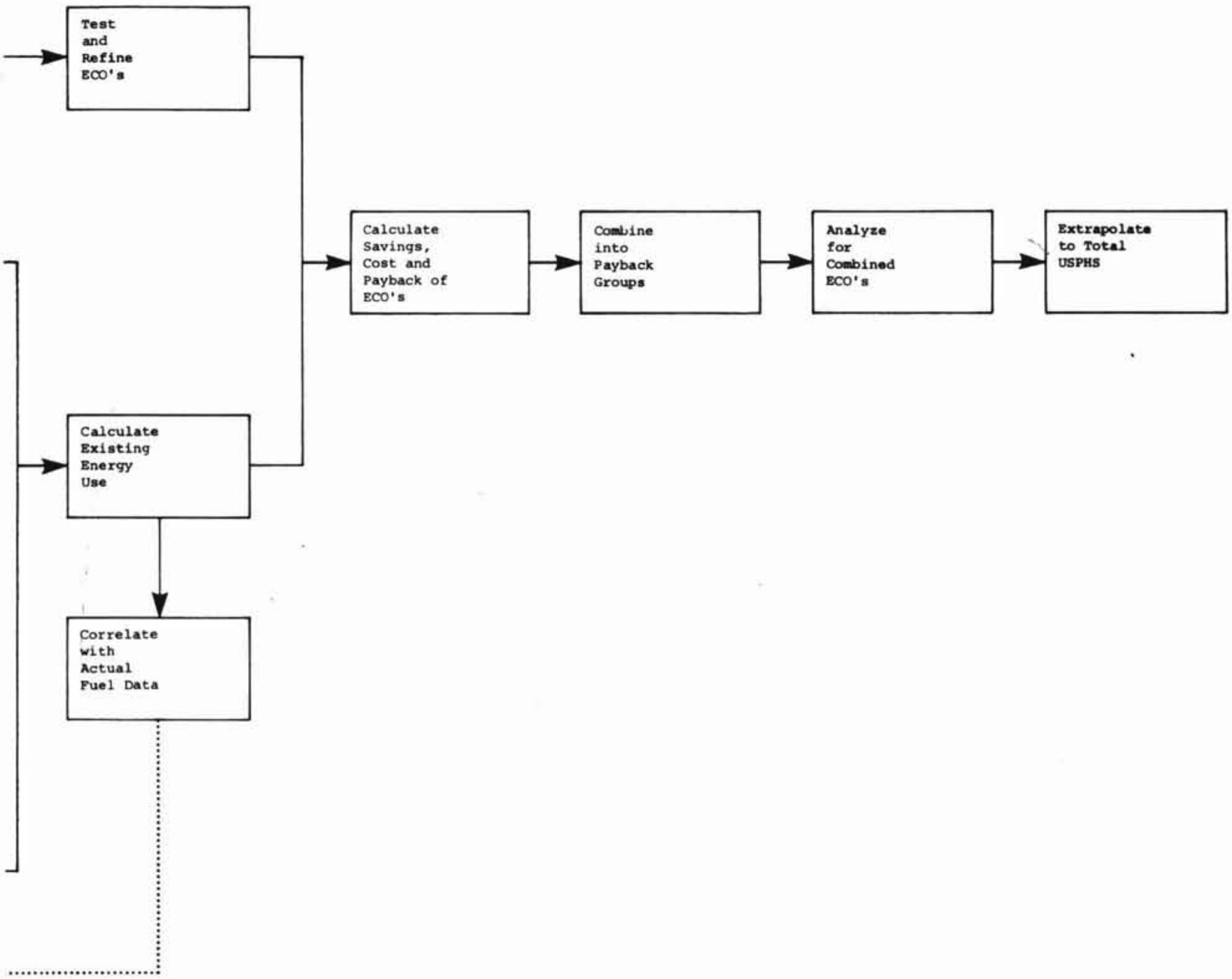


Illustration 4.2 (continued)

Project Methodology Flow Chart



4.2 Analysis

A method to organize the projects by significant categories of building type and climate was needed for the following reasons:

1. To show the significant energy uses and savings profiles of the Public Housing Stock
2. To develop a manageable number of theoretical housing prototypes for detailed analysis of energy conservation retrofit savings
3. To eliminate and include groups of ECOs for consideration
4. To extrapolate detailed survey data and analytical results to the total housing stock.

Based upon available data for the majority of housing projects, the following four classifications were developed:

- Building Configuration (high-rise or low-rise) (H,L)
- Heating System Configuration (space or central) (S,C)
- Heating Energy Source (oil, gas or electric) (O,G,E)
- Climate Zone (5 degree day zones) (1,2,3,4,5)

When building configuration, heating configuration and heating fuel are combined in all possible ways, twelve "building types" are created, each possibly occurring in all climate zones. This combination of twelve building types and five climate zones creates a matrix of sixty cells as shown in Table 4.1.

A random sample of approximately 30% of the total public housing stock provided information on number of projects, number of dwelling units and building types for each state. This sample was then extrapolated to the total for each state for each building type. In this way estimates of the total number of dwelling units in each cell was made.

The results are shown in Table 4.1. It can be seen that four building types do not occur in the sample:

Low-rise, central heating, electric heating fuel (LCE)
High-rise, space heating, oil heating fuel (HSO)
High-rise, space heating, gas heating fuel (HSG)
High-rise, central heating, electric heating fuel (HCE).

It can be noted further that not all climatic zones have a significant percent of dwelling units occurring within a building type. Since the sample of surveyed buildings was limited, it was decided that all cells which have less than one-half of one percent (0.5%) of the total dwelling units would not be used. These cells total approximately 8 percent of the total dwelling units.

The twenty-two cells remaining were considered to represent the significant building type/climate zones classifications.

Table 4.1

Distribution of Dwelling Units by Building Type and Climatic Zone

	Climatic Zone:				
Bldg Type	1	2	3	4	5
LSO			15,159 1.4%		
LSG	103,933 9.5%	150,002 13.5%	170,407 15.5%	53,230 4.8%	8,477 .8%
LSE	20,701 1.9%	16,511 1.5%	27,641 2.5%		
LCO			38,985 3.5%	16,328 1.5%	
LCG		6,686 .6%	43,138 4.1%	16,103 1.4%	
LCE					
HSO					
HSG					
HSE			23,741 2.1%	9,488 .9%	
HCO			118,413 10.7%	42,353 3.8%	
HCG		18,529 1.7%	42,484 3.9%	32,118 2.9%	11,439 1.0%
HCE					

Top number = Number of Dwelling Units
Bottom number = Percent of Total Stock

L = Low-Rise
S = Space Heating
O = Oil Heating Fuel
E = Electric Heating

H = High-Rise
C = Central Heating
G = Gas Heating Fuel

4.2.1 Energy Conservation Opportunity Analysis

After yearly energy consumption was calculated for each project and prototype, 58 ECOs were analyzed individually for each project.

The ECOs selected for analysis were divided into the following two categories:

1. ECOs that are maintenance or no-capital-cost items (11 ECOs)
2. ECOs that require an initial capital cost investment (47 ECOs).

These classifications are referred to as "no cost" and "cost" ECOs.

Energy savings analyses were performed in two steps to reflect the "no cost" and "cost" distinction between ECOs. To enhance the accuracy of the ECO savings predictions, all of the no cost ECOs were analyzed as a group. The resulting energy usage with the no cost ECOs implemented was used as the base for calculating the savings of all cost ECOs. It was therefore assumed that all operational and maintenance ECOs would be implemented before capital investments were made.

Cost ECOs were analyzed individually except where experience or physical constraints dictated that more than one ECO would be implemented at the same time. In those cases the designation of the ECOs is shown together, for example, AR1/AR2.

4.2.2 Economic Analysis

Based upon the information gathered and analyzed an economic evaluation was performed for each applicable ECO to determine whether it provided adequate economic benefit or whether it was only marginally effective in reducing consumption and costs.

To determine ECO economic feasibility, a number of investment decision methods were considered. Included were: simple and discounted payback, net present worth and internal rate of return. The discounted payback method was selected. This method takes into account the time value of cash flows and is used as an indicator for prioritizing investment decisions. It is also used to determine economic worth in existing HUD policy. Its disadvantage is that it ignores benefits which accrue after the payback date and, therefore, does not reflect the total net benefit during the life of the project.

The discounted payback period is the time period in years for an investment to pay for itself through yearly savings taking into consideration yearly fuel escalation, maintenance costs, general inflation, and the discount rate. An energy conservation opportunity (ECO) is considered feasible if its payback is less than its useful life.

4.2.3 Combined Analysis

Detailed energy savings and capital cost analyses were performed on each building type/climate zone prototype (22) for applicable ECOs (58). Resulting ECO savings, costs and corresponding payback period, are arranged by prototype in order of best-to-worst payback. These individual ECOs are then grouped in the following three categories:

1. Less than 5 years discounted payback
2. Less than 10 years discounted payback
3. Less than 15 years discounted payback

Since some ECOs are mutually exclusive and interdependent, total energy savings and costs would, therefore, be less than a total for the ECOs taken independently. To take this into account, each payback group is reanalyzed to show diminishing returns of combined ECOs, resulting in three final totals for each prototype corresponding to the payback groupings.

4.3 Summary of Results and Conclusions

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4.3 Summary of Results and Conclusions

This summary of results section is organized in four parts: a) Existing energy use in public housing which summarizes existing energy consumption profiles by building types and defines the magnitude of the problem b) Energy Conservation Opportunities in public housing which summarizes the cost saving potential, capital cost and economic worth of various energy conservation measures c) Solar energy retrofit potential in public housing was analyzed to determine where and to what extent solar energy retrofit systems are cost effective d) Conclusions reached in this study of energy conservation opportunities in public housing are presented.

4.3.1 Existing Energy Use in Public Housing

It was necessary to calculate the existing energy usage rather than using actual fuel data for two reasons. The first reason was that a large portion of the projects surveyed could not provide actual energy consumption data because of individual tenant billing. The second reason was that yearly fuel consumption data, even if available, did not provide a breakdown of energy consumption by end use such as lighting, heating or domestic water, which is desirable for energy savings estimates. Calculating energy consumption had the further benefit of providing a common method of comparison between projects since the same calculations and weather data source and use profiles were normalized to eliminate abberations. Energy consumption calculations however, were correlated with actual consumption data where they were available.

Existing energy use was calculated using standard algorithms such as those described in the American Society of Heating, Refrigeration and Air-Conditioning Engineers' Handbooks and other engineering manuals. Simplifying assumptions were made when data were not available for detailed analysis. Weather data were based on average years and projects were matched to the nearest city with available weather data. This process is detailed in the following section.

It is estimated that the existing yearly energy consumption for all public housing averages 146.1 million BTUs per dwelling unit. This figure includes all office/public/community space energy use, allocated to the dwelling units they serve in addition to the energy used by the dwelling unit for heating, lights, etc.

Illustration 4.3 shows the energy profile of the average dwelling unit. The major categories of energy use as percent of total energy dollars are as follows:

Heating 52%
Domestic Hot Water. 18%
Lights and Appliances 26%
Miscellaneous 4%

This average varies widely between climates and building types.

Average dwelling unit energy use is equal to 192 million BTUs of source energy, that is, the actual total energy used to deliver the 146.1 million BTUs to the dwelling unit. This number takes into account conversion and transmission losses for electricity and refining and transportation energy use for gas and oil. The following multipliers based on DOE national averages were used:

Gas = 1.11
Oil = 1.16
Electricity = 3.4

The distinction between the energy used at the building (site energy) and total energy (source energy) is important as can be seen in the example of an electrically heated building.

Two identical dwellng units located next to each other, one electric and one gas, might use 100 million BTUs (MMBTUs) and 120 million BTUs respectively. The electric dwelling unit seems to use less energy. When total energy is taken into account however, it requires an average of 340 MMBTUs of fuel to deliver 100 MMBTUs of electricity at the building, and only 132 MMBTUs of fuel to deliver 120 MMBTUs of gas. It can be seen from this example that an electric building uses far more total energy than a gas or oil building when conversion and distribution losses are taken into account. This difference is reflected in the much higher cost of electricity per unit of energy. This analysis is based on national averages and would differ for electricity from hydrogeneration.

Conversion to source energy, although based on national averages, is used here as a common denominator to compare energy consumption between different fuel types.

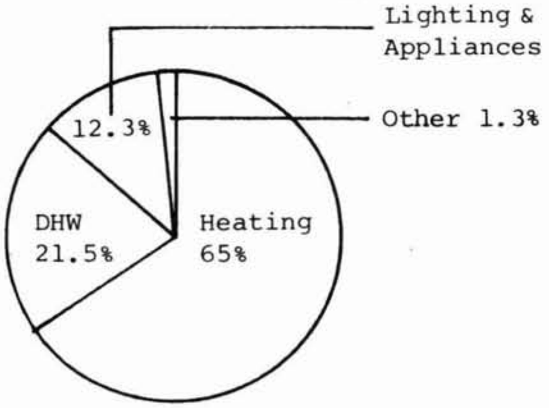
Illustration 4.3

Profile of Existing Public Housing Energy Use by End Use and Fuel Type

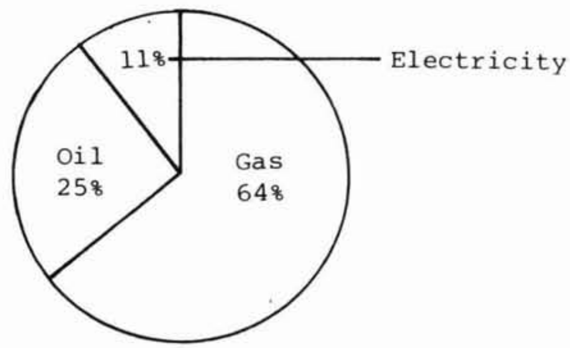
By End Use

By Fuel Type

Existing energy use by percent of site energy consumption (%BTU)

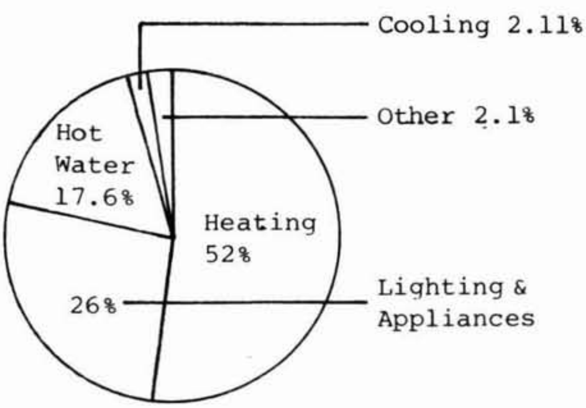


Average - 146.1 million BTU/D.U./Yr.
Total - 162.7 trillion BTU/Yr.

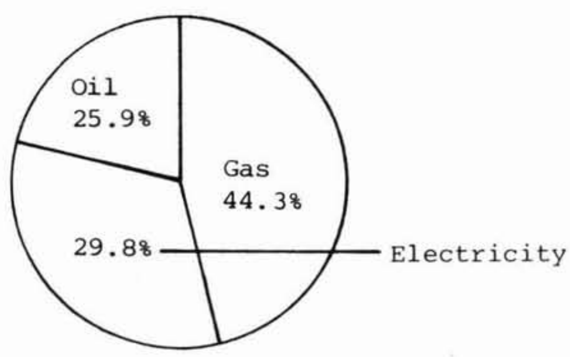


Total - 17.4 million barrels of oil equivalent

Existing energy use by percent of energy costs (%$)



Average - $672/D.U. - 1980
Total - $749 million - 1980



Average cost of fuel - $4.56/million BTU

Based on collected utility rate data, energy use figures were converted to dollars. Since utility rates collected ranged from 1977 to 1979 data, all rates were normalized to first half of 1979. The average energy cost per dwelling unit for 1979 was $547. Assuming a 23 percent cost increase, this amount is estimated to increase to $672 per dwelling unit for 1980.

Table 4.2 summarizes total existing energy use in United States public housing stock.

Among other things, it can be seen from Table 4.2 that electricity, although accounting for only 11% of the energy use in a dwelling, accounts for 27 percent of the energy cost. This is because electricity costs much more per BTU than oil and gas.

Because individual tenant billing data for energy use were not available to the project team, the energy use and costs estimated here include both project and tenant paid energy use.

It can also be seen that public housing pays less for energy than private housing. This is due primarily to larger quantities purchased.

Table 4.2

Annual Existing Energy Use and Energy Data

Annual Energy Use	Dwelling Unit	Total Housing Stock
Site Energy		
- MMBTU	146.1	162,721,650
- Barrels of oil equivalent	25.2	28,100,000
- Gas	64%	1040 million therms
- Oil	25%	289.1 million gallons
- Electricity	11%	5.3 billion kilowatts
Source Energy		
- MMBTU	192	214,000,000
- Barrels of oil equivalent	33.1	36,896,390
- Gas	51.5%	115.4 trillion BTU
- Oil	21 %	47.0 trillion BTU
- Electricity	27.5%	61.5 trillion BTU
1980 Energy Cost (Est.)	$672	$749 million
- Gas	44.3%	$332 million
- Oil	25.9%	$194 million
- Electricity	29.8%	$223 million

Energy Data	Unit Cost	Cost Per Million BTU
Cost of Energy - Early 1979		$3.90/million BTU
- Gas	$.285/therm	$ 2.85/million BTU
- Oil	.461/gallon	3.30/million BTU
- Electricity	.04/kilowatt hr.	11.72/million BTU
Cost of Energy - Early 1980 (based on DOE fuel price escalation factors)		$ 4.56/million BTU
- Gas	$.32/therm	$ 3.15/million BTU
- Oil	$.67/gallon	4.74/million BTU
- Electricity	$.042/kilowatt hr.	12.20/million BTU

Note: Includes both project and tenant paid energy use.

It should be noted that the figures given above for an average dwelling unit do not reflect the great diversity that exists between different types of dwelling units and climates. The range in usage between the prototype dwelling units is over five to one, with individual dwelling unit variations even greater.

These differences can be seen in Tables 4.3 and 4.4 where energy use and energy profile are illustrated by buildng type and climate zone. Table 4.3 illustrates the differences in energy consumption and energy cost between different building types and climate zones.

Table 4.4 illustrates the difference in use of the energy by showing the percent of total energy dollars spent on heating, domestic hot water and electricity for lighting and appliances.

Table 4.3

Annual Energy Use and Cost Per Dwelling Unit

Bldg Type	Climatic Zone: 1	2	3	4	5
LSO			E 160.1 $ 635		
LSG	E 98.7 $ 347	E 148.7 $ 534	E 218.4 $ 706	E 447.5 $ 1221	E 219.0 $ 784
LSE	E 92.0 $ 1221	E 174.5 $ 1547	E 122.3 $ 791		
LCO			E 156.2 $ 451	E 220.1 $ 1107	
LCG		E 224.3 $ 684	E 195.6 $ 656	E 220.4 $ 585	
LCE					
HSO					
HSG					
HSE			E 84.2 $ 302	E 95.6 $ 1219	
HCO			E 100.0 $ 389	E 100.1 $ 377	
HCG		E 97.3 $ 312	E 95.4 $ 397	E 103.5 $ 388	E 109.9 $ 330
HCE					

E = Energy Consumption (MMBTU/yr.)
$ = Dollars spent on energy per average dwelling unit per year.

Table 4.4

Existing Energy Cost by End Use Categories as Percent (%) of Total Energy Cost

Bldg Type	Climatic Zone: 1	2	3	4	5
LSO			57.7 19.8 21.6		
LSG	30.0 22.4 89.5	46.9 19.8 25.1	62.1 11.8 20.0	79.0 7.7 11.8	58.2 13.3 26.5
LSE	43.5 38.0 15.5	71.6 16.4 7.8	63.6 16.6 12.1		
LCO			46.4 18.7 34.2	71.7 16.7 11.6	
LCG		60.5 17.9 21.0	62.13 17.9 19.5	64.8 13.5 19.5	
HSE			53.1 18.8 23.8	64.0 15.2 19.5	
HCO			37.7 15.5 40.0	52.4 22.4 23.2	
HCG		27.3 18.1 37.2	41.1 10.3 41.8	40.5 10.3 39.8	42.4 10.4 37.1

Top number = Heating % of Dollars
Middle number = DHW % of Dollars
Bottom number = Lighting and Appliances % of Dollars

Note:

Lighting and appliances percent is high because electrical costs are much higher than fossil fuel per energy unit. As percent of total energy use lighting and appliances are a much smaller percent.

4.3.2 Energy Conservation Opportunities in Public Housing

There are hundreds of ways to save energy in the residential and non-residential buildings and spaces making up the United State Public Housing stock. These range from such widely applicable measures as installing storm windows to very specific retrofits like installing hydro-pneumatic pumping systems in high rise buildings without roof tanks.

Fifty-eight Energy Conservation Opportunities (ECOs) were found to represent significant energy savings modifications that can be made to the existing Public Housing stock. These fifty eight ECOs are not meant to encompass every possible retrofit, but only those that are expected to be widely applicable and save substantial energy. There is no doubt that there will be additional ECOs that will save energy on a cost-effective basis in a specific project. These additional ECOs were not included in the study in the attempt to analyze only the major ECOs within the limitations of the time and effort available.

It is not the intention of the study to limit funding to only the ECOs mentioned. It is expected that all energy-saving retrofits will be considered when individual projects are surveyed for energy conservation.

The fifty-eight ECOs are grouped into twelve major categories:

Major ECO Group	ECOs
Architectural	AR 1, 2, 3, 4, 5, 6, 7, 8, 9, 10
Space Heating	SH 1, 2, 3, 4, 5
Space Hot Water	SW 1, 2, 3, 4
Space Lighting	SL 1, 2, 3, 4, 5
Space Cooling	SC 1, 2
Central Radiation	CR 1, 2, 3, 4, 5
Central Air	CA 1, 2, 3, 4, 5, 7, 9
Central Heating	CH 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11
Central Heating Distribution	HD 1
Central Water Supply	WS 1, 2, 3
Central Cooling	CC 1, 2, 3
Exterior Lighting	EL 1, 2, 3

The final list of fifty-eight ECOs underwent further refining as a result of their use in the energy analysis. It should be noted that AR 1 and AR 2, as well as CA 3, 4 and 5 were analyzed in combination and will be listed as such in subsequent sections of this report. Combining these ECOs was necessary because of calculation techniques.

A listing of ECOs is included in Table 4.5. A detailed description of each ECO can be found in Appendix 9.0.

Table 4.5

Energy Conservation Opportunities (ECO)

Architectural

AR1 Door Weather Stripping
AR2 Window Weather Stripping
AR3 Attic Insulation
AR4 Floor Insulation
AR5 Roof Insulation
AR6 Storm Window Retrofit
AR7 Insulating Glass
AR8 Storm Doors
AR9 Wall Insulation
AR10 Vestibules

Space Heating

SH1 Reduce Temperature
SH2 Nightime Set Back Thermostat
SH3 Automatic Flue Damper
SH4 Flue Heat Recovery
SH5 Electric Automatic Pilots

Space Domestic Hot Water

SW1 Reduce Temperature
SW2 Flow Restrictors
SW3 New Hot Water Heaters
SW4 Refurbish/Replace Fixtures

Space Lighting

SL1 Delamping
SL2 Reduce Lighting Level
SL3 Automatic Time Control
SL4 Incandescent to Fluorescent
SL5 High Efficiency Ballasts

Space Cooling

SC1 Clean Condensors and Evaporators
SC2 Require High EER Units

Central Air Handling Systems

CA1 Reduce Outdoor Air Intake
CA2 Reduce Supply Air Quantities
CA3 Reduce Outdoor Air Damper Leakage
CA4 Automatic Start and Stop
CA5 Warm-Up Cycle
CA7 Zone Reset Control
CA8 Heat Recovery

Central Heating Boiler

CH1 Boiler Water Maintenance
CH2 Burner Adjustment
CH3 Boiler Control Adjustment
CH4 Automatic Cycling
CH5 Lead/Lag Control
CH6 Reduce Burner Size
CH7 Modulating Burner
CH8 Part Load Boiler
CH9 Automatic Breecher Damper
CH10 Flue Gas Heat Recovery
CH11 Fuel Conversion

Central Heating Distribution

HD1 Refurbish Steam Traps

Central Domestic Water Supply

WS1 Hydro-pneumatic System
WS2 Variable Speed Pumping
WS3 Separate Domestic Hot Water Heater

Central Cooling

CC1 Chiller Control Adjustment
CC2 Ambient Control
CC3 Timed Control

Table 4.5 (continued)

Energy Conservation Opportunities (ECO)

Central Radiation/Convector System		Exterior Lighting	
CR1	Individual Room Control	EL1	Timed Switching
CR2	Zone Control Retrofit	EL2	Photocell Switching
CR3	Radiation Pump Control	EL3	Sodium Vapor Conversion
CR4	Hot Water Reset Control		
CR5	Radiation Part Load Pump		

Energy Conservation Opportunities (ECOs) were analyzed individually to determine savings and capital cost per dwelling unit. A discounted payback analysis was made of each to determine relative economic value.

The significant energy-saving ECOs with low payback included many modifications to the structure such as installing weatherstripping, storm doors and windows and increased insulation. Other major ECOs included setback thermostats for night time temperature reductions and modifications to the central plant to increase efficiency of older equipment. Of major importance were the energy savings attributable to operation and maintenance items (No Capital Cost).

Table 4.6 is a summary of the major ECOs with less than 15 year payback, listed in order of greatest potential dollar savings for the entire public housing stock. Note that these are only presented for comparison; individual projects were found to vary substantially.

The savings presented here are for ECOs analyzed individually and are not additive because many are mutually exclusive when installed in the same project. Others are affected by combination with other ECOs, for example, weatherstripping savings are applicable only if storm windows and doors are not installed because both of them already incorporate weatherstripping.

Since some ECOs are mutually exclusive of one another or are dependent on other ECOs, the total energy savings of combined ECOs would therefore result in less than the total for the ECOs independently. To take this into account, each payback group is reanalyzed to show diminished savings of combined ECOs.

The resulting savings and costs of these three categories, in addition to the "No Cost" ECO savings are shown in Illustration 4.4 along with the curve of diminishing returns that it creates. Note that these results are for the national average, and building types as well as individual projects may vary widely from national averages.

It can be seen that at some point the cost of installing energy conservation opportunities is beyond an incremental fifteen year payback. This point is shown in Illustration 4.4 as a dotted line. At this point investment costs would equal $1347 per dwelling unit and would save $324 per year. Individual projects and building types would, of course, vary substantially depending on their climate and specific characteristics. This variation is analyzed in more detail in Volume 4.

Table 4.6

Summary of Major Energy Conservation Opportunities (ECOs) Analyzed Individually*

Rank	ECO	Expected(1) Applica-Bility To Bldg Type	Actual(2) Applica-Bility Found	Percent Savings Energy Use	Percent Savings Energy Cost
1.	Operation and Maintenance ECOs	100%	100%	14.4%	11.2%
2.	Storm Windows	100	67	10.9	10.3
3.	Storm Doors	70	52	9.2	8.8
4.	Weatherstripping	100	47	8.8	8.2
5.	Setback Thermostat	100	95	10.8	9.9
6.	Automatic Flue Damper	48	45	8.5	7.2
7.	Wall Insulation	70	46	5.6	5.2
8.	Upgrade Faucet Plumbing	100	98	4.3	3.4
9.	Flow Restrictors-Shower	100	98	3.4	3.1
10.	Replace D.H.W. Heater	61	25	2.6	3.1
11.	Flue Heat Recovery	48	3	2.6	2.5
12.	Radiator Room Control	39	13	1.4	1.4
13.	Central Heating Flue Heat Recovery	39	36	1.8	1.8
14.	Roof Insulation	100	33	1.2	1.2
15.	Separate DHW Heater	39	23	.6	.7
16.	Conversion to Fluorescent	100	95	.5	.7
17.	Electric Automatic Pilots	48	45	.8	.74
18.	Vestibules	30	18	.7	.6
19.	Floor Insulation	70	17	.7	.6
20.	Modulating Burner	39	7	.6	.5
21.	Sodium-Vapor Conversion	100	71	.3	.3
22.	Automatic Lighting Level	100	40	.1	.1
			Total	*	*

Notes:

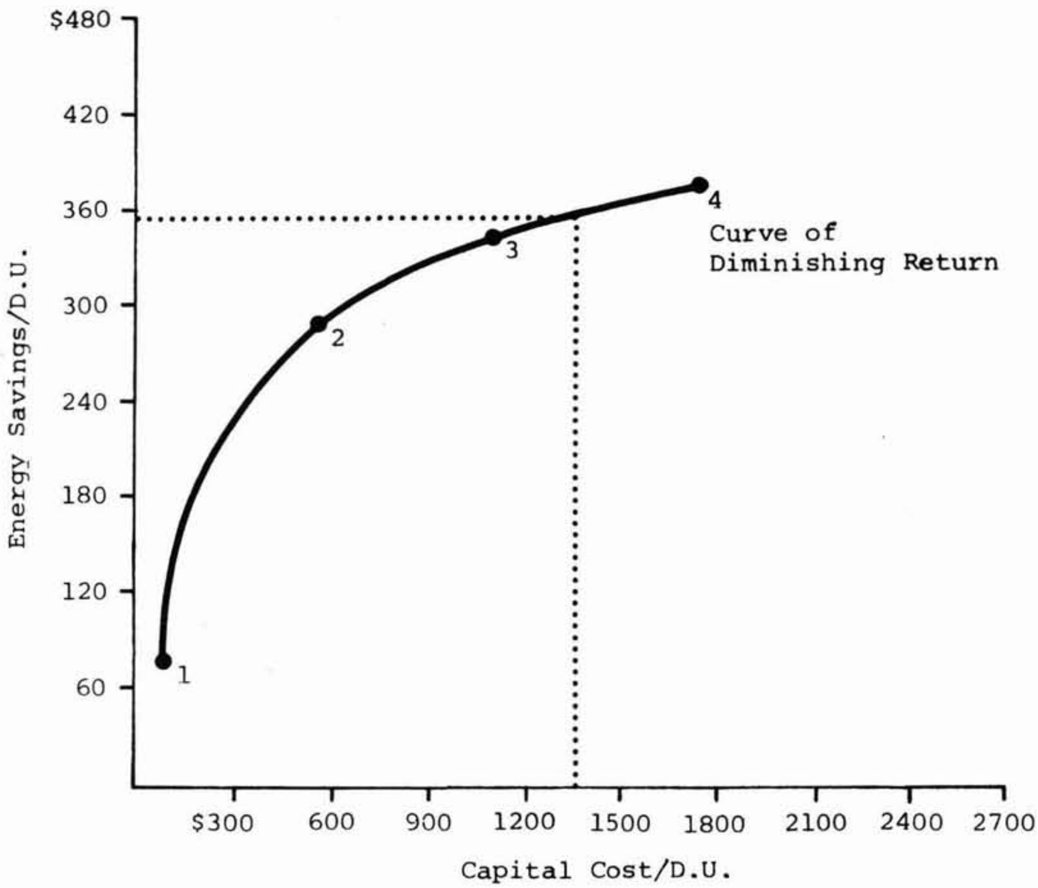
1. This is the percent of the total public housing stock for which an ECO is targeted. Example: Radiator room control is only aplicable to central heating systems which account for 39 percent of the public housing.
2. The percent applicability actually found is the actual number of buildings that this ECO was found to be applicable, not already having it and is cost effective.

* Many ECOs are mutually exclusive or affected by combination with other ECOs which could negate or significantly reduce savings. Because of this individual ECOs are presented here for comparison only and results are not additive. Actual energy savings through a comprehensive energy conservation retrofit program would reflect these combinations and the results are discussed elsewhere in this report.

All ECOs listed above have payback periods of less than fifteen years but are not listed in order of least-to-greatest payback.

Illustration 4.4

Cost/Benefit Analysis of Combined Energy Conservation Opportunities (ECOs)



See facing page for reference to Points 1 - 4 on graph.

Illustration 4.4 (continued)

Cost/Benefit Analysis of Combined Energy Conservation Opportunities (ECOs)

	Average per DU	Site Energy Savings (MMBTU)	Source Energy Savings (MMBTU)	Dollar Savings (%)	Dollar Savings ($)	Capital Cost ($)
1.	All 'no cost' ECOs	21.97	27.57	11.2	75.36	(75.36)*
2.	All ECOs with 5 yr individual payback	75.64	94.55	43.4	291.79	576.10
3.	All ECOs with 10 yr individual payback	86.13	108.45	50.5	339.95	1068.90
4.	All ECOs with 15 yr individual payback	95.90	120.16	56.0	376.50	1745.27
	Marginal payback analysis (dotted line ......)	78	100.4*	48	324**	1347
	Total + Marginal Payback	88,880,000	111,822,000	48	460,860,000	1,500,240,000

+ These totals are extrapolations of 1,113,769 dwelling units(i.e. total PHA stock)
* Cost of maintenance ECOs is assumed to be equal to first year savings
**Discounted 10% for implementation contingencies.

4.3.3 Solar Energy

Public housing, as in most housing, is already partially heated by solar energy which enters through windows (and to a lesser extent through walls) and contributes to the heating of the space. The magnitude of this contribution varies and on average accounts for 5-15% of the annual heating load. The energy conservation analysis in this report took this solar contribution into consideration by assuming that no mechanical heating is needed until the outside temperature drops below 65°F. The heat from occupants, appliances and the sun warms the house until this point.

Increasing this solar contribution through solar energy retrofit involves many alternative techniques varying from adding south facing windows to the use of photovoltaics. Solar has the technical ability to provide 100% of the energy needs for public housing. Although this is possible, it is not cost effective. What is cost effective is to selectively use solar technologies in appropriate applications. Table 4.7 summarizes the results of the solar feasibility study performed as part of this study.

Solar Energy Approach

The physical and economic feasibility of solar retrofit is dependent on a large number of variables that affect system performance (savings), installed cost, maintenance costs and user compatibility. The major variables include:

- climate
- building type
- physical condition of the building and systems
- system type
- building orientation
- roof type and area
- shading conditions
- fuel type
- fuel cost
- user characteristics
- maintenance system.

In order to provide a preliminary study on solar's potential savings and costs and since it was not possible within this study to analyze all 27,000 projects individually, significant prototypes were developed and analyzed in each state in the attempt to include all major variables. Each of these prototypes was analyzed at a level of detail that was practically feasible and, where necessary, simplified assumptions were made.

For each major variable listed below, the state averages were used to estimate energy performance and cost.

- Climate - a representative city in each state is used to model solar and climate data for that state.

- Fuel price - DOE fuel price data are available on a state basis for 1977 which is then escalated to 1980 costs using DOE projections by region.

- Construction Cost - Estimates of system costs for each solar retrofit system based on published national averages are modified using state construction multipliers to reflect local cost differences.

- Extrapolation to Public Housing Totals was based on state estimates of public housing broken down by building type.

- Characteristics of building types existed only for climatic zones. For the state-by-state analysis the predominant climatic zone in each state was chosen as the best approximation. Building type characteristics of that climate zone are then used for that state.

Three typical solar retrofit systems were chosen for each major application - heating, domestic hot water, lighting - and analyzed for energy savings by state. Active solar systems for domestic hot water and combination heating/domestic hot water systems were modeled using the F-chart computer program developed at the University of Wisconsin. Daylighting estimates were modeled based on an in-house computer program - Daylight II. Energy savings, cost savings, capital cost and payback are estimated for each building type in each state.

In recognition of limited funds for energy conservation and solar retrofit applications, a method of ranking opportunities according to cost/benefit (simple payback) analysis is used. This simple payback method is based on existing HUD regulations requiring energy conservation measures to be implemented in order of least-to-greatest payback.

Utilizing this method (described in the HUD rule dated May 7, 1980) two levels of payback are established.

The first is for all systems with paybacks of less than 15 years and the second is for all systems with less than 30 year payback. All results are shown for these 'minimum' and 'maximum' investment categories.

A more complete explanation can be found in Volume 4 of this report.

Solar Energy
Summary of Results

Fuel prices range over 7 to 1 when compred on a per BTU basis. For this reason the largest single factor influencing the economics of solar retrofit systems is existing fuel costs, illustrated by the fact that most cost-effective solar retrofits were in electric projects where electricity prices are high. Highest prices for electricity and fossil fuels were found in the industrial northeast and north central states. It is here that most of the solar retrofits with less than 15 and 30 year payback periods were found, outweighing the Sunbelt states even though their climate is better suited for solar.

Although it is difficult to generalize because of differences in climate and project-specific characteristics, solar is competitive for domestic hot water systems when fuel costs are above \$7/million BTUs, while for combined heating and domestic hot water systems it is competitive only when fuel prices are above \$13/million BTUs. Other types of solar retrofit, such as "passive" solar heating, can be expected to show much better cost benefit results after more detailed analysis is made of this application than was possible in this study.

<u>Domestic hot water</u> accounts for about 18 percent of the energy costs in public housing. It is here that solar energy retrofit systems have their largest immediate potential. Domestic solar hot water systems have been in existence for over 50 years in the United States. Examples of these long-lived systems, in operation since the 1930's, can be found in Georgia's public housing.

Systems that were found to pay back in less than 15 years were those which replaced existing electric systems. Five percent of public housing, primarily low-rise projects with electrically heated domestic hot water, were found to pay back in less than 15 years.

(High-rise electric systems are not feasible because of the extensive plumbing retrofit required.) Seventeen percent of the dwelling units, all-electric systems and some gas and oil systems, were found to pay back in less than 30 years.

Space heating is the largest user of energy in public housing, accounting for 52 percent of the total. Typical combination space heating and domestic hot water retrofit systems were found to be only marginally cost effective when replacing electric heating systems and are not competitive with oil and gas. A more promising solar heating retrofit strategy would be to install simple "passive" solar systems (systems integral to the building design and requiring no mechanical systems) where it is compatible with existing structures and tenant needs. Since passive solar retrofit analysis requires a much more detailed study of project-specific characteristics, no quantitative results were estimated here. Published results of other residential "passive" solar retrofit applications show that, with sensitive design, these strategies can be very cost effective.

It is recommended that "passive" solar retrofit applications be analyzed by individual project during a comprehensive conservation auditing program. In addition, it is recommended that a representative sample of projects be retrofitted with passive solar based on economic optimization.

A pilot program to accomplish this can be expected to cost $1 million and would assess possible tenant conflicts and cost/benefits.

Lighting is a large user of energy in public housing and accounts for 8 percent of the total. Solar lighting retrofit was analyzed in office/public spaces where lighting levels are high and constant during the daytime hours. "Daylighting", as it is called, supplements the electric lighting systems by sensing solar lighting entering the space through the windows.

When solar light is sufficient, electric lights are automatically dimmed. This "daylighting" technique always maintains desired lighting levels while taking advantage of the sunlight existing in the room.

Daylighting is almost always cost effective in offices and public spaces and would require a pro-rated investment of $10 per dwelling unit to install and would save about 10% of the office/public space lighting energy.

Electricity for appliances and lights accounts for only 11% of the energy used in public housing but over 30% of the dollars spent on energy. Alternative energy systems such as photovoltaics are being developed to use solar energy to create electricity.

Photovoltaics is the direct conversion of sunlight into electricity. This is typically done with a silicon cell having an efficiency today of 12-16 percent. The solar cells are mounted on panels and angled toward the sun. Storage of the electricity they generate can be either in batteries or manufacturing of hydrogen to be used in fuel cells. Photovoltaics is a proven technology used to power satellites and remote weather stations for over twenty years.

There is an extensive research and development effort underway by government and private industry to bring down the cost of photovoltaic systems. Substantial progress has been made to date and a goal of $1-2/peak watt installed price is set for 1983-84. This cost level is considered the point where photovoltaics can begin to compete with existing electric costs. A large residential market is seen for photovoltaics after 1984.

The government has been very supportive of photovoltaic technology development and has enacted legislation to encourage its development through direct government purchases. Public housing is a potential market for photovoltaics and should be considered in any government purchasing program designed to demonstrate its technology.

Cooling is not a large energy user in public housing. It represents less than 3 percent of the total energy use. This small cooling energy use is the major difference in the energy profile between public and private housing. It is attributable to its classification as a luxury. This percent is changing as new housing is built and many new high-rise elderly projects incorporate central cooling.

This small use and the high cost of solar cooling technology is why solar cooling is not considered in this report. It is felt that a minimum of a 30 year payback would never be obtained.

Table 4.7

Summary of Solar Retrofit Feasibility Study

Application	All Systems With 15 Yr Payback No. DUs	%	All Systems With 30 Yr. Payback No. DUs	%
Domestic Hot Water (17.6)				
- No of D.U. applic.	51,714	5%	185,907	17%
- Energy Savings - MMBTU[1]	642,125[1]		2,646,008	
- Cost Savings - $/yr	9,884,326	1.33%	23,345,493	3.15%
- Capital Cost - $	121,126,000		449,121,000	
- Combined Payback	12.3		19.2	
Combined Heating (52) and Domestic Hot Water				
- No of D.U. applic.	0[2]	0	34,421	3.1%
- Energy Savings - MMBTU[1]	0[2]		926,370	
- Cost Savings - $/yr	0[2]	0	14,473,636	2.0%
- Capital Cost - $	0		326,042,398	
- Combined Payback	0		22.5	
Lighting (2)				
- No. of projects applic.		90%		100%
- Energy Savings - MMBTU[1]	52,703[1]		16,354,243	
- Cost Savings - $/yr	893,512	.1%	924,096	.1%
- Capital Cost - $	9,790,327		10,347,617	
- Combined Payback	11.0		11.2	
Electricity - (Appliances and Lighting) (27)				
- Energy Savings	0		0	
Cooling (2.1)				
- Energy Savings	0		0	
Totals:[3,4]				
- Energy Savings MMBTU[1]	642,124		3,140,542	3%
- Cost Savings - $/yr	9,884,326	1.4%	31,013,104	4.2%
- Capital Cost	121,125,000		688,921,000	
- Combined Payback	12.1		22.2	

See following page for notes.

Table 4.8 (continued)

Summary of Solar Retrofit Feasibility Study

Notes

1. Energy savings are presented as site energy use per year. Source energy savings would be on the order of 3 times greater because the majority of solar savings is for electricity.

2. Although no 'active' solar system retrofits were found to pay back in less than 15 years, it is expected that 'passive' solar retrofits have a large potential to save heating energy. Because of many unquantified factors effecting 'passive' retrofit, no results could be presented in this limited study. It is recommended that passive solar be studied in greater detail in representative projects and pursued in all energy conservation audit programs.

3. These totals take into account duplicating systems between the domestic hot water analysis and the combined heating and domestic hot water analysis.

4. Totals do not include daylighting results because they are included in the energy conservation opportunities section of the study(see ECO-SL2).

   Numbers in parentheses ( ) indicate the percent of total energy dollars that the application accounts for.

4.3.4 Conclusions

The cost of Energy in the public housing stock for 1980 is expected to exceed $740 million. This averages over $670 per dwelling unit. This average varies widely, more than five to one in some cases, between building types, climates and user characteristics. It is within this context that energy conservation retrofit is being recommended at an investment level of $2 billion to save about half of the existing usage. On a per dwelling unit basis, this investment comes out to between $600 and $1800, depending on type and location. Expected return on this investment will be over 15% with a combined payback of about 6 years for all actions having a payback within 15 years.

An undertaking of this magnitude will require substantial effort and time, and will be subject to many additional concerns aside from economic ones.

This chapter is organized into five sections summarizing the major conclusions of this study.

Recommended Levels of Investment

Based upon the study of ECOs reanalyzed together, graphs were produced to illustrate diminishing return of investment. Such a graph, shown in Illustation 4.4 (previous section), plots investment cost versus energy savings for the average dwelling unit. A marginal cost/benefit analysis suggests a level of investment at the tangent of the curve equal to a fifteen-year payback. Further energy savings are possible beyond this point but on a cost/benefit basis any further reduction in energy savings would require a capital investment yielding greater than 15-year payback.

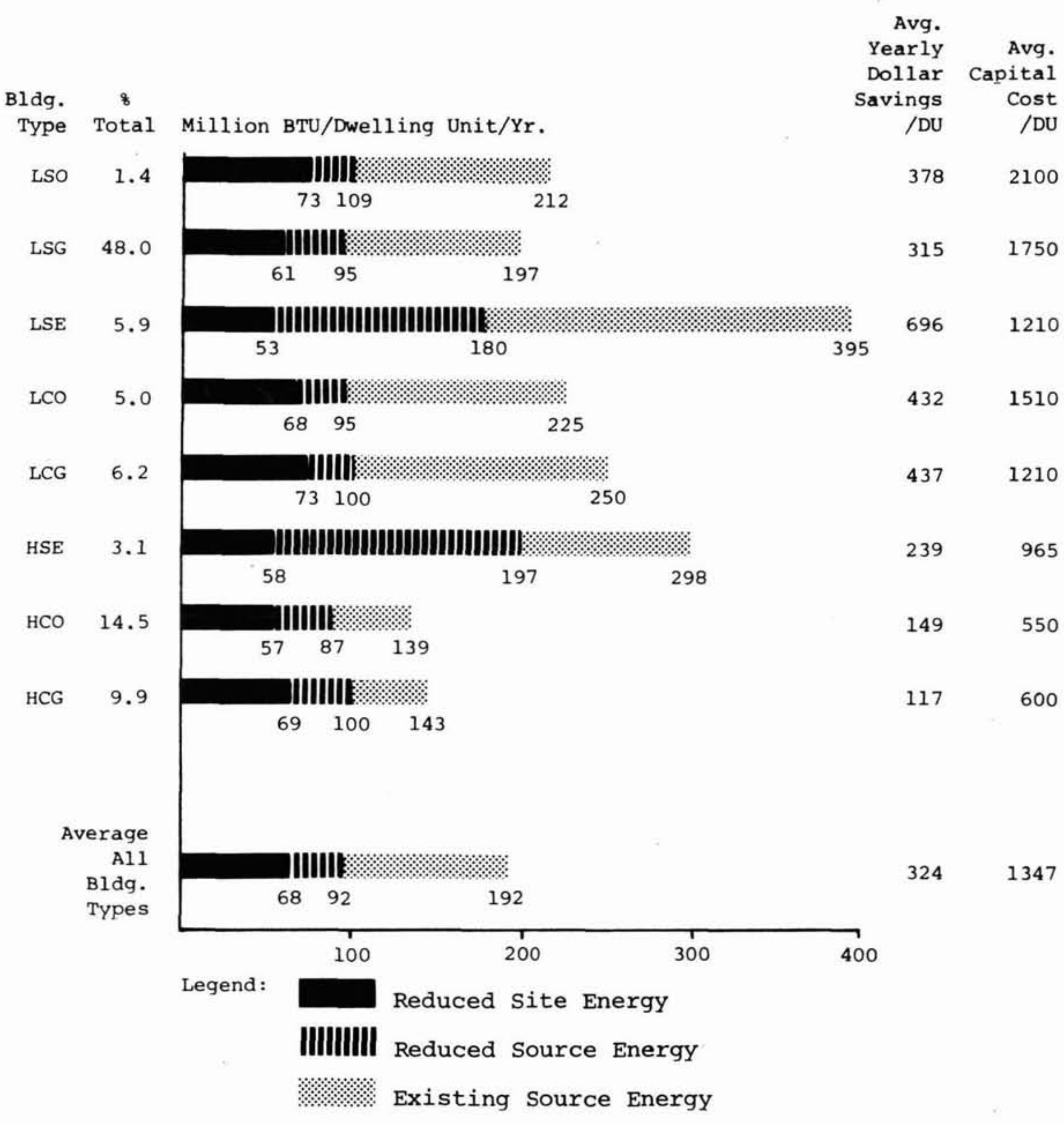
This fifteen-year marginal payback level yields an investment for the average dwelling unit of $1347 (1980) with a corresponding energy savings of $324 per dwelling unit. Individual investment and savings for specific building types or projects will vary widely according to existing conditions.

This investment would reduce the energy consumption for the average dwelling unit by 78 million BTUs a year to 68 million BTUs per year.

The variation in investment level and savings between buildng types can be seen in Illustration 4.5.

Illustration 4.5

Summary of Energy and Dollar Savings for Recommended Energy Conservation Investment Levels



Existing energy consumption varies within building types by climate. In general warmer climates use less energy and colder climates use more. Energy savings would be less in warmer climates and more in colder climates, both as percent of total and in magnitude.

This investment level per average dwelling unit will be less than a corresponding private housing sector energy retrofit because a public housing dwelling unit is smaller in size and because of the corresponding lower unit costs of ECO items due to the large number of dwelling units being retrofitted at one time (quantity discount).

As an example of the $1750 investment level for a low-rise, space heating, gas heating fuel dwelling unit (LSG), which represents almost half of the entire U.S. Public Housing Stock, the following items might be installed.

1.	Maintenance and operational items	$ 70*
2.	Storm windows w/window weatherstripping	$ 510
3.	Storm door w/door weatherstripping	$ 112
4.	Attic insulation	$ 530
5.	Flow restrictors, shower and faucets	$ 30
6.	Setback thermostat	$ 70
7.	Fluorescent light conversions	$ 72
8.	Flue damper w/electric pilot	$ 350
9.	Timed light switching in public spaces and site lighting (prorated to D.U.)	$ 5
	Total all items	$1749

*The cost for operation and maintenance items is assessed to be equal to the first year savings to account for training and increased maintenance efforts.

When extrapolated to the total public housing stock these figures yield the following totals:

Energy conservation opportunity installation -	$1.50 billion
Construction management fees @ 15%	.23 billion
A/E fees @ 5%	.09 billion
Contingency fees @ 20%	.36 billion
Total investment	$2.18 billion
Contract authority	$199 million

This total is exclusive of government overhead and includes a 20% contingency. Allocating a time frame of five years would have to account for inflation.

Total energy savings per year would be $324 million (1980 dollars) after retrofit. Since energy costs can be expected to rise above general inflation for the next decade these savings would increase yearly.

A cost-effectiveness analysis of this program yields a combined payback period (for all ECOs with less than 15 years) of between 6 and 7 years. A discount payback analysis would decrease payback to about 6 years, yielding a return of investment of over 15 percent. The discounted analysis takes into account the rising cost of energy above inflation and the opportunity cost of money (discount rate).

Savings from this program would accrue annually yielding the following totals by the year 2000:

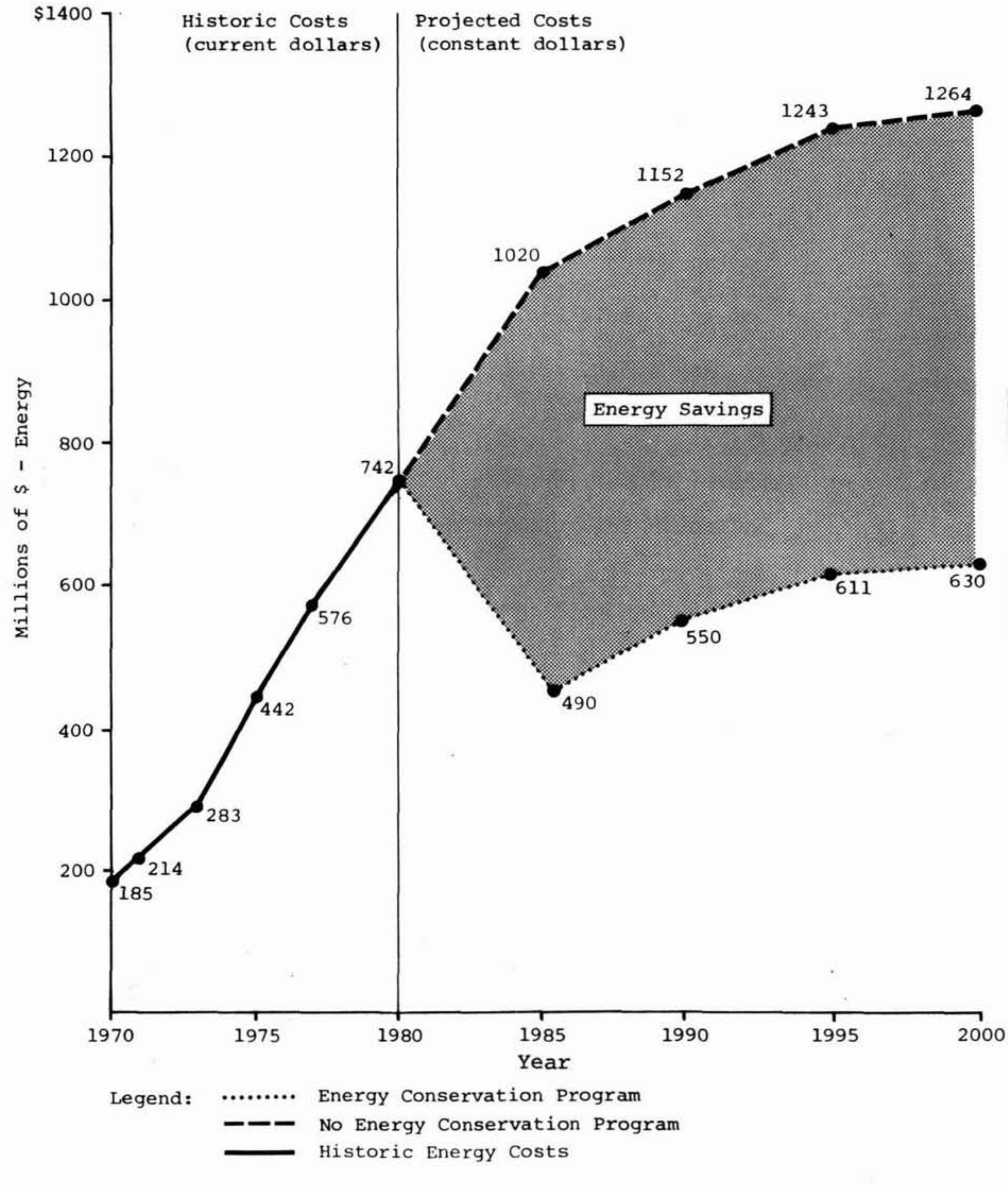
Energy Savings	= 1.5 quads
Barrels of oil equivalent savings	= 250 million
Total energy cost savings	= $8.6 billion
Total implementation cost	= $2.2 billion
Net dollar savings	= $6.4 billion

(Dollar amounts are 1980 constant dollars.) Illustration 4.5 shows these savings.

This analysis assumes a three-year implementation program starting in 1981 and assumes a 4% replacement rate of existing housing.

Illustration 4.6

Twenty-Year Projection of Energy Costs for the Total Public Housing Stock



Solar Energy

In addition to the recommended investment level for energy conservation retrofit, selective solar energy retrofit systems are also cost effective and are recommended for funding.

These systems are primarily for domestic hot water since active solar space heating retrofit systems were found to be only marginally economical. It was found that 5 percent of the public housing stock would have solar domestic hot water systems that payback in less than 15 years, and 17 percent would payback in 30 years.

Solar retrofit in public housing depends on unique building specific characteristics which make any attempt to generalize about solar potential subject to numerous assumptions and simplifications. Ultimately, solar energy feasibility reports must be made individually, at the specific building site, possibly as part of the comprehensive modernization program.

In any event, solar retrofit must be viewed as integrated with energy conservation efforts, since energy conservation measures will initially be more cost effective. Solar retrofit should be considered only after energy conservation is addressed.

Although solar heating retrofit is generally not cost effective, a number of applications were found to payback in less than 30 years. These are generally located in favorable climates where fuel prices are high. In addition to these "active" (requiring mechanical equipment) solar retrofits for heating, it is recommended that "passive" (utilizing non-mechanical methods) retrofit be analyzed as part of the comprehensive energy program.

The following results were obtained by assuming energy conservation opportunities were already installed and are based on the best available data.

These recommended investment levels with their corresponding energy savings are presented for both a minimum solar retrofit program (all systems with less than 15 year payback), and a "maximum" program (all systems with less than 30 year payback).

	Less than 15 yr. payback	Less than 30 year payback
Energy Savings MMBTU	642,124	3,140,542
Cost Savings - $/yr	9,884,326	31,013,104
Capital Cost - $	121,125,000	688,921,000
Combined Payback - yrs.	12.1	22.2

In addition to the savings quantified above, it is expected that "passive solar" retrofit could reduce energy use still further cost effectively, but requires more analysis for quantitative results.

Limitations of Energy Conservation Analysis

The maximum limit of cost effective energy conservation retrofit cannot be determined for a specific project without a detailed survey of its unique physical, climatic and user characteristics, in addition to its specific fuel rate structure and local construction costs. Actual public housing projects vary significantly in their need and application of energy conservation retrofit. A broad overview of the public housing stock's energy conservation potential, such as this report, can only begin to suggest this need.

Because every project is unique, a limited sample of projects, no matter how large, can only be used to develop regional and national averages. There is no possibility that these averages represent specific buildings beyond the most general sense.

Other studies of residential energy conservation retrofit programs indicate that although energy savings of over half of the existing use are technically and economically feasible, results are dependent on accurate assessments and knowledgable actions for specific buildings. This level of expertise and quality is an unknown factor in the analysis.

For these reasons the potential energy savings have been discounted 10 percent to account for normal contingencies in implementation. This number, however, is still only a potential for energy conservation and assumes that implementation will include an accurate assessment of individual projects and a well-managed implementation program with a good quality retrofit construction.

Add
and

Such a comprehensive uniform plan is being developed by this contractor at the present time.

The following items are suggested to speed up the learning curve for energy conservation implementation:

- Create an Energy Task Force within HUD to run a five-year energy conservation program in public housing.

- Assess the savings, costs and other concerns associated with prior energy conservation retrofits in public housing such as individual metering, and added insulation.

- Implement a pilot program immediately for the 1980-81 winter in representative projects whose results will feed into the comprehensive modernization and energy program scheduled for completion in 1981.

  The pilot program should assess the following issues:

  . Management procedures
  . Energy audit methods
  . Role of professional auditors vs. self-assessment by project staff
  . Energy monitoring programs
  . User/Tenant conflicts
  . Administrative and personnel skill levels
  . Savings and costs of select ECOs that are most promising

- Monitor the progress of energy conservation measures being installed in public housing under the rules dated May 7, 1980 and June 23, 1980, that set aside $5 million and $25 million for testing energy conservation measures.

- Set up a central clearing house of energy information relevant to public housing. This would include creating a monitoring program of energy consumption and conservation efforts in public housing with regular feedback to housing authorities.

- Test selected passive solar retrofits in representative projects for cost-effectiveness and social implications.

- Install solar domestic hot water systems in selected projects as part of community job training programs to determine the extent to which existing job assistance programs can be used to reduce costs of installing solar systems while providing beneficial effects on community employment.

4.0 Energy Conservation

5.0

Methodology and Statistical Analyses Appendix

5.1 Results of the Resample

The resample of the public housing projects and the corresponding statistical analysis have been completed. We will assume that the reader has the original report plus the two addenda which follow as we will use the same notation and refer to tables and formulas in these reports.

5.1.1 Data from the Original Sample

Because the cost estimates for some projects were completed after the original report was written and data for some other projects were edited, the original estimates (given November 7) have been changed somewhat. The updated values are given below.

Basic Data

Stratum	Fixed Costs ($ Unit)	In-Unit Costs ($ Unit)	Weight
I	$ 509.79	$ 51.77	.222
II	1,095.04	227.38	.425
III	1,961.08	437.95	.042
IV	869.38	275.22	.311
Total	$ 931.31	$212.12	1.000

Thus, the estimated cost per unit is now $931.31 + $212.12 = $1,143.43, of which 18.6 percent is due to in-unit costs.

P*, the estimated proportion of units contained in projects with positive in-unit costs, is now .597 so that the basic estimator is of the form:

$$\bar{y} = .597\ \bar{v} + .403\ \bar{w}$$

5.1.2 Estimates of Costs Based on the Resample

The updated values of the q_i and x_i, based on the complete original sample, are given below along with the number in the resample per stratum.

Stratum	q_i	$\bar{X}_i^*$	# in Resample
I	.126	152.75	5
II	.454	356.65	17
III	.059	521.79	4
IV	.362	397.25	10
TOTAL	1.000		36

* Averaged over positive in-unit costs.

For the positive in-unit resample, th observed R_{ij}'s are quite concentrated about 1.0, suggesting that the effects of any bias in the original sample are small. Across all 36 observations, the ratios vary from .976 to 1.403 with only five being outside the interval (.98, 1.02). The summary values for the resample are given in the below table.

Stratum	$\bar{R}_i$	Within Stratum Variance	$\bar{v}i$
I	1.000	0.0	152.75
II	1.005	0.000453	358.54
III	1.000	0.0	521.79
IV	1.039	0.00984	412.86

The "Within Stratum Variance" given in the above table is the estimate of the variance of the R_{ij}'s, based on the observed R_{ij}'s in the particular stratum. We pooled these four estimates to get .00299 as our final estimate of variance.

Finally, the estimated in-unit cost per unit for the positive in-unit group is v = \$362.26. This number is the result of weighing the above v_i's by the q_i's.

For the zero in-unit group the resample consisted of 15 projects, of which only 2 were judged to have positive in-unit costs in the resample. These results lead to an estimate of w = \$67.09 for the in-unit costs per unit for the zero in-unit group of projects. We will continue to use this value of \$67.09 in further calculations but it should be noted that this estimate is quite volatile due to one extreme value in the resample. If that value were eliminated, the estimated cost per unit would be \$8.29.

Combining the positive in-unit and zero in-unit groups, we get the estimated cost per unit for in-unit repairs to be y = $243.31. Added to the previously derived estimated fixed costs, the total costs per unit are now estimated by

$931.31 + $243.31 = $1,174.62

This estimate is $31, or 2.7 percent higher than the estimate based on the original sample.

5.1.3 Variance of Estimated In-Unit Costs

The variance of the extimate of the in-unit costs has three components. The first is in the original report while the latter two (dealing with the variance components due to the estimated value of X_i and P^*) are referred to in the two addenda.

Altogether, the estimated standard error of y is $36.74. This results in a 95 percent confidence interval for y of $y \pm 2 \times \$36.74 = \$243.31 \pm \$73.48$. Of course, the estimate for total costs per unit ($1,174.62) has an added component, due to the estimated fixed costs, in its variance and standard error.

5.2 Estimating Characteristics of the Universe

We will gear our method to handle the estimation of proportions as low as .05 (equivalently, as high as .95). Lower proportions can be estimated, but not always with meaningful precision.

Using standard rules of thumb like np (1-p) _5) it can be shown that the normal approximation to the binomial distribution is valid for the p's (i.e., proportions) and sample sizes proposed. For instance, with n 106 the normal approximation is valid for .05_p_.95.

To have faith in an estimate, one would like to know with a certain high probability, that the estimate is within C, a given number, of the true proportion. Typical C's used are .01, .02, .05 and .10; typical confidence probabilities are .90, .95 and .99.

Given C and a confidence probability 1- , the n needed so that we are 1- percent sure that our estimate is within C of the true proportion is

$n = p \times (1-p) \times (Z\ (\ )\ )^2/c^2$ where Z ( ) is the appropriate number from the normal distribution tables (1.645 for 99 percent). This formula is valid when n x p x (1-p) is 5 or more. When n is large, the finite population correction should be used. This is $1 - \frac{n}{10,000}$ since there are about 10,000 projects in the universe.

The formula can be used to get estimates of precision for various n's and p's. We won't do this here except for some special cases.

1. for n = 167 +, one can be 99 percent sure of being within .10 of the true proportion for any p.

2. for n _ 1000, one can be 95 percent sure of being within .05 of any p.

3. for n _ 2000, one can be 90 percent sure of being within .01 of the proportion for any p _.10.

4. for n _ 3000, one can be 90 percent sure of being within .01 for any p _.06.

Additionally, for n _ 3000, one can be sure of being within .02 of the true proportion for any p.

Thus, with n = 3000, we are 99 percent sure of being within .01 for any p _ .06. Thus, if p = .05, we are 99 percent sure the estimate will be between .04 and .06. For any p we are 99 percent sure to be within .02. Thus, if p = .10, we are 99 precent sure that the estimate will be between .08 and .12. This seems to be adequate accuracy.

Instead of random sampling the n = 3000, it is suggested that a 30 percent sample be taken in each state. Except for pathological cases, the national estimate based on aggregating the 50 state estimates will have lower variance than a national random sample of the total sample. (See Cochran, section 5.-).

5.3 Resampling Plan

We are attempting to measure what effect, if any, the sampling method within projects has on the estimated costs of rehabilitation. The concern is that for some or all of the projects within that project but instead sampled from a restricted group determined by practical consideration and/or by the particular housing project's manager. Thus, some bias may have entered into the cost estimation.

The procedure we propose for measuring the suspected bias will be to select a certain subset of the projects for analysis. For these selected projects strict random samples will be taken. Then these results will be extrapolated to give, within a certain tolerance, an estimate of the results if all the projects were to be sampled.

5.3.1 Features of the Present Sample

The projects in the analysis were chosen by a stratified random sample. Then, for each of the selected projects, an estimate of the costs of rehabilitation was determined. This cost has two components, fixed and in-unit. The fixed component is based on various exterior features of the project and interior design defects by the sampling plan within the project. The in-unit component is based on the costs of repair and/ or replacement of items which are unit-specific, thus would not necessarily be in every unit of the project. The in-unit cost estimates obviously can depend on which units were chosen for study.

We will use two pieces of information gleaned from the surveys already done. These are (1) only about 22 percent* of the present cost estimates are in-unit. Thus, the fixed costs, which are not due to the sampling plan, dominate the total cost estimate. (2) There is an observed homogeneity within the projects that allows us to determine sensible bounds on what could happen to the in-unit cost estimates based on any sampling plan.

The basic data are given below.

The strata are

(I) Elderly projects
(II) Non-elderly, 200+ units, _ 10 vacancy rate
(III) Non-elderly, 200+ units, 10 vacancy rate
(IV) Non-elderly, in less than 200 units

Basic Data

Stratum	Fixed Costs ($/unit)	In-unit costs ($/unit)	Weight
I	447.02	46.74	.222
II	948.61	260.29	.425
III	724.43	586.22	.042
IV	704.58	224.36	.311
Total	751.95	215.40	1.000

The weight for a stratum is the proportion of housing units in the universe contained in that stratum. Fixed and in-unit cost estimates are estimated via the standard ratio means.

From the table, the estimated total cost per unit is $751.95 + $215.40 = $967.35 of which 22.3 percent is due to the in-unit costs.

Now we will introduce the needed notation.

*This number, along with all the other numbers reported, is subject to slight change since, at this time, not all the data have been coded for this analysis.

X_{ij} = in-unit cost estimates for the jth project of the ith stratum based on the old sampling method. These costs are known.

Y_{ij} = in-unit cost estimates based on a strict random sample.

V_{ij} = number of units in the ( ) project.

P_i = stratum weight (given in above table)

$\bar{X}_i$ = $_j X_{ij} / \ _j (V_{ij})$

$\bar{Y}$ = is similarly defined.

R_{ij} = Y_{ij}/X_{ij}

We want to estimate

$Y = \ P \bar{Y}$. To attain more precision in the estimate, we will use the information contained in the X's. This necessitates breaking the projects into two groups, the units with positive in-unit cost estimates and those with in-unit cost estimates of zero. Thus, we split Y into two components.

$\bar{Y} = p^* \bar{V} + (1-p^*) \bar{W}$

Where $\bar{V}$ is the average in-unit costs per unit among these projects with X_{ij} greater than zero and W is the average for those projects with X_{ij} equal to zero. P* is the proportion of units contained in the projects with X_{ij} above 0, for the present data, P* = .649.

5.3.2 Proposed Procedure

Our procedure will consist of taking a sample of 35 (yielding an estimate $\bar{v}$) from the positive in-unit group and a sample of 15 (yielding $\bar{w}$) from the zero group. This gives, as our estimate of $\bar{Y}$,

$\bar{y} = .659 \text{ v} + .341 \text{ w}$
which has variance
$(.659)^2 \text{ var } (\bar{v}) + (.341)^2 \text{ var } (\bar{w})$.

The sample of 50 will guarantee, under conservative assumptions, that the estimate of the total costs per unit

$\$751.95 + \bar{y}$

will be within about 8 percent of the "true" estimate.

$\$751.95 + \bar{Y}$

Estimate of $\bar{V}$

First, ${}_4\bar{V}$ can be written

$V = {}_{i=1} \quad q_i \bar{V}_i$ where the q_i are new weights depending on the p_i's and P (=.659).

This information is given in the table below.

Stratum	q_i	x_i	# in Resample
I	.128	124.97	2
II	.470	363.01	18
III	.055	682.91	4
IV	.347	3.9.26	11
	1.000		35

The most important information contained in the present sample is that for essentially all of the projects R_{ij} is between 0 and 3. The lower limit is trivially true; the upper limit is computed by comparing the in-unit costs if all the sampled units were to be in the worst category for the particular project and comparing this with the X_{ij} actually obtained. This induces a correlation between the X_{ij}, thereby suggesting the use of the X_{ij}'s in the estimation procedure. Either a ratio estimate or a probability sample based on the X_{ij} will achieve this purpose. We opt for the latter method for it makes the variance calculations more tractable. Cochran (Sampling Techniques) also has a mild preference for the latter method.

To estimate V we will use

$v = \quad q_i v_i$ where each v_i is an estimate of the corresponding V_i. Based on sampling the projects proportional to their X_{ij}'s.

v_i will equal $X_i \quad R_{ij})/n_i$ where the sum is over the over the n_i projects resampled in the $_i$th stratum. We have no reason to think that the variance of the R_{ij}'s will differ across strata, so we will assume a constant variance $\;^2$.

Then var (v) = $\quad q_i^2 \, X_i^2 \;^2/ni$. Using Neyman allocation, this variance is minimized y taking the n_i to be proportional to the $q_i X_i$. The corresponding n_i's are are given in the last column of the preceeding table.

Estimation of Var (v)

The variance of v is approximately 3139 $\;^2$ using the proposed allocation.

The S^2 is not known exactly, but within a stratum Cochran shows that an estimate of s^2 is the sampling variance of the observed R_{ij}. We will put some bounds on this sampling variance, call it $s2$.

As mentioned previously, the R_{iJ} are bounded by 0 and 3. Fitting a uniform distrbution to this range would give an s^2 about .75 and a $\pm$ 25 interval for V of approximately v + \$97. Besides fitting the uniform distribution, this interval will be conservative if the distribution of the R_{ij}'s is Gaussian-like on (0.3), i.e. unimodal and not too skew. Much more likely, however, is that essentially all the R_{ij}'s will be between .5 and 2. (so the present cost estimates are not less than half nor more than double the estimates based on a strict random sample). For any distribution on the interval (.5, 2.) the above interval is conservative. (s^2 is at most .5625 here.) Since the v $\pm$ \$97 interval is sensible or conservative in all anticipated cases, we feel safe wih n = 35 here.

5.3.3 Estimation of W

This is the estimate of the mean in-unit costs for the projects that have $X_{ij} = 0$. Here we will put the bounds on the Y_{ij} based on knowledge gathered during the original sample. This information is partly due to the instruction given to the interviewers; they were instructed to seek out deteriorated units if there was any suspicion that such units existed based on external signs. Thus, we can be fairly sure that little in-unit costs are present in the projects for whcih $X_{ij} = 0$.

However, the Y_{ij} for these projects certainly can be non zero. Thus, we propose a random sample of 15 projects be chosen to estimate W. This will enable us to get sufficient precision for two cases, the second of which is almost surely conservative. The first case is to assume that one-half of the Y_{ij} are 0 and one-half are \$100/unit. For this case $w \pm 2s$ will be about $w \pm \$333$. The second case allows up to ten percent extremely rundown projects, i.e. needing \$1000 per unit for in-unit costs. Explicitly this second case assumes fifty percent of the Y_{ij}'s are 0, forty percent are 100 and ten percent are \$1000. Then, $\pm$ 2s is approximately $\pm$ \$150. This latter number we consider an upper bound since most likely the distribution of the Y_{ij}'s is similar to the first case, or at worst a combination of the first and second cases.

5.3.4 Total Estimate

The estimate we propose for Y is

$$y = .649\ v + .351\ w.$$

The $\pm$ 2s interval for this estimate is (using the extreme cases for both var (v) and var (w) is

$$y \pm \$82.$$

This \$82 is roughly 8 percent of the original total estimate (of \$967.35). This estimate of \$82 is likely to be significantly too high so that y will actually be a much more precise estimate. However, a $\pm$ \$82 is a "worst-case" estimate based on the knowledge that we have from the original sample.

Estimates prepared by the Department of Housing and Urban Development (1978) counted the total population of low-rent housing units as 1.3 million in 10,000 projects and 2700 authorities.

Additionally, several characteristics were known for the majority of these projects. These characteristics were:

a. Size of project (in dwelling units)
b. Vacancy rate
c. Type of construction (low-rise/high-rise)
d. Type of fuel (oil, gas, electricity)
e. Type of heating distribution (central, space heat)
f. Age of project
g. Type of project (elderly, family).

A two-stage sample was decided on in order to use knowledge gained in the first stage to aid in project selection for the second stage.

First, using a master list of the 10,000 projects, a random sample of 200 projects (2%) was initially selected and surveyed with respect to the cost of bringing those projects up to pre-determined standards regarding modernization, energy conservation and accessibility by the disabled.

Following the initial survey of 200 projects, costs were estimated in each of the three areas of interest and the projects were grouped into mutually exclusive strata that:

a. Were believed to be related to the projects' physical condition (cost of retrofit) and

b. Were known for most of the universe, thereby allowing extrapolation of sample findings.

Analysis of these data suggested that additional projects should be selected from certain strata and surveyed in that these strata represented a disproportionate percent of total cost. Elderly projects, for example, were generally in excellent condition and additional estimates would not significantly impact aggregate costs. However, large inner-city family projects with high vacancy rates were often in poor condition. Though these units represented only 5% of the housing stock, the initial survey suggested that they might account for almost half of the modernization costs required. It was therefore decided to weight the second stage in favor of these high-cost projects as described in Section 2.1. The second stage selection was therefore a stratified random sample. Again, 200 projects were selected.

The universe to which sample results were to be extrapolated was not fully documented in any single file and required the merging of several sources.

Upon thorough analysis of HUD documents in both printed and machine-readable media, it was found that there was no complete file listing each public housing authority with its respective unit count and descriptive characteristics. Characteristics, Report S-11A Consolidated Development Directory, R42 CECA Public Housing with Projects that Have 0% or More Vacancies, and telephone-solicited information from 46 area or service offices, it was determined that there are 2700 public housing authorities administering 1,173,000 units in the nation.

The following sections describe the sample, the universe, and a subset of both called "distressed projects." These sections also contain the methods by which the final count was extrapolated and subsequently costed.

6.1 Development of the Sample

The 400-project sample forms the basis from which all three areas of the study were costed. To arrive at preliminary strata or profile of the universe one-half of the projects were randomly selected from the full list of projects in the universe. Thus, the first 200 projects were surveyed without regard to the location of the last 200. This was done so that interim findings could be made, and if necessary, adjustments could be made to the second 200 projects to be surveyed. Preliminary findings suggested the need to weight the second 200 projects towards large, problem projects since they appeared to be under-represented in the first 200, yet were the most costly to modernize. These projects represented 5% of the total projects and 15-20% of the units in the initial sample of 200. Additionally, 1-2% of the total was visibly deteriorated housing in large family projects in the inner-city with the remaining projects distributed among the more typical low-rise family projects. This subset came to be called "distressed projects" pertaining to a specific modernization dollar cutoff figure.

As with modernization, the first 200 randomly selected and surveyed projects enabled preliminary hypotheses in accessibility and energy conservation. It was found that there was very little formal accommodation for the handicapped. Additionally, interior layouts did not vary significantly among different structural types of projects regardless of the location. This enabled the development of an abbreviated accessibility survey which collected enough information to allow for prototype assignments to each type of project. This procedure for defining accessible prototype units and site is discussed in Section 3.0.

Similarly in energy conservation, the relative homogenity of the 200 surveyed projects with respect to significant structural variables, (e.g. type of construction, building height, fuel type, heat type) also allowed for the development of an abbreviated energy conservation survey. Preliminary analyses suggested that there were 58 possible Energy Conservation Opportunities (ECO) in 25 public housing types. Consequently the remaining energy surveys were directed at filling the cells of a matrix of prototype conditions illustrating ECO's by climatic zone, building type, heat type and fuel type. This matrix is presented in Section 4.0, and in Volume IV - Energy Conservation.

6.2 Description of the Sample

Of the 400 projects selected for the sample survey, 350 projects were used in the final analysis. The remaining 50 projects were not used because 6 were Section 23 - Leased Housing and in the process of being phased out; 32 were Section 8 or on scattered sites and previous experience had demonstrated that such units varied too much in condition to arrive at a single cost figure in any of the three study areas; 6 had sequence numbers no longer under the PHA contract authority as low-rent housing and in 6 the surveyor was not allowed access by the PHA or project management.

The breakdown of these projects with respect to state, city, units, tenant type, age and building height, is shown in the following table.

Table 6.1

Sample Project Characteristics

Case	Project No.	City	State	D.U.	Stories	Tenant Type	Age
1	01047001	HUNTSVILLE	AL	180	2	2	27
2	01048004	DECATUR	AL	124	1	2	18
3	01050003	AUBURN	AL	16	1	2	21
4	01057002	SYLACAUGA	AL	35	1	2	26
5	01077004	TUSCALOOSA	AL	30	1	1	13
6	01126001	BRUNDIDGE	AL	40	1	2	18
7	01139002	JACKSONVILLE	AL	58	1	2	18
8	05002007	NO. LITTLE ROCK	AK	221	5	1	8
9	05004005	LITTLE ROCK	AK	188	2	2	27
10	05004008	LITTLE ROCK	AK	168	6	2	26
11	05020006	FORMAN	AK	20	1	1	4
12	05026003	MORRILTON	AK	40	1	1	8
13	05035003	SEARCY	AK	50	1	1	8
14	05050001	HELENA	AK	152	1	2	28
15	05063001	POCAHONTAS	AK	64	1	1	13
16	06001002	SAN FRANCISCO	CA	469	3	2	37
17	06001009	SAN FRANCISCO	CA	226	2	2	24
18	06001018	SAN FRANCISCO	CA	327	3	2	22
19	06001028	SAN FRANCISCO	CA	100	5	1	8
20	06001033	SAN FRANCISCO	CA	1	2	2	8
21	06002001	NO. LONG BEACH	CA	713	2	2	38
22	06002002	LOS ANGELES	CA	300	2	2	38
23	06002004	LOS ANGELES	CA	504	2	2	4
24	06003033	OAKLAND	CA	3	1	2	9
25	06003069	OAKLAND	CA	42	2	2	7
26	06004006	LOS ANGELES	CA	449	3	2	36
27	06005018	SACRAMENTO	CA	40	2	1	30
28	06006001	FRESNO	CA	86	2	2	37
29	06006003	FRESNO	CA	70	2	2	37
30	06008009	BAKERSFIELD	CA	60	1	2	10
31	06019002	SAN BERNADINO	CA	254	6	2	36
32	06021008	LOMPAC	CA	245	1	2	20
33	06024001	STOCKTON	CA	400	1	2	27
34	06024004	STOCKTON	CA	300	1	2	21
35	06024006	STOCKTON	CA	200	1	2	17
36	06035002	VENTURA	CA	80	2	2	18
37	06052001	MARIN	CA	300	6	2	18
38	06076003	SANTA BARBARA	CA	222	6	1	13
39	06088001	SANTA ROSA	CA	153	3	1	5
40	08001002	DENVER	CO	410	6	2	38
41	08002004	PUEBLO	CO	25	2	2	8
42	08007001	HOLLY	CO	16	1	2	13

Table 6.1 (continued)

Sample Project Characteristics

Case	Project No.	City	State	D.U.	Stories	Tenant Type	Age
43	09003003	HARTFORD	CT	601	5	2	37
44	09003004	HARTFORD	CT	1000	2	2	17
45	09004020	NEW HAVEN	CT	506	3	2	12
46	09006001	WATERBURY	CT	344	5	2	25
47	09009001	MIDDLETOWN	CT	188	2	2	37
48	09019002	GREENWICH	CT	50	1	1	17
49	11001001	WASHINGTON	DC	314	6	2	38
50	11001008	WASHINGTON	DC	169	6	2	38
51	11001020	WASHINGTON	DC	612	6	2	21
52	11001030	WASHINGTON	DC	124	6	1	14
53	12001001	JACKSONVILLE	FL	600	2	2	40
54	12005044	MIAMI	FL	200	5	1	9
55	12012001	AVON PARK	FL	130	1	2	10
56	12016001	SANFORD	FL	125	2	2	28
57	12047001	FORT MYERS	FL	200	1	1	15
58	12047006	FORT MYERS	FL	470	2	2	9
59	12055001	ARCADIA	FL	70	1	2	14
60	12063001	GAINSVILLE	FL	250	1	2	9
61	12065001	MACLENNY	FL	80	1	2	8
62	13003001	ATHENS	GA	54	6	2	39
63	13009006	BRUNSWICK	GA	51	1	2	10
64	1301005	MARIETTA	GA	25	1	1	18
65	13024001	THOMASVILLE	GA	40	1	2	28
66	13025004	CEDARTOWN	GA	20	1	2	21
67	13070002	FITZGERALD	GA	78	1	2	28
68	13086006	WAYNESBORO	GA	14	1	2	28
69	13095006	NEWNAN	GA	70	1	2	13
70	13116001	CARROLLTON	GA	66	6	2	26
71	13119004	CALHOUN	GA	84	1	1	7
72	13133005	ALMA	GA	12	1	2	12
73	13156001	MONTEZUMA	GA	16	1	2	21
74	13161003	HAMILTON	GA	12	1	2	19
75	13232003	COLLEGE PARK	GA	267	2	2	7
76	13243001	BYRON	GA	32	1	2	11
77	15001022	KALAHEO	HA	8	2	2	12
78	15001030	KOOLAN VILLAGE	HA	80	2	2	10
79	15001033	MAILI	HA	20	1	2	10
80	15001055	ELEELE	HA	40	1	1	3
81	16001004	TWIN FALLS	ID	50	1	1	12
82	17001003	E. ST. LOUIS	IL	300	2	2	26
83	17001008	E. ST. LOUIS	IL	285	5	1	12
84	17001017	E. ST. LOUIS	IL	199	5	1	6

Table 6.1 (continued)

Sample Project Characteristics

Case	Project No.	City	State	D.U.	Stories	Tenant Type	Age
85	17002002	CHICAGO	IL	586	2	2	36
86	17002024	CHICAGO	IL	895	4	2	41
87	17002030	CHICAGO	IL	1093	5	2	16
88	17004002	SPRINGFIELD	IL	100	5	1	15
89	17009001	KEWANEE	IL	125	2	2	37
90	17014016	OTTOWA	IL	60	5	1	8
91	17022005	ROCKFORD	IL	209	5	1	10
92	17022006	ROCKFORD	IL	187	5	1	10
93	17024006	JOLIET	IL	330	5	1	8
94	17026001	WAUKEGAN	IL	120	2	2	14
95	17028002	PETERSBURG	IL	16	1	2	18
96	17047002	CARLINVILLE	IL	46	2	2	21
97	17062002	ALTAMONT	IL	14	1	2	12
98	17079002	JACKSONVILLE	IL	236	6	1	11
99	17086002	PRINCETON	IL	22	2	2	9
100	17092002	ELGIN	IL	70	2	2	10
101	18005001	MUNCIE	IN	279	2	2	38
102	18007002	KOKOMO	IN	24	6	2	28
103	18010001	HAMMOND	IN	400	2	2	37
104	18011012	GARY	IN	72	1	2	10
105	18015003	SOUTH BEND	IN	108	6	2	12
106	18017016	INDIANAPOLIS	IN	250	6	2	10
107	18017024	INDIANAPOLIS	IN	248	5	1	5
108	18021004	TERRE HAUTE	IN	44	2	2	8
109	18021005	TERRE HAUTE	IN	194	5	1	5
110	18026002	ELKHART	IN	198	2	2	12
111	19003001	AFTON	IO	30	2	1	12
112	20001010	KANSAS CITY	KN	42	2	2	6
113	20001013	KANSAS CITY	KN	80	1	1	5
114	20002001	TOPEKA	KN	170	1	2	16
115	20066001	SEDGWICK	KN	20	1	2	5
116	21001003	LOUISVILLE	KY	641	2	2	36
117	21015001	NEWPORT	KY	283	2	2	25
118	21059001	FALMOUTH	KY	30	6	2	13
119	21074003	ASHLAND	KY	140	5	1	9
120	22001003	NEW ORLEANS	LA	858	2	2	38
121	22001014	NEW ORLEANS	LA	1860	2	2	22
122	22001039	NEW ORLEANS	LA	202	2	2	7
123	22002001	SHREVEPORT	LA	270	3	2	28
124	22006010	MONROE	LA	152	1	2	6
125	22029006	CROWLEY	LA	140	1	2	6
126	22030004	VILLE PLATTE	LA	30	1	2	11

Table 6.1 (continued)

Sample Project Characteristics

Case	Project No.	City	State	D.U.	Stories	Tenant Type	Age
127	22042003	BOSSIER CITY	LA	56	1	2	21
128	22055006	OPELOUSAS	LA	220	1	2	7
129	22073001	GRAND COTEAU	LA	28	1	2	16
130	22074002	MANY	LA	40	1	2	16
131	22129001	ALEXANDRIA	LA	100	1	2	3
132	23003001	PORTLAND	ME	200	2	2	14
133	23011002	SANFORD	ME	84	5	1	17
134	24002029	BALTIMORE	MD	140	2	2	9
135	24002033	BALTIMORE	MD	161	1	2	10
136	24002045	BALTIMORE	MD	1000	6	2	5
137	24006002	HAGERSTOWN	MD	210	2	2	27
138	24006008	HAGERSTOWN	MD	200	5	1	6
139	25002001	BOSTON	MA	1149	3	2	36
140	25002003	BOSTON	MA	1023	3	2	38
141	25002005	BOSTON	MA	774	3	2	37
142	25002006	BOSTON	MA	508	5	2	28
143	25002007	BOSTON	MA	420	3	2	37
144	25002014	BOSTON	MA	588	5	2	27
145	25002019	BOSTON	MA	732	6	2	25
146	25002020	BOSTON	MA	1504	5	2	25
147	25002034	BOSTON	MA	48	2	1	7
148	25005101	HOLYOKE	MA	167	2	2	40
149	25006001	FALL RIVER	MA	356	2	2	38
150	25007004	NEW BEDFORD	MA	200	2	2	25
151	25012013	WOOSTER	MA	215	5	1	9
152	25012014	WOOSTER	MA	60	5	1	10
153	25035015	SPRINGFIELD	MA	52	5	2	7
154	26001005	DETROIT	MI	428	2	2	38
155	26001008	DETROIT	MI	879	6	2	24
156	26001013	DETROIT	MI	703	6	2	41
157	26035002	BATTLE CREEK	MI	84	6	2	13
158	26054001	LAURIUM	MI	30	3	1	11
159	26117001	IONIA	MI	70	5	1	9
160	27001001	ST. PAUL	MN	489	2	2	27
161	27001004	ST. PAUL	MN	186	5	1	10
162	27001025	ST. PAUL	MN	44	2	2	79
163	27002022	MINNEAPOLIS	MN	28	5	1	14
164	27002025	MINNEAPOLIS	MN	280	4	1	12
165	27002031	MINNEAPOLIS	MN	501	5	1	8
166	27002037	MINNEAPOLIS	MN	220	5	1	8
167	27003033	DULUTH	MN	706	6	2	79
168	27032001	BRAINARD	MN	154	6	1	9

Table 6.1 (continued)

Sample Project Characteristics

Case	Project No.	City	State	D.U.	Stories	Tenant Type	Age
169	28001001	HATTIESBURG	MS	120	2	2	38
170	28057005	MACOMB	MS	20	1	2	17
171	28064002	BAY ST. LOUIS	MS	18	1	2	26
172	28071002	ABERDEEN	MS	60	1	2	21
173	29001001	ST. LOUIS	MO	658	3	2	36
174	29001003	ST. LOUIS	MO	704	2	2	26
175	29001006	ST. LOUIS	MO	112	5	1	16
176	29001012	ST. LOUIS	MO	600	6	2	8
177	29002002	KANSAS CITY	MO	388	0	2	25
178	29002004	KANSAS CITY	MO	730	5	2	18
179	29003001	ST. JOSEPH	MO	150	2	2	8
180	29007003	COLUMBIA	MO	44	2	2	14
181	29040001	HOUSTON	MO	70	1	1	9
182	31001001	OMAHA	NB	386	2	2	39
183	31004002	KEARNEY	NB	80	1	1	10
184	31018001	WYMORE	NB	30	1	1	14
185	32006001	RENO	NV	15	1	2	15
186	34002019	NEWARK	NJ	1680	6	2	16
187	34005005	TRENTON	NJ	81	3	2	27
188	34005011	TRENTON	NJ	108	2	1	9
189	34009002	JERSEY CITY	NJ	462	0	2	37
190	34009010	JERSEY CITY	NJ	712	5	2	20
191	34010004	CAMDEN	NJ	368	2	2	24
192	34010011	CAMDEN	NJ	93	2	2	5
193	34014001	ATLANTIC CITY	NJ	330	6	2	38
194	34024004	MORRISTOWN	NJ	76	5	1	13
195	35012024	KAYENTA	AZ	30	1	2	79
196	35016002	NAMBE	NM	13	1	2	11
197	35050001	SANTA FE	NM	103	1	2	4
198	36005049	BRONX	NY	925	5	2	15
199	36009003	ALBANY	NY	400	5	2	17
200	36009005	ALBANY	NY	354	6	1	5
201	36033003	YONKERS	NY	415	5	2	26
202	36041003	ROCHESTER	NY	66	2	2	39
203	36041012	ROCHESTER	NY	30	2	2	11
204	36041022	ROCHESTER	NY	208	5	1	5
205	36050005	LONG BEACH	NY	66	5	1	7
206	36054001	ITHACA	NY	209	6	1	9
207	36058001	CARTHAGE	NY	100	5	1	8
208	36061001	HUDSON	NY	135	2	2	6
209	37005002	NEW BERN	NC	253	2	2	37
210	37009004	FAYETTEVILLE	NC	220	2	2	26

Table 6.1 (continued)

Sample Project Characteristics

Case	Project No.	City	State	D.U.	Stories	Tenant Type	Age
211	37012010	WINSTON SALEM	NC	198	2	2	10
212	37022001	GREENVILLE	NC	65	1	2	12
213	37051001	ANDREW	NC	50	1	2	9
214	37073001	OXFORD	NC	200	2	2	6
215	38014001	FARGO	ND	250	5	1	4
216	39003017	CLEVELAND	OH	218	4	1	10
217	39003033	CLEVELAND	OH	285	5	1	8
218	39004008	CINCINNATI	OH	1250	4	2	11
219	39005004	DAYTON	OH	138	2	2	36
220	39005005	DAYTON	OH	200	2	2	26
221	39005026	DAYTON	OH	139	0	1	7
222	39007001	AKRON	OH	276	2	2	38
223	39007016	AKRON	OH	106	0	1	9
224	39012004	LORAIN	OH	105	6	2	13
225	39014003	STEUBENVILLE	OH	200	5	1	13
226	40002001	OKLAHOMA CITY	OK	354	2	2	42
227	40002002	OKLAHOMA CITY	OK	242	1	2	5
228	40002003	OKLAHOMA CITY	OK	354	2	2	39
229	40002004	OKLAHOMA CITY	OK	201	5	1	7
230	40002007	OKLAHOMA CITY	OK	288	2	2	8
231	40032001	SEMINOLE	OK	50	1	2	10
232	40047014	ADA	OK	22	1	1	7
233	40073012	TULSA	OK	225	2	2	8
234	41002009	PORTLAND	OR	9	0	1	15
235	41011001	SALEM	OR	50	2	2	10
236	42001001	PITTSBURG	PA	802	3	2	38
237	42001002	PITTSBURG	PA	420	6	2	39
238	42001004	PITTSBURG	PA	660	3	2	36
239	42001007	PITTSBURG	PA	1089	6	2	24
240	42001011	PITTSBURG	PA	324	6	1	15
241	42001012	PITTSBURG	PA	632	6	2	15
242	42001020	PITTSBURG	PA	135	2	2	7
243	42002002	PHILADELPHIA	PA	1000	3	2	38
244	42002010	PHILADELPHIA	PA	816	5	2	25
245	42002013	PHILADELPHIA	PA	746	6	2	25
246	42002032	PHILADELPHIA	PA	200	2	2	37
247	42002036	PHILADELPHIA	PA	576	5	2	19
248	42002076	PHILADELPHIA	PA	175	5	1	9
249	42003008	SCRANTON	PA	90	2	1	7
250	42004002	ALLENTOWN	PA	99	6	2	36
251	42005003	MCKEESEPORT	PA	150	6	2	36
252	42005006	MCKEESEPORT	PA	300	5	2	18

Table 6.1 (continued)

Sample Project Characteristics

Case	Project No.	City	State	D.U.	Stories	Tenant Type	Age
253	42013001	ERIE	PA	224	2	2	37
254	42014001	BEAVER	PA	104	2	2	36
255	42024006	EASTON	PA	60	6	1	5
256	42031003	ALTOONA	PA	168	5	1	6
257	42037005	POTSVILLE	PA	32	2	2	4
258	42064002	CANTON	PA	20	2	2	4
259	42079001	WARRREN	PA	200	5	1	5
260	44001002	PROVIDENCE	RI	420	3	2	39
261	44002001	PAWTUCKET	RI	310	2	2	37
262	44003001	WOONSOCKET	RI	300	2	2	36
263	44004001	CENTRAL FALLS	RI	125	5	1	13
264	44005001	NEWPORT	RI	262	6	2	37
265	44005002	NEWPORT	RI	76	6	2	25
266	44005003	NEWPORT	RI	502	2	2	38
267	45001008	CHARLESTON	SC	216	6	2	26
268	45002007	COLUMBIA	SC	74	2	2	21
269	45008040	LAURENS	SC	14	1	2	25
270	45008055	LAURENS	SC	68	1	1	15
271	45017002	GAFFNEY	SC	58	1	2	26
272	45024001	BARNWELL	SC	40	0	2	9
273	45035001	NEWBERRY	SC	200	2	2	5
274	47003009	KNOXVILLE	TN	270	2	1	12
275	47012009	LAFOLLETTE	TN	24	1	2	16
276	47015009	ATHENS	TN	20	1	1	4
277	47038005	MORRISTOWN	TN	200	1	2	8
278	47068005	SMITHVILLE	TN	34	1	1	8
279	48004004	FORT WORTH	TX	244	3	2	16
280	48004005	FORT WORTH	TX	234	6	2	6
281	48005001	HOUSTON	TX	564	3	2	38
282	48005006	HOUSTON	TX	348	2	2	27
283	48006008	SAN ANTONIO	TX	204	2	2	27
284	48009001	DALLAS	TX	650	2	2	37
285	48009011	DALLAS	TX	3500	6	2	25
286	48018001	LUBBOCK	TX	130	1	2	37
287	48029003	MERCEDES	TX	31	4	1	15
288	48043002	RANGER	TX	26	1	2	13
289	48044002	JEFFERSON	TX	25	1	2	26
290	48049001	PITTSBURG	TX	30	1	2	27
291	48053002	HASKELL	TX	8	1	2	27
292	48062002	EDINGBURG	TX	50	1	2	13
293	48065003	HARLINGTON	TX	200	1	2	36
294	48069002	DELEON	TX	21	1	1	13

Table 6.1 (continued)

Sample Project Characteristics

Case	Project No.	City	State	D.U.	Stories	Tenant Type	Age
295	48078001	SHERMAN	TX	300	2	1	9
296	48080002	ANSON	TX	30	1	1	13
297	48114001	KINGSVILLE	TX	80	6	2	25
298	48121004	NAPLES	TX	10	1	1	12
299	48122005	OMAHA	TX	12	1	1	11
300	48153002	HALTOM	TX	60	1	1	13
301	48177002	DONNA	TX	20	1	2	15
302	48182001	ROTAN	TX	26	1	2	16
303	48190002	STANTON	TX	78	1	2	13
304	48191002	TAFT	TX	30	2	2	14
305	48192003	GORMAN	TX	20	5	1	11
306	48207002	CLARKSVILLE	TX	60	1	1	7
307	48224002	ELSA	TX	50	1	1	13
308	4824001	VERNON	TX	224	2	1	10
309	48315001	ANDREWS	TX	35	1	1	11
310	48318001	MARFA	TX	56	1	1	9
311	48358001	BURNET	TX	52	1	2	27
312	49003008	SALT LAKE CITY	UT	24	2	2	5
313	51001001	BRISTOL	VA	296	6	2	38
314	51003001	NEWPORT	VA	252	2	2	38
315	51007001	RICHMOND	VA	297	3	2	36
316	51007015	RICHMOND	VA	18	2	2	8
317	53001007	SEATTLE	WA	894	1	2	26
318	53002023	SEATTLE	WA	70	3	1	9
319	53002034	SEATTLE	WA	346	2	2	27
320	53008003	VANCOUVER	WA	50	1	2	8
321	54003004	WHEELING	W.VA	100	2	1	16
322	54009001	FAIRMONT	W.VA	60	2	2	13
323	55002022	MILWALKEE	WI	41	2	2	5
324	55014003	BOWLER	WI	34	1	2	6
325	55021001	BRILLION	WI	32	1	2	10
326	55047001	SHEBOYGAN	WI	210	5	1	8
327	55055001	ALBANY	WI	33	3	1	8
328	55093001	SAUK CITY	WI	40	1	1	5
329	55127001	WASHBURN	WI	37	1	1	6
330	78001016	ST. THOMAS	VI	400	3	2	5
331	78001017	ST. THOMAS	VI	300	3	2	5
332	25003005	CAMBRIDGE	MA	282	3	2	41
333	39003016	CLEVELAND	OH	618	6	2	42
334	17108005	ROCK ISLAND	IL	100	3	1	11
335	40002012	OLAHOMA CITY	OK	200	2	2	8
336	06001005	SAN FRANCISCO	CA	208	3	2	25

Table 6.1 (continued)

Sample Project Characteristics

Case	Project No.	City	State	Dwelling Unit	Stories	Tenant Type	Age
337	17003005	PEORIA	IL	202	0	1	8
338	72003087	SAN JUAN	PR	150	0	2	20
339	21024001	HAZARD	KY	88	6	2	16
340	34009012	JERSEY CITY	NJ	205	6	2	8
341	48006007	SAN ANTONIO	TX	275	6	2	26
342	02001005	SITKA	AA	24	2	2	15
343	05002001	NO. LITTLE ROCK	AK	148	1	2	37
344	05002001	NO. LITTLE ROCK	AK	201	5	1	12
345	36002001	BUFFALO	NY	668	3	2	40
346	36002003	BUFFALO	NY	772	2	2	38
347	36002005	BUFFALO	NY	472	6	2	79
348	34002013	NEWARK	NJ	1542	5	2	23
349	34002015	NEWARK	NJ	1206	5	2	19
350	11001013	WASHINGTON	DC	440	3	2	34

Stories:

1 - One Story
2 - Two Stories
3 - Three Stories
4 - Four Stories
5 - Hi-Rise
6 - Hi-Rise/Lo-Rise Combination

Tenant Type:

1 - Project has 50% or more of total units designated for elderly occupancy.
2 - Project has 50% or more of total units designated for family occupancy.

6.3 Extrapolation to the Universe

The universe of low-rent public housing is constantly shifting. This is in large part due to the fact that the development, conversion, listing, exclusion and inclusion processes are decentralized. Consequently, depending upon the analysis period the count of total public housing projects has ranged from 9600 to 10,000. The most complete list available to the project team had 10,000 projects with 1,222,079 units, however the essential descriptive characteristics needed for extrapolation by strata were neither consistently nor randomly available from the listing. It was decided to compile a list from the HUD Form 1885 - Physical Characteristics and R42 CECA Public Housing with Projects that Have 0% or More Vacancies. The result of this listing yielded 5600 more projects with all data necessary for extrapolation.

These projects were not a random sample and could not be used as an estimate of the universe. Consequently, using the complete master file of 10,000 projects, a 30 percent random sample of projects in each state, plus Puerto Rico, the Virgin Islands and the District of Columbia was drawn.

Additionally, for n - 3000, one can be sure of being within .02 of the true proportion for any p. For example, if the true percentage of high-rise projects is 20%, then one can be 95% sure that the estimate of the proportion is between .18 and .22.

Of the 2939 randomly selected projects to be used for extrapolation, data for 2598 projects were returned from the appropriate area offices or from inhouse sources with usable data. Three hundred (300) projects were returned with no readily available data and forty-one (41) projects no longer existed due to razing, phasing out of Section 23 - Leased Housing Contracts - resequencing of numbers, or had never been built. Based upon a recount of total housing projects, the selection resulted in 26% of the total housing projects in the universe for 1,172,486 units.

Since the projects for each state were randomly selected at the field office level of jurisdication, it was assumed that returned data represented a true proportion of each state's projects in both number and type of housing thereby allowing extrapolation on a state-by-state basis.

It was assumed that the percent incidence of the sample's characteristics for each state was the percent incidence of those characteristics for the state's total public housing stock.

Finally, to determine aggregate costs for modernization, energy retrofit and accessibility at the state, regional and national levels, the number of units falling in each stratum at each level of aggregation was counted and multiplied by the relevant mean cost per dwelling unit of retrofit for the surveyed projects. (Note that within each stratum, surveyed projects were selected randomly.)

The table which follows, shows the estimates of dwelling units by state and stratum.

Table 6.2

Low Rent Public Housing Dwelling Units by State and Stratum

State	1	2	3	4	5
Alabama	0	4638	2699	11966	297
Alaska	0	0	0	0	0
Arizona	0	0	0	1782	0
Arkansas	0	0	0	0	1843
California	0	5718	0	26946	0
Colorado	0	0	0	1135	0
Connecticut	2719	0	6045	3167	1588
Delaware	0	0	0	1714	232
District of Columbia	0	0	0	7293	517
Florida	0	0	0	12926	0
Georgia	754	0	4033	14000	2202
Hawaii	0	0	0	1028	279
Idaho	0	0	0	0	0
Illinois	0	0	17706	20763	2176
Indiana	0	987	0	1205	0
Iowa	0	0	0	0	512
Kansas	0	0	1171	0	0
Kentucky	0	0	0	7325	0
Louisiana	0	803	3742	10999	0
Maine	0	0	0	0	0
Maryland	0	0	0	14100	1892
Massachusetts	4560	2729	2598	8972	548
Michigan	0	0	8577	5055	0
Minnesota	0	0	0	0	744
Mississippi	0	0	674	2797	0
Missouri	7921	2142	3536	1999	554
Montana	0	0	0	0	0
Nebraska	0	0	0	0	0
Nevada	0	0	0	0	0
New Hampshire	0	0	0	0	0
New Jersey	5197	0	7047	8953	913
New Mexico	0	0	0	0	0
New York	935	0	81392	17390	2432
North Carolina	0	0	0	12914	0
North Dakota	0	0	0	0	0
Ohio	0	4231	4767	19858	511
Oklahoma	0	4207	0	1859	1037
Oregon	0	0	0	2335	0
Pennsylvania	0	1198	16970	13491	447
Puerto Rico	0	0	11003	29654	1564
Rhode Island	0	1953	1218	5681	353
South Carolina	0	0	0	6129	0

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Table 6.2 (continued)

Low Rent Public Housing Dwelling Units by State and Stratum

State	6	7	8	Total	%
Alabama	15326	1038	2058	38771	3.3
Alaska	1521	0	0	1521	-
Arizona	5027	377	632	7817	1.1
Arkansas	5945	1904	3113	12805	5.7
California	24754	3081	6008	66507	.6
Colorado	2255	2451	1610	7450	1.6
Connecticut	805	3588	557	18469	.3
Delaware	436	407	116	2905	1.0
District of Columbia	618	3459	0	11886	3.3
Florida	13368	10239	2585	39117	4.2
Georgia	22021	4253	1771	49033	.1
Hawaii	2554	0	959	4927	-
Idaho	0	973	0	973	1.5
Illinois	9361	17450	3662	71118	.3
Indiana	5517	7871	1521	17101	.6
Iowa	0	1239	1996	3746	1.8
Kansas	2771	1762	1909	7553	2.5
Kentucky	10312	2424	521	20582	.3
Louisiana	11085	0	2921	29550	2.1
Maine	904	1215	1584	3703	3.5
Maryland	3617	3430	1003	24041	2.2
Massachusetts	6292	7624	8276	41599	1.6
Michigan	6522	3676	2111	25941	1.1
Minnesota	1161	12289	4176	18370	1.9
Mississippi	8691	0	389	12550	.3
Missouri	2167	1905	1899	22121	.7
Montana	2088	0	952	3040	.3
Nebraska	458	1680	6318	8455	.4
Nevada	2932	0	638	3569	3.9
New Hampshire	1720	587	1815	4122	.6
New Jersey	5247	15805	2772	45934	10.6
New Mexico	6288	0	998	7474	3.1
New York	4929	15024	1633	123734	.3
North Carolina	19411	3018	465	35808	4.3
North Dakota	1820	0	2016	3835	1.6
Ohio	5120	11394	4258	50139	.8
Oklahoma	7216	1701	3141	19161	6.2
Oregon	2416	2759	1498	9008	.8
Pennsylvania	20578	14086	5537	72307	1.0
Puerto Rico	7124	0	0	49345	.4
Rhode Island	0	581	0	9785	3.0
South Carolina	5676	0	186	11990	4.6

Table 6.2 (continued)

Low Rent Public Housing Dwelling Units by State and Stratum

State	1	2	3	4	5
South Dakota	0	0	0	0	0
Tennessee	0	1490	0	13661	548
Texas	0	12446	711	10270	548
Utah	0	0	0	0	0
Vermont	0	0	0	0	0
Virgin Islands	0	0	2395	0	0
Virginia	0	0	818	10703	262
Washington	0	5993	0	3679	415
West Virginia	0	0	1576	938	286
Wisconsin	0	0	0	0	198
Wyoming	0	0	0	0	350
Total	22,086	48,455	178,679	312,687	23,248

1. Family Hi-rise ≥200 units, ≥10% vacancy
2. Family Lo-rise ≥200 units, ≥10% vacancy
3. Family Hi-rise ≥200 units, <10% vacancy
4. Family Lo-rise ≥200 units, <10% vacancy
5. Family Hi-rise <200 units
6. Family Lo-rise <200 units
7. Elderly Hi-rise
8. Elderly Lo-rise

Table 6.2 (continued)

Low Rent Public Housing Dwelling Units by State and Stratum

State	6	7	8	Total	%
South Dakota	4090	663	437	5190	.1
Tennessee	15311	1807	2858	35593	.2
Texas	18768	3414	7716	53872	1.5
Utah	227	1137	0	1364	1.4
Vermont	1439	359	313	2110	.5
Virgin Islands	2155	0	0	4550	1.0
Virginia	3532	851	1227	17394	.1
Washington	896	3990	1626	16598	.1
West Virginia	1516	1235	104	5654	.4
Wisconsin	3388	1493	6602	11680	4.2
Wyoming	152	181	0	694	.4
Total	307,466	174,421	105,236	1,172,486	100.1

7.1
Limiting Factors

The Modernization Standards are intended exclusively for existing builings. There are, therefore, a number of limiting factors that would not be present in standards for new construction. Among the more important of these factors are certain design, planning and dimensional considerations; performance standareds for mechanical systems other than readily observable conditions and the greater stringency of local codes. Examples of such limitations include:

1. Design, planning and dimensional considerations are addressed in the Modernization Standards only when they are readily observable or when they directly affect health, safety or relevant qualities of living that can be addressed without major construction expenditure. When wall moving is cost beneficial or has particular relevance to public housing, the standard is provided as a recommendation only.

Example:
Minimum Property Standards room size requirements are not included in these standards, whereas National Fire Protection Association requirements for public egress exit door widths are included in Modernization Levels I and II.

Example:
When kitchen/dining areas cannot accommodate a large family, moving of a non-structural wall is recommended.

2. The Modernization Standards are limited to observable, measurable or implied criteria which can be evaluated without the disruption of any portion of the building, as per direction from HUD.

Example:
Exterior walls shall not be opened to determine the presence of wall insulation where plans are unavailable, whereas attic insulation is addressed in Level II because its presence may be determined by physical inspection.

3. Modernization performance standards for mechanical systems are limited to observable criteria that can be ascertained by the inspectors through site inspection and information obtained from project managers and residents.

Example:
Modernization Standards for elevators address the operation and physical condition of cabs, control panels and leveling whereas Minimum Property Standards requirements for speed and capacity are not included.

4. Standards established in the Minimum Property Standards Guideline for New Construction that cannot be accommodated in existing buildings have been omitted. In these cases, the satisfction of the rehabilitative intent is sufficient. All new work performed for compliance with the modernization Levels I, II and III shall comply with the Guidelines for New Construction.

Example:
For Level II, MPS 508-7.1 required that building entrance door hardware serving more than two families conform to Federal Standards FF-H-00106b, Series 161 or 86. It will be considered that existing locking systems that provide required security and are in good working condition will comply with Level II standards.

5. When local codes are more stringent than the Standards, local codes shall be met.

Example:
In areas receiving greater than average amounts of rain or snow, drainage and ramp ratio requirements become more critical to public health and safety. In such cases as these, more stringent local codes must be adhered to.

6. Modernization standards only address repair items that are cumulatively substantial in scope and are not routine maintenance items regularly corrected by housing authority staff or contractors. It was assumed that the majority of projects being surveyed were at least in part inhabited and, therefore, had some form of maintenance program to address emergency and routine deficiencies.

Example:
The Modernization Standards address conditions of kitchen and bathroom sinks due to normal wear, whereas they do not address leaky faucets or missing washers.

8.1 History of Design Criteria

The design criteria originally developed as the "Accessibility Standard" were developed from the draft ANSI A117.1-1978 standards and other existing accessibility standards across the country. This formed the basis for design of the survey instrument and was ultimately to be used for the cost estimate. As described below, the criteria were changed by HUD at a later date.

Level I of the design criteria was originally interpreted as providing minimum accessibility to a residential building and its site while assuring the health and safety of the occupant. Level II provided for an environment equivalent to that established by the proposed ANSI A 117.1 (1978) Specifications (now ANSI A117.1-1980, which permits the occupant a close to normal life in public housing. Based upon decisions by the contractor however, Level I compliance was in accordance with the proposed ANSI and forms the basis of all cost estimates. The design criteria, survey instruments and additional reference materials used in the development of this portion of the study are contained in Volume III.

Consequently, the two levels of accessibility were defined as Level I - compliance with ANSI and/or its equivalent, and Level II - equal to ANSI with supplemental recommendations. These criteria and standards are contained in Volume III as Acessibility Standards and in the Accessibility Manual as a working paper aimed at implementing accessible units at the public housing authority level.

9.1 Overview

The analysis of the total United States Public Housing stock for existing energy use and potential energy savings was completed in two phases. Phase I was the survey process and Phase II the analysis process. The following overview is diagrammed in Illustration 4.2. (previous section).

During the survey phase, three major tasks were completed before the actual survey could begin. The first was to research, analyze and establish energy use factors and criteria applicable to public housing. This analysis was then applied to create the survey instruments. The survey instruments would be used to record utility data and the significant features of a project to calculate energy use. A classification system for projects was also developed to create a manageable number of housing prototypes for detailed analysis. This classification consisted of twelve building types and five climate zones. These prototypes show the significant energy use and potential savings profile of the public housing stock. After the survey instrument was complete and tested, 350 randomly selected projects were surveyed.

From project data gathered in the field, prototypes were analyzed for distribution of dwelling units and physical characteristics. Of sixty possible prototypes (twelve building types by five climate zones), only 22 were found to be significant. Ninety-five projects, based on dwelling unit distribution and representative physical characteristics, were selected to represent these prototypes. The data on these projects were entered in the computer for detailed energy analysis.

A set of algorithms was developed to determine existing energy use for each prototype. As projects were surveyed and analyzed for energy use, a list of potential energy conservation opportunities (ECOs), with corresponding costs and energy saving algorithms, was analyzed and refined. Energy savings, cost and discounted payback were estimated for each applicable ECO and prototype on a per dwelling unit basis. Based on the results of the economic analysis, ECOs were ranked according to greatest benefit-to-cost and grouped into the following four categories:

1. Operation and maintenance ECOs (No cost ECOs);
2. Less than five-year payback ECOs;
3. Less than ten-year payback ECOs; and
4. Less than fifteen-year payback ECOs.

Since some ECOs are mutually exclusive or interdependent, each payback category was reanalyzed as a group, to show diminishing returns of combined ECOs. The results are four final totals of energy savings and cost, corresponding to the three payback categories and the "No Capital Cost" maintenance ECOs category. These results were then extrapolated to the total Public Housing stock for each prototype and the United States as a whole.

A more detailed discussion of these following topics will follow: Classification of the Public Housing Stock, Survey Instruments, Prototype Development, Existing Energy Estimates, ECO Development, ECO Savings and Cost Estimates, Economic Analysis and Combined ECOs Savings.

9.1.1 Public Housing Classification

Classification of Public Housing Projects is required to perform the following functions:

1. To show the significant energy use and savings profiles of the Public Housing Stock.

2. Development of a manageable number of theoretical housing prototypes for detailed analysis of energy conservation retrofit savings.

3. Elimination and inclusion of groups of ECOs for consideration.

4. Extrapolation of detailed survey data and analytical results to the total housing stock.

A classification system must be sufficiently detailed to describe uniquely the major energy usage and conservation potential characteristics of a housing project. It cannot, however, be so detailed that the population of projects in each cell of the classification system matrix is restricted. The primary purpose of a classification system is to provide an organizational link between the projects for which there is detailed survey data and those projects for which there are only abbreviated physical characteristics.

Based upon available data for the majority of housing projects, the following four classifications were developed:

- Building Configuration (high-rise or low-rise)
- Heating System Configuration (space or central)
- Heating Energy Source (oil, gas or electric)
- Climate Zone (5 degree day zones)

Building configuration was determined primarily by the presence or absence of an elevator, but other general distinctions are also present.

	High-Rise	Low-Rise
Elevator	Yes	No
System Complexities	Air handling systems, central radiation	Simple, usually space heating systems
Control	Complex central temperature control	Simple, local control
Thermal Characteristics	Exterior surface-to-square-footage ratio of .8 to 1.2	Exterior surface-to-square-footage ratio of 1.3 to 2.0
ECO Selection	Central and secondary systems are predominant	Architectural and space heat are predominant

Heating System Configuration was determined primarily by whether the primary heating source was located within the dwelling unit and controlled by the tenant (space) or whether it was centrally located with no or limited control by the tenants (central). A secondary characteristic is that space heating systems are relatively simple and central systems more complex, involving heavy transfer mediums and more sophisticated controls.

A general division between gas, oil, and electric energy in conjunction with the two categories above yields a direct correlation to the cost of supplying heating energy. Cost of heating energy in turn will help determine the applicablility and economic feasibility of many of the energy conservation opportunities.

The advantage of including climate characteristics in the classification system is that the primary energy use in housing is heating, which is directly related to climate. Since the primary determinant of heating energy use is outside temperature, a climate classification based on heating degree days was selected.

The five heating degree day zones are established geographically to create 0 to 2000, 2000 to 4000, 4000 to 6000, 6000 to 8000, and 8000 to 10,000 degree day ranges (zones 1 through 5 respectively). These zones are based on weather data from the United States Weather Bureau.

When building configuration, heating configuration and heating fuel are combined in all possible ways, twelve "building types" are created, each possibly occurring in all climate zones. This combination of twelve building types and five climate zones creates a matrix of sixty cells as illustrated below:

	Climatic Zone				
Building Type	1	2	3	4	5
LSO	x	x	x	x	x
LSG	x	x	x	x	x
LSE	x	x	x	x	x
LCO	x	x	x	x	x
LCG	x	x	x	x	x
LCE	x	x	x	x	x
HSO	x	x	x	x	x
HSG	x	x	x	x	x
HSE	x	x	x	x	x
HCO	x	x	x	x	x
HCG	x	x	x	x	x
HCE	x	x	x	x	x
Total Cells	12	12	12	12	12

Building type code:
L = Low Rise
H = High Rise
S = Space Heating
C = Central Heating
O = Oil Fuel
G = Gas Fuel
E = Electric

9.2 Survey Instrument

Several energy conservation survey instruments were developed during the early period of building audits. The purpose of developing these survey instruments or "building audit questionnaires" was to standardize data collection and organization in order to collect the information required for energy and retrofit savings assessment of the 350 public housing projects surveyed.

The four types of energy conservation questionnaires developed were:

1. Original Long Form
2. Revised Long Form
3. Original Short Form
4. Revised Short Form

Long and short forms differed in the amount of information required by the building auditor during site visits. Completion of both of these forms required the use of building drawings. Revised forms were developed from the original survey forms as a result of a refinement in data requirements. See Volume 4 for samples of survey forms.

The overall data required in the survey instrument consists of the following four major groups.

1. Utility Data
2. Building Envelope Data
3. Specific Area Data
4. Central Systems Data

Following completion of the survey forms, the data were transcribed to computer data entry forms which simulate Hollerith data cards. These data forms were developed as computer input forms consisting of the essential data required for energy and economic analysis of Energy Conservation Opportunities (ECOs).

9.3 Prototype Development

Based on a classification of projects by building type and climate characteristics, prototypes were developed for extrapolation of energy usage, savings and cost to the total U.S. Public Housing Stock.

This classification system consists of twelve building characteristics and five climate zones forming a matrix of 12X5 and consisting of 60 cells. Although each cell represents a possible prototype, it was found by analyzing the total public housing stock that only twenty-two cells or prototypes were significant.

This analysis of the total public housing stock estimated the total number of dwelling units applicable to each cell. A random sample of approximately 30% of total public housing stock provided information on number of projects, number of dwelling units and building types on a per state basis. The sample was extrapolated to the total for each state for each building type.

In order to determine building type distribution within climate zones, an estimate was made of the percent of the state population located in each climate zone. Population per climate zone was estimated by referring to the climate zone map. Building types were assumed to be distributed by climate zone the same way population was.

The results are illustrated in Table 9.1. It can be seen that four building types do not occur in the sample: LCE, HSO, HSG, HCE. This was expected because these combinations, although possible, are not commonly used. Most of the other dwelling units fall into the remaining eight building types and represent 95% of the total. The remaining 5% are abberations that could not be classified within this system, but were included in the total on the assumption that they have approximately the same average energy use as the other 95%.

Further, it can be noted that not all climate zones have a significant percent of dwelling units occurring within a building type. Since the sample of surveyed buildings was limited, it was decided that all cells which have less than one-half percent (.5%) of the total dwelling units would not be used. These cells total 8 percent of total dwelling units.

The twenty-two cells remaining were considered to represent the significant building type/climate zone classifications. These can be seen in Table 9.2.

Public Housing in Hawaii, Puerto Rico and the U.S. Virgin Islands is not included in the analysis due to the significant differences in energy usage resulting from their unique climate and physical characteristics. Public Housing in these locations accounts for 5% of the total and requires individual analysis for assessment of savings.

The 350 projects surveyed were classified as described above and were analyzed for dwelling unit (DU) distribution and physical characteristics to determine the profile of each significant prototype. Of these surveyed projects 95 were selected for detailed energy analysis based upon their representative characteristics and correlation of DUs to the total public housing stock DU distribution. These projects were grouped by type and were used to develop the twenty-two prototypes for extrapolation. Prototypes are averages of the surveyed projects that comprise them.

Table 9.3 illustrates the distribution of dwelling units per prototype for both the total U.S. Public Housing Stock, and the surveyed projects used to develop the prototypes. Differences in percent distribution are attributable to the limited size of the sample.

Extrapolation to the total United States Public Housing Stock is accomplished by multiplying the number of total dwelling units estimated in the Public Housing Stock per prototype by the per dwelling estimated energy use or savings.

Example:
Prototype LSE average energy cost (1979) per dwelling unit = $1113, estimated LSE dwelling units in the total USPHS = 64,853. Total yearly energy cost for this building type: 64,853 dwelling units X $1113/ dwelling unit = $72,181,000/year.

Table 9.1

Breakdown of Total Public Housing Units by Building Type and Climate Zone

	Climate Zone:					
Bldg Type	1	2	3	4	5	Total
LSO	6,124 .5%	2,653 .3%	15,159 1.36%	4,200 .4%	767 .1%	28,903 2.7%
LSG	103,933 9.5%	150,002 13.5%	170,407 15.5%	53,230 4.8%	8,477 .8%	486,049 .46%
LSE	20,701 1.9%	16,511 1.5%	27,641 2.5%	8,240 .7%	3,682 .33%	76,775 7.3%
LCO	0 0	4,259 .4%	38,985 3.5%	16,328 1.5%	5,599 .5%	65,191 6.2%
LCG	1,568 .1%	6,686 .6%	43,138 4.1%	16,103 1.4%	5,348 .5%	72,843 6.9%
LCE	0	0	0	0	0	0
HSO	0	0	0	0	0	0
HSG	0	0	0	0	0	0
HSE	6,055 .5%	9,105 .81%	23,741 2.1%	9,488 .9%	1,148 .1%	49,537 4.7%
HCO	0	971 .1%	118,413 10.7%	42,352 3.8%	5,593 .5%	167,329 15.8%
HCG	5,606 .5%	18,529 1.7%	42,484 3.9%	32,118 2.9%	11,439 1.0%	110,176 10.4%
HCE	0	0	0	0	0	0

Total	1,056,803
Percent of Total Public Housing	95%
Total Public Housing (100%)	1,113,769*

*This is the number used to extrapolate to the total U.S. Public Housing Stock and is exclusive of Hawaii, Puerto Rico and U.S. Virgin Islands but inclusive of miscellaneous building types.

Table 9.2

Significant Building Types / Climate Zones Only

Bldg Type	Climate Zone: 1	2	3	4	5	Total
LSO			15,159 1.4%			15,159 1.4%
LSG	103,933 9.5%	150,002 13.5%	170,407 15.5%	53,230 4.8%	8,477 .8%	486,049 46%
LSE	20,701 1.9%	16,511 1.5%	27,641 2.5%	*		64,853 5.9%
LCO			38,985 3.5%	16,328 1.5%		55,313 5%
LCG		6,686 .6%	43,138 4.1%	16,103 1.4%		65,927 6.2%
LCE						
HSO						
HSG						
HSE		*	23,741 2.1%	9,488 .9%		33,229 3.1%
HCO			118,413 10.7%	42,352 3.8%		160,765 16%
HCG		18,529 1.7%	42,484 3.9%	32,118 2.9%	11,439 1.0%	104,570 9.9%
HCE						
Total						970,707
Percent of Total Public Housing						87.2%

*This cell was not used because preliminary numbers used to determine prototypes indicated less than .5 percent of total. Final estimates raised percentages slightly.

Table 9.3

Distribution of Significant Building Types/Climate Zone for Total and Sample

		Total Public Housing:		Sample:	
Bldg Type	Zone	# of Units	% Total	# of Units	% Total
LSO	3	15,159	1.4	622	4.2
LSG	1	103,933	9.5	1,696	11.5
	2	150,002	13.5	1,913	12.9
	3	170,407	15.5	748	5.1
	4	53,230	4.8	746	5.0
	5	8,477	.8	520	3.5
Total		486,050	46.0	5,623	38.0
LSE	1	20,701	1.9	280	1.9
	2	16,511	1.5	94	.6
	3	27,641	2.5	382	2.6
Total		64,853	5.9	1,433	5.1
LCO	3	38,985	3.5	1,193	8.1
	4	16,328	1.5	240	1.6
Total		55,313	5.0	1,433	9.7
LCG	2	6,686	.6	489	3.3
	3	43,138	4.1	1,198	8.1
	4	16,103	1.4	320	2.2
Total		65,927	6.2	2,007	13.6
HSE	3	23,741	2.1	120	.8
	4	9,488	.9	70	.5
Total		33,229	3.1	190	1.3
HCO	3	118,413	10.7	1,258	8.5
	4	42,352	3.8	438	3.0
Total		160,765	14.5	1,696	11.5
HCG	2	18,529	1.7	321	2.2
	3	42,484	3.9	736	5.0
	4	32,118	2.9	745	5.0
	5	11,439	1.0	663	4.5
Total		104,570	9.9	2,465	16.7
All Bldg. Types Tot.		970,707	87.2%	14,792	100%

Note: Percent distribution of total DUs and prototype DU differ because of limited sample size.

9.4 Existing Energy Usage Calculations

It was necessary to calculate the existing energy usage of the HUD projects, as opposed to using actual fuel data. This approach was required for two reasons. The first reason was that a large portion of the projects surveyed could not provide actual energy consumption data because of incomplete records, or because of individual tenant billing. The second reason was that yearly total fuel consumption data, even if available, did not provide a breakdown of energy consumption by end use such as lighting, heating or domestic water, which is required for energy savings calculations. Calculating energy consumption had the further benefit of providing a common method of comparison between projects since all used the same calculations and weather data source and use profiles were normalized to eliminate abberations. Energy consumption calculations were based on standard algorithms and results were correlated with actual consumption data where they were available.

All energy calculations were based on standard algorithms such as those described in the ASHRAE Handbooks and other engineering manuals. Simplifying assumptions were made when data were not available for detailed analysis. Weather data were based on average years and projects were matched to the nearest city with available weather data.

Existing energy use was calculated by end use category for all prototypes selected for analysis. Existing energy calculations were divided into nine sets of algorithms corresponding to the nine energy end use categories

1. Heating
2. Ventilation
3. Domestic Hot Water
4. Cooling
5. Interior Lights
6. Appliances
7. Exterior Lights
8. Water Supply
9. Elevators

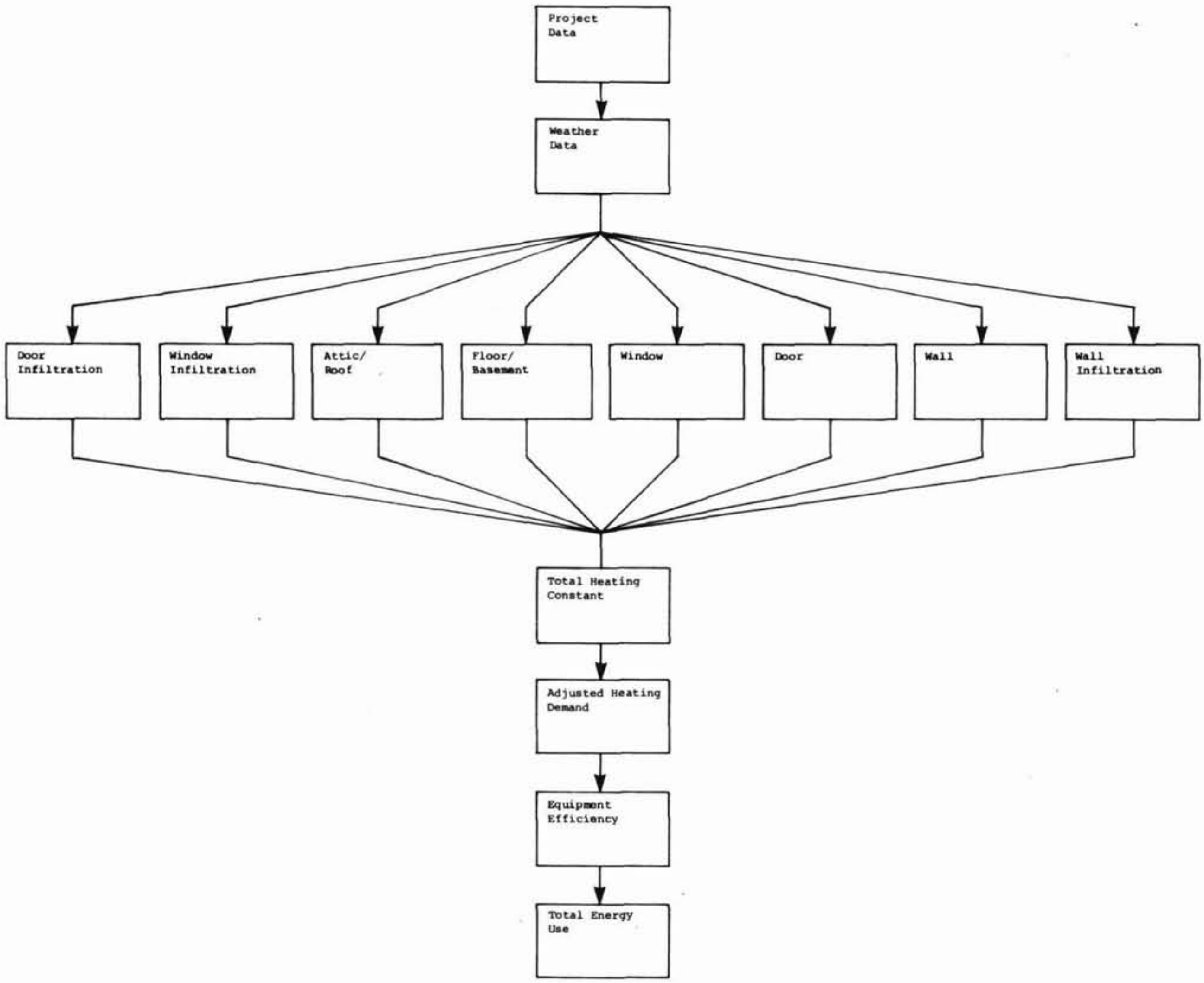
The following is a brief overview of the existing energy use algorithms. All algorithms were programmed into a computer for analysis.

Heating

Heating is the first category of analysis with a set of algorithms divided into two parts. The first part estimates the heating demand of the project; the second part estimates the actual energy consumption by taking into account the heating equipment efficiencies. This calculation procedure is diagrammed in Illustration 9.1 below.

Illustration 9.1

Heating Energy Analysis



The first step is to determine the weather data that are applicable to a project. Temperature "groups" were used to represent hours of temperature occurrence. These take the form of five degrees groups, called "bins", for which number of hours of occurrence are assigned. For example, there may be 35 hours of temperatures between $0^{\circ} \pm 5^{\circ}$ a year. For calculating heating energy use, only temperatures below 65° are considered, because internal heat gain from people, lights and incident solar radiation are expected to be sufficient to satisfy heating requirements between $65^{\circ}F$ and $70^{\circ}F$ ($70^{\circ}F$ being considered the desirable indoor temperature). Each temperature bin is assigned a temperature differential, called delta temperature, between the mean of the temperature bin and the base, $65^{\circ}F$. For example, the delta temperature of the 0°-5° temperature bin is $65^{\circ} - 2.5^{\circ} = 62.5^{\circ}F$.

This temperature differential is used to directly approximate heat loss of the building(s) through envelope and infiltration losses. Heat loss is estimated for eight building components representing the major areas of building heat loss.

The sum of these eight components comprises the total heating constant which, when multiplied by the hours of occurrences for each temperature bin, results in the total heating demand. Adjusting for the type of heating control, the heating demand represents the heat needed to balance the heat loss through the building envelope and through infiltration.

If the heating system consists of a central boiler that also provides ventilation and domestic hot water requirements for the building, these loads are included to obtain a total heating demand for all loads.

Equipment efficiencies are estimated based upon percent load of total capacity. If multiple boilers are used then efficiency is calculated based on proper sequence of units. The heating demand is divided by this percent to obtain the total heat energy used. This load is expressed in 106 BTUs if the fuel source is oil or gas, and in kilowatts, if the fuel source is electricity. Energy units are multiplied by fuel rates obtained from project fuel bills adjusted for inflation to 1979 dollars to finally obtain total dollars spent for heating energy.

Ventilation

Ventilation energy use was calculated only when applicable. Projects with public space were applicable and field data determined whether ventilation was used. Ventilation energy use consisted of the fan energy used to circulate the air and the energy required to heat the outdoor air.

Exhaust fans were estimated as increased air infiltration loads in the heating load section.

Fan energy usage was determined by horsepower data collected in the field and an approximate schedule of use. Heating energy use was calculated by the temperature "bin" method previously described. Outdoor air requirements were assumed to be those recommended by ASHRAE since accurate field data were not available.

Domestic Hot Water

Domestic hot water energy use was applicable to all projects. Energy use was dependent on water temperature, gallons of water used per day, and type of heating equipment.

Domestic hot water energy consumption was calculated by estimating hot water use as a function of type of occupancy, namely family, elderly, or mixed. Hot water temperature data obtained in the field were then used to determine the heating load. Equipment efficiency determined by type, water condition, and age was divided into the load, to determine total consumption.

Cooling

Cooling energy was calculated for individual dwelling unit air-conditioners and central chillers for public spaces. Dwelling unit air-conditioning energy was estimated by data collected at every project. The data included the number of air-conditioners and BTUH ratings by which energy consumption could be estimated. Central chiller calculations used the temperature "bin" method and took into account actual field data on existing chillers and the schedule of operation.

Interior Lights

Interior light energy was calculated for both dwelling units and public areas. Average watts per square foot of lighting in dwelling unit areas was derived from a detailed survey of 50 representative projects. Public area lighting was based on field observations and estimated watts per square foot.

Appliances

Appliance energy was based on average watts per square foot derived from observed field conditions.

Exterior Lights

Exterior light energy was calculated by multiplying the number of site lighting fixtures and average watts per fixture by hours of use per year.

Water Supply

Water supply applied only to high-rise buildings that did not use city water pressure or a roof tank. The motor horsepower of the water pumps was multiplied by a kilowatt conversion factor and the estimated hours of operation per year.

Elevators

Elevator energy usage was calculated in the same way as water supply based upon observed elevator motor horsepower.

Energy Conservation Opportunities

Fifty-eight Energy Conservation Opportunities (ECOs) were found to represent the significant energy savings modifications that can be made to the existing Public Housing. These ECOs are less than the original preliminary seventy-seven ECOs established for analyses. After detailed analyses of calculations, methods, and required data, in addition to studies on the applicability of ECOs to the Public Housing stock, eighteen ECOs were either combined with existing ECOs or eliminated from the list. ECOs are grouped into twelve major categories:

Major ECO Group	ECOs
Architectural	AR 1, 2, 3, 4, 5, 6, 7, 8, 9, 10
Space Heating	SH 1, 2, 3, 4, 5
Space Hot Water	SW 1, 2, 3, 4
Space Lighting	SL 1, 2, 3, 4, 5
Space Cooling	SC 1, 2
Central Radiation	CR 1, 2, 3, 4, 5
Central Air	CA 1, 2, 3, 4, 5, 7, 9
Central Heating	CH 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11
Central Heating Distribution	HD 1
Central Water Supply	WS 1, 2, 3
Central Cooling	CC 1, 2, 3
Exterior Lighting	EL 1, 2, 3

The final list of fifty-nine ECOs underwent further refining as a result of their use in the energy analysis. It should be noted that AR 1 and AR 2, as well as CA 3, 4 and 5 were analyzed in combination and will be listed as such in subsequent sectors of this report.

A listing of ECOs, Table 9.4, followed by a series of ECO descriptions, Table 9.5, is included.

Table 9.4

Energy Conservation Opportunities (ECO) - Key

Architectural	
AR1	Door Weather Stripping
AR2	Window Weather Stripping
AR3	Attic Insulation
AR4	Floor Insulation
AR5	Roof Insulation
AR6	Storm Window Retrofit
AR7	Insulating Glass
AR8	Storm Doors
AR9	Wall Insulation
AR10	Vestibules
Space Heating	
SH1	Reduce Temperature*
SH2	Nighttime Set Back Thermostat
SH3	Automatic Flue Damper
SH4	Flue Heat Recovery
SH5	Electric Automatic Pilots
Space Domestic Hot Water	
SW1	Reduce Temperature*
SW2	Flow Restrictors
SW3	New Hot Water Heaters
SW4	Refurbish/Replace Fixtures
Space Lighting	
SL1	Delamping*
SL2	Reduce Lighting Level
SL3	Automatic Time Control
SL4	Incandescent to Fluorescent
SL5	High Efficiency Ballasts
Space Cooling	
SC1	Clean Condensors and Evaporators*
SC2	Require High EER Units*
Central Air Handling Systems	
CA1	Reduce Outdoor Air Intake*
CA2	Reduce Supply Air Quantities
CA3	Reduce Outdoor Air Damper Leakage
CA4	Automatic Start and Stop
CA5	Warm-Up Cycle
CA6	Not used
CA7	Zone Reset Control
CA8	Not used
CA9	Heat Recovery
Central Heating Boiler	
CH1	Boiler Water Maintenance*
CH2	Burner Adjustment*
CH3	Boiler Control Adjustment*
CH4	Automatic Cycling
CH5	Lead/lag Control
CH6	Reduce Burner Size
CH7	Modulating Burner
CH8	Part Load Boiler
CH9	Automatic Breeching Damper
CH10	Flue Gas Heat Recovery
CH11	Fuel Conversion
Central Heating Distribution	
HD1	Refurbish Steam Traps*
Central Domestic Water Supply	
WS1	Hydro-pneumatic System
WS2	Variable Speed Pumping
WS3	Separate Domestic Hot Water Heater
Central Cooling	
CC1	Chiller Control Adjustment*
CC2	Ambient Control
CC3	Timed Control

Table 9.4 (continued)

Energy Conservation Opportunities (ECO) - Key

Central Radiation/Convector System		Exterior Lighting	
CR1	Individual Room Control	EL1	Timed Switching
CR2	Zone Control Retrofit	EL2	Photocell Switching
CR3	Radiation Pump Control	EL3	Sodium Vapor Conversion
CR4	Hot Water Reset Control		
CR5	Radiation Part Load Pump		

Note: * indicates operation and maintenance (O&M) opportunities which are not reflected by charts.

SH1
SW1
SL1
SC1
SC2
CA1
CH1
CH2
CH3
HD1
CC1

Table 9.5

Energy Saving Rationale

ECO DESCRIPTION	
AR1 and 2 Install Door and Window Weather Stripping	Improving weather stripping at all operable windows and doors decreases infiltration thereby reducing heating energy required to bring the infiltrated air to room temperature.
AR 3, 4 and 5 Add Attic, Floor or Roof Insulation	Addition of insulation in attic, floor and roof spaces would increase the thermal resistance of the space and reduce heat transfer during the winter.
AR6 Storm Window Retrofit	Storm windows will reduce thermal and infilatration losses during the winter months.
AR7 Insulating Glass Retrofit	New insulating glass window provides for a reduced heat flow through windows during heating and cooling seasons and reduces infiltration.
AR8 Install Storm Doors	Storm doors will, like storm windows, decrease thermal and infiltration losses from the space.
AR9 Add Wall Insulation	Addition of wall insulation would increase the thermal resistance of the exterior walls and reduce winter heat transfer through wall surfaces.
AR10 Install Vestibules	Vestibules should be considered in high rise buildings to reduce heat losses from entrance infiltration where there is frequent door usage.
SH1 Reduce Space Temperatures	Energy savings result from reduced heat transfer through exterior surfaces and reduced infiltration heating losses due to the smaller temperature differential between inside and outside temperatures.
SH2 Night Set Back Thermostats	Night set back thermostats allow the space temperature to fall approximately 8 to 10°F during normal sleeping hours. Energy savings result from reduced transmission and infiltration heating losses due to a smaller temperature differential between inside and outside temperatures.

Table 9.5 (continued)

Energy Saving Rationale

ECO DESCRIPTION	
SH3 Automatic Flue Damper	The flue of a residential furnace or space heater discharges unwanted combustion gases to the atmosphere. However, when the furnace is not operating, the flue continues to discharge room air from the space surrounding the furnace because of the stack effect. This air flow is facilitated by the presence of the draft diverter in the gas furnace flue and the air lost has to be replaced by outside air which infiltrates through the building envelope. Installation of an automatic flue damper will essentially eliminate this loss of warm air. When the furnace shuts off, the damper closes and stops the flow of heated air. The energy saved is that energy required to heat cold infiltration air to room temperature.
SH4 Flue Heat Recovery	Approximately 30 percent of the fuel input to the space heater or furnace burners is lost in the combustion gases which go up the flue. Heat exchangers can be installed in furnace flues to recover a portion of the heat lost up the stack. This ECO may also apply to water heaters.
SH5 Electric Automatic Pilots	Energy can be saved by using electrically activated burner pilot lighters in place of gas pilot lights which burn constantly. This ECO may also apply to cooking stoves.
SW1 Reduce Domestic Hot Water Temperature	If the hot water supply temperature to lavatories and showers is reduced, energy can be saved because of the decrease in temperature rise required through the hot water heater and reduced heat loss from stored water through the walls of he heater. Energy savings were calculated based on a reduction of water temperature to 120^{o}F.
SW2 Flow Restrictors-Showers	If the present hot water flows are reduced to showerheads energy saings would result because less water needs to be heated.

Table 9.5 (continued)

Energy Saving Rationale

ECO DESCRIPTION	
SW3 New Hot Water Heaters	As water heaters age, their efficiency tends to decrease through the buildup of deposits which are impossible to remove from the heater. In addition, new hot water heaters are much more efficient and better insulated.
SW4 Refurbish/Replace Plumbing	Flow restrictors on kitchen and bathroom sink faucets will use less water. Sometimes flow restrictors cannot be retrofited to existing faucets, requiring plumbing fixtures to be replaced. New plumbing fixtures will use less water than older, less efficient fixtures. If booster pumps are in use, electrical energy will also be saved due to the smaller pumping load.
SL1 Reduce Lighting Levels (De-Lamping)	Many of the public spaces in housing projects have been designed with excessive lighting capacity. Much of the excess lighting can be taken out of service thereby reducing energy consumption while still maintaining minimum lighting level requirements.
SL2 Reduce Lighting Level (Automatic Control)	Inexpensive devices are now available which use photocells to control the light output of fluorescent fixtures. These devices are preset to maintain a given light level (lower in hallways than offices, for example). The photocell reduces the power to the lighting fixture in proportion to the amount of daylight contribution. Automatic control is applicable to public areas.
SL3 Automatic Timer Control	Time clocks can be used to operate lighting only when required by occupancy. This would prevent lights from being left on after hours. Lighting circuits must be adaptable for retrofit of timers. This action is applicable to public areas.
SL4 Incandescent to Fluorescent Conversion	Fluorescent lighting is approximately three times as efficient in converting electricity to light as incandescent. Fluorescent fixtures use 55 to 65 percent less electricity than the incandescents they replace. Installation is applicable to both public spaces and dwelling units.

Table 9.5 (continued)

Energy Saving Rationale

ECO DESCRIPTION	
SL5 High Efficiency Ballast	Installation of high efficiency ballasts on existing fluorescent fixtures will reduce ballast energy consumption while maintaining present lighting levels.
SC1 Clean Tenant Air Conditioners, Condensers and Evaporators	Most tenant air conditioners have never had their heat exchangers cleaned. The heat transfer efficiency is reduced if this maintenance item is not attended to.
SC2 Replace Window AC Units with High Efficiency Units	If the present standard type window air conditioning units are replaced with high energy efficient units as they need replacement, electrical energy could be saved. This could be accomplished by minimum standards set by the housing authority.
CR1 Individual Room Control	If automatic control valves are installed at individual radiators of overheated rooms, heating energy is saved by controlling the introduction of steam or hot water to radiators and convectors in proporation to the need for heat to maintain a set temperature. If there is no control of radiation, tenants typically open doors and windows to control space temperature, therby wasting energy.
CR2 Zone Control Retrofit	The retrofit of central control valves at the base of distribution risers allows one valve to control heat distribution to the dwelling units and public spaces served by that riser. This retrofit will not provide as accurate control of temperature as individual room control would (CR1), but may be comparable in overall economic benefit if central control valve retrofit is less costly than individual room temperature control.
CR3 Radiation Pump Start/Stop Control	Buildings with central radiation systems will often have only manual start/stop control of the central radiation pumps. Pumps controlled in this manner will continue to operate during outdoor conditions which do not require hot water supply to radiation. An outdoor air temperature controller can be interlocked to the pump starter which will stop the pump(s) when the outdoor

Table 9.5 (continued)

Energy Saving Rationale

ECO DESCRIPTION	
	air temperature exceeds a preset temperature. The controller's sensing element may be mounted so that it senses both the air temperature and the effect of solar radiation further increasing the number of hours for which the pumps may be stopped.
CR4 Hot Water Reset Control	The temperature of hot water supplied to the radiator need only be warm enough to satisfy the building zone with the greatest heating requirement. Supplying heating water at a temperature higher than that required unnecessary thermal loss through the piping system and contributes to overheating of the building. In addition, excessive supply temperature inhibits the proper control action of room control or zone control systems which may have been installed.
CR5 Radiation Part-Load Pump	It is possible to reduce the annual pumping energy requirements by installing pumps of reduced capacity (part-load pumps) which will deliver less supply water during periods of partial heating requirements (typically between 35 and 65°F in temperate climates). When the radiation heating load begins to exceed the capacity of the part-load pump the associated pump controller stops the part-load pump(s) and starts the existing radiation pump(s).
CA1 Reduce Outdoor Air Intake	The heating and cooling of outdoor air brought into a building is a significant building load. If the amount of outside air brought in can be reduced, energy savings will result in proportion to the reduction in air. This reduction in outdoor air quantity often can be accomplished through an adjustment of existing temperature control systems.
CA2 Reduce Air Supply Quantities	Energy savings result from reductions in fan power for both supply and return/exhaust fans when air supply quantities can be reduced within code limitations. This action is accomplished by reducing the speed of both fans through pulley replacement or adjustment. Heating and cooling coils should be cleaned before performing these changes.

Table 9.5 (continued)

Energy Saving Rationale

ECO DESCRIPTION	
CA3 Reduce Outdoor Air Damper Leakage	Heating energy will be saved if outside air intake dampers close tightly when outdoor air is not required. Outdoor air leakage can be reduced in most installations by replacing the damper blade seals and caulking and flashing around the damper frame. Outdoor air dampers which are irreparable should be replaced.
CA4 Automatic Start/Stop	Savings from an automatic supply fan start/stop retrofit arise from timed starting and stopping of fan systems, reducing periods when fans run unnecessarily. This results in savings of fan power and heating and cooling energy.
CA5 Warm-Up Cycle	Implementation of a warm-up cycle will reduce outdoor air intake during fan start up on cold mornings. Energy savings will result from heating indoor air instead of colder outdoor air to bring the building up to temperature.
CA7 Zone Reset Control	Air handling systems which use simultaneous heating and cooling to control temperature can use a zone reset system to limit amount of heating and cooling energy required. Zone thermostat signals are used to adjust the cooling coil temperature so that no more cooling energy is expended than required for the hottest building zone. The same zone signals are also used to adjust the heating coil temperature(s) so that no more heating energy is expended than required for the coolest building zone. When cooling is not in operation (or nonexistent) the zone signals are used to adjust the mixed air temperature.
CA9 Heat Recovery	Heat from exhaust air will be recovered and transferred to the supply air to reduce energy consumption by installing a coil run around cycle, heat recovery wheel, cross flow heat exchanger or heat pipe recovery. In the coil run around cycle, a coil is placed in the exhaust air stream and a similar coil is placed in the make-up supply air stream. A pump circulates water or antifreeze through a piping loop between both coils to accomplish heat transfer, when the make-up air tempera-

Table 9.5 (continued)

Energy Saving Rationale

ECO DESCRIPTION	
	ture is lower than the fan discharge air temperature setting. The heating energy savings are slightly offset by the heat recovery system fan loss and the pump enery usage. Heat recovery wheels, cross flow heat exchanges and heat pipe systems all operate on an air-to-air cycle, eliminating the need for a pump. They require, however, that the supply and exhaust duct work be directly adjacent.
CH1, 2, and 3 Boiler Water and Fireside Maintenance (CH1) Burner Adjustment (CH2) Boiler Control Adjustment (CH3)	Energy can be saved by operating boilers at their peak efficiency. The annual cleaning of boiler heat transfer surfaces, boiler blow down, proper adjustment of fuel oil or gas-to-air mixtures, and water treatment will each improve boiler efficiency. Boiler efficiency should be monitored by CO_2 and temperature measurements of stack gases. These actions are assumed to have been implemented before any of the other Central Heating ECOs are evaluated.
CH4 Automatic Cycling	The heat load on a boiler is dependent on numerous factors, such as outdoor air temperature, building and system mass and occupancy. The heat output of the boiler should vary as the load changes. If it does not do so, space conditions will deteriorate and energy will be wasted. A boiler (especially a steam boiler) with only internal (i.e, steam pressure) controls will tend to overheat spaces when the weather gets warmer, wasting energy in the process. Installation of a boiler cycling control system can minimize this problem. The control system senses outdoor air temperature and the presence of condensate return at a point in the system that may be remote from the boiler. The control then cycles the boiler on a timed basis according to outdoor air temperature and the condensate sensor ensures that heat reaches all parts of the building.

Table 9.5 (continued)

Energy Saving Rationale

ECO DESCRIPTION	
	Energy savings will depend on reduction of the degree of overheating, thermal losses from the boiler and the distribution system and to some degree on the higher level of firing efficiency due to a somewhat higher load on the boiler with less frequent firing.
CH5 Lead Lag Control	A lead lag control sequences multiple boilers so that only the number of boilers needed to satisfy heating demand are in operation. The energy savings result from minimizing standby losses caused by boilers running unnecessarily and from operating boilers close to their full load capacities.
CH6 Reduced Burner Size	If an existing burner on a boiler is oversized, it will operate below full capacity more often than a smaller burner. At low loads, efficiency of a burner decreases. Therefore, the oversized burner will be less efficient than a properly sized burner.
CH7 Modulating Burner	As the heat load on a boiler decreases below full load, the firing rate of the burner should decrease accordingly. One way to do this is with a modulating burner. This type burner will burn less fuel at part load than will a conventional on-off or high-low-off burner. As the load decreases, the conventional burner continues to burn full fuel while the modulating burner will be burning fuel at a rate that more closely matches the load.
CH8 Part Load Boiler	In a system with large boilers, there may be light load conditions when the boilers are running at small percentages of their full-load capacities. Radiative and convective losses remain near full load levels and become a larger percentage of the energy input. If such part load operation is frequent throughout the year, installation of a small boiler to handle the reduced loads will save energy by allowing the larger boilers to be shut down, reducing losses and inefficiencies.

Table 9.5 (continued)

Energy Saving Rationale

ECO DESCRIPTION	
CH9 Automatic Breeching Damper	When a boiler is not being fired, breeching and stack become excellent natural ventilators. They promote the flow of warm air up the stack and out of the building. The cold infiltration air replacing it must then be heated, wasting energy. This air flow up the stack may be stopped by installation of automatic breeching dampers. When the boilers are not operating, the dampers automatically close, sealing room air from the stack. This action applies to boilers which are located in conditioned building spaces.
CH10 Flue Gas Heat Recovery	The exhaust gases from a boiler are normally at fairly high temperatures. This high temperature gas, when exhausted to the atmosphere, carries a significant amount of energy with it. It is possible to install a heat exchanger to recover some of this waste heat and use it to preheat incoming combustion air, returning boiler water and/or DHW. The energy savings would be the amount of preheating that is not already done by the boiler. A drawback of installing such a device is that it presents a flow restriction. This may require stack alterations or mechanical draft generation.
CH11 Burner Fuel Conversion	In buildings which heat with oil and have gas available to them, conversion of the burner from oil to gas firing may be considered if local gas costs are less than oil costs. Heating energy may also be saved through potentially higher boiler operating efficiencies achievable when burning gas. Note: Although this ECO has the potential for reducing energy costs in some projects, this study found that it could not be fully analyzed at this time. The following factors contributed to this situation: - In many cases conversion to gas burners within an oil combustion chamber might decrease efficiency thereby increasing total energy use. This is not considered energy conservation even it it might save money.

Table 9.5 (continued)

Energy Saving Rationale

ECO DESCRIPTION	
	- Accurate cost estimation of this retrofit is very difficult to assess because of the many unknown factors not attainable from the site survey including cost of installing a gas line to a central plant and exact combustion chamber type. - Cost of gas per unit of energy (BTU) is expected to rise faster than oil with some estimates predicting gas will equal oil prices in five years because of deregulation. This escalation of gas prices would make fuel conversion ineffective.
HD1 Refurbish Steam Traps	Faulty steam traps reduce a heating system's efficiency by allowing steam to pass into the condensate return system. Steam in the condensate lines causes higher condensate temperature than normal, which causes greater heat loss from the condensate piping and receivers. Faulty steam traps also cause higher steam consumption by not controlling the flow of steam at the individual radiators. Energy savings will result from lower steam consumption and smaller heat losses from the condensate return system.
WS1 and 2 Hydro-Pneumatic System (WS1) Variable Speed Pumping (WS2)	High-rise projects require pumping systems to deliver domestic water to the upper floors. Many of these systems run constantly, using the same amount of energy input during both conditions of low or high water demand. It is possible to reduce the pumping energy requirements by initiating one of the following retrofits: 1. Hydro-pneumatic systems pump domestic water into a pressurized tank. The tank pressure provides the force required to deliver water to the upper floors. During the periods of low demand the pumps are not required and may be turned off. 2. Variable speed pumping adjusts the pump speed to match the demand for water.

Table 9.5 (continued)

Energy Saving Rationale

ECO DESCRIPTION	
WS3 Separate Domestic Hot Water Heater	In a system where heat for domestic hot water heating is supplied from large heating system boilers, the boilers must remain in operation at all times when domestic hot water is needed. In the summer this may mean that a large boiler is running only to supply domestic hot water. Operation in this manner is wasteful. As the output of a boiler drops to fractional load levels, say 10 percent of full loads, boiler losses increase an additional 10 to 20 percent of the total energy used by the boiler. At these low load percentages, burner combustion efficiency is also decreased, further increasing unnecessary energy losses. For these reasons, installation of a separate domestic hot water heater should be considered.
CC1 Chiller Control Adjustment	Chiller control adjustments will result in energy savings due to increased chiller efficiency.
CC2 Ambient Control	Cooling systems without ambient control will circulate cooling media at a constant temperature regardless of outside air temperature. Installing an ambient control will allow adjustment of the cooling media temperature to supply only the amount of cooling needed to meet loads based on outside temperature.
CC3 Timed Control	Timed control of public area central cooling will allow the system to run only during periods of occupancy. Energy savings will result proportional to the cutback in running time of the system.
EL1 Time Switching	If exterior lighting is manually controlled, additional electrical energy is required to operate those lights which remain on longer than required. Time clocks may be installed to more accurately control the periods during which the lights are turned on. An astrological timer which continually resets its own starting and stopping times according to the day of the year may be used for this operation. The timer installation may also require the installation of contactors to switch the power to the lighting circuits.

Table 9.5 (continued)

Energy Saving Rationale

ECO	DESCRIPTION
EL2 Photocell Switching	A photocell actuated controller can be installed to replace manual switching of exterior lighting. This retrofit may not save quite as much energy as an astrological timer (EL1), for the photocell may cause additional operation of the lights during periods of inclement weather.
EL3 Sodium Vapor Conversion of Fixtures	Sodium vapor fixtures produce approximately twice as much light per watt as mercury vapor lighting and approximately five times as much light per watt as incandescent lighting.

9.5 Energy Conservation Opportunity Analysis

After yearly energy consumption was calculated for each project and prototype, ECOs were analyzed individually.

The ECOs selected for analysis were divided into the following two categories:

1. ECOs that are maintenance or no capital cost items (11 ECOs)
2. ECOs that require an initial capital cost (47 ECOs).

These classifications are referred to as "no cost" and "cost" ECOs. "No cost" ECOs are noted in Table 9.6. Energy savings analyses were performed in two steps to reflect the "no cost" and "cost" distinction between ECOs. It is assumed that all operational and maintenance ECOs (no cost) would be implemented before capital investments were made.

ECO savings analysis was based on the existing energy usage calculations outlined previously. Energy savings estimates were computed by creating temporary data sets with selected data points modified to reflect the implementation of the ECO being analyzed. The predicted savings were the difference between the existing usage and the usage resulting from the ECO (temporary data).

It was possible that an existing project would have some or all of the energy conservation opportunities implemented. Thus, the existing energy program was written to account for the occurrence of most ECOs. With discrete modifications to project data, the performance of most of the ECOs could be simulated.

For example, the "U" value of a window is used to calculate existing use - i.e., 1.13 for single glazing. This is changed to .6 to simulate retrofit of storm windows.

To permit maximum flexibility, the existing energy programs were not altered to calculate ECO savings. A short program was written for each ECO that would create a temporary data set with appropriate changes to the data, run the existing energy program using the temporary data set, and compare the new output to the original existing energy output to find the savings.

Certain ECOs could not be analyzed by changing data. In these cases a direct savings calculation was done.

To enhance the accuracy of the ECO savings predictions, all of the no cost ECOs were analyzed as a group. The resulting energy usage with the no cost ECOs implemented was used as the base for calculating the savings of all cost ECOs.

Cost ECOs were analyzed individually except where experience or physical constraints dictated that more than one ECO would be implemented at the same time. In those cases the designation of the ECOs are shown together, for example, AR1/AR2.

Table 9.6 gives the applicability of the ECOs, indicating compatibility to building type and fuel source, and whether an ECO is to be analyzed independently or not. Table 9.7 shows the relationship of dependent ECOs for beneficial or reduced energy savings effects on one another if implemented together.

Table 9.6

ECO Characteristics

Applicable ECO Characteristics:

		No Capital Cost	Indep-dent	Building Type: Low Rise	High Rise	Heating System: Space Heating	Central Heating	Heating Fuel: Oil	Gas	Electricity
AR1&2	Weather Strip'g			•	•	•	•	•	•	•
AR3	Attic Insulation			•		•	•	•	•	•
AR4	Floor Insulation			•		•	•	•	•	•
AR5	Roof Insulation				•	•	•			
AR6	Storm Windows			•	•	•	•	•	•	•
AR7	Insulating Glass			•	•	•	•	•	•	•
AR8	Storm Doors			•		•	•	•	•	•
AR9	Wall Insulation			•		•	•	•	•	•
AR10	Vestibules				•	•	•	•	•	•
SH1	Reduce Temperature	•		•	•	•	•	•	•	•
SH2	Set Back Thermostat			•	•	•	•	•	•	•
SH3	Auto Flue Damper			•		•		•	•	
SH4	Flue Heat Recovery		•	•		•		•	•	
SH5	Elec Auto Pilots		•	•		•		•	•	
SW1	Reduce Temperature	•		•	•	•	•	•	•	•
SW2	Flow Restrictors			•	•	•	•	•	•	•
SW3	New D.H.W. Heaters			•	•	•		•	•	•
SW4	Upgrade Plumbing			•	•	•	•	•	•	•
SL1	Delamping	•		•	•	•	•	•	•	•
SL2	Auto Light Level		•	•	•	•	•	•	•	•
SL3	Auto Timer Control		•	•	•	•	•	•	•	•
SL4	Conv To Fluorescent		•	•	•	•	•	•	•	•
SL5	High Eff Ballast		•	•	•	•	•	•	•	•
SC1	Clean Cooling System	•		•	•	•				•
SC2	Require High Eer Units	•		•	•	•				•
CR1	Room Control			•	•		•	•	•	
CR2	Zone Control			•	•		•	•	•	
CR3	Pump Control			•	•		•	•	•	
CR4	H.W. Reset Control			•	•		•	•	•	
CR5	Part Load Pump			•	•		•	•	•	
CA1	Reduce Out Air Intake	•	•	•	•		•			
CA2	Reduce Supply Air		•	•		•	•			
CA3-5	Upgrade Air System		•	•	•		•			
CA7	Zone Reset Control		•	•	•		•			
CA9	Heat Recovery		•	•	•		•			
CH1	Boiler Water Maint'ce	•		•	•		•	•	•	
CH2	Adjust Burner	•		•	•		•	•	•	
CH3	Adjust Burner Control	•		•	•		•	•	•	
CH4	Auto Cycling			•	•		•	•	•	
CH5	Lead/Lag Control			•	•					
CH6	Reduce Burner Size			•	•		•	•	•	
CH7	Modulating Burner			•	•		•	•	•	
CH8	Part Load Burner			•	•		•	•	•	
CH9	Auto Breech Damper			•	•		•	•	•	
CH10	Flue Heat Recovery			•	•		•	•	•	
CH11	Fuel Conversion			•	•		•	•	•	
HD1	Upgrade Stem Traps	•		•	•		•	•	•	
WS1	Hydro-Pneu System				•	•	•	•	•	•
WS2	Var Speed Pump				•	•	•	•	•	•
WS3	Sep D.H.W. Heater			•	•	•	•	•	•	•
CC1	Adjust Chiller Control	•		•	•	•	•	•	•	•
CC2	Ambient Control		•	•	•	•	•	•	•	•
CC3	Timed Control		•	•	•	•	•	•	•	•
EL1	Timed Switching		•	•	•	•	•	•	•	•
EL2	Photo Switching		•	•	•	•	•	•	•	•
EL3	Sod-Vapor Conversion		•	•	•	•	•	•	•	•

Table 9.7

Energy Conservation Opportunity Relationship Matrix

	AR1&2 Weather Strip'g	AR3 Attic Insulation	AR4 Floor Insulation	AR5 Roof Insulation	AR6 Storm Windows	AR7 Insulat'g Glass	AR8 Storm Doors	AR9 Wall Insulation	AR10 Vestibules	SH2 Set Back Thermos	SH3 Auto.Flue Damper	SH4 Flue Heat Recov.	SH5 Elec.Auto.Pilots	SW2 Flow Restrictors	SW3 New DHW Heaters	SW4 Upgrade Plumbing	SL2 Auto.Light Level	SL3 Auto.Timer Contr	SL4 Conv.to Fluoresc	SL5 High Eff.Ballast	CR1 Room Control	CR2 Zone Control	CR3 Pump Control	CR4 H.W. Reset Contr	CR5 Part Load Pump	CA2 Reduce Sup. Air	CA3-5 Upgrade Air Syst	CA7 Zone Reset Contr	CA9 Heat Recovery	CH4 Auto Cycling	CH5 Lead/Lag Control	CH6 Reduce Burner Sz.	CH7 Modulat'g Burner	CH8 Part Load Boiler	CH9 Auto.Breech Damp	CH10 Flue Heat Recov.	CH11 Fuel Conversion	WS1 Hydro-Pneu Syst.	WS2 Var. Speed Pump	WS3 Sep. DHW Heater	CC2 Ambient Control	CC3 Timed Control	EL1 Timed Switching	EL2 Photo Switching	EL3 Sod-Vapor Conver
AR1&2 Weather Strip'g		o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
AR3 Attic Insulation	o		o	●	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
AR4 Floor Insulation	o	o		o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
AR5 Roof Insulation	o	o	o		o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
AR6 Storm Windos	●	o	o	o		●	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
AR7 Insulat'g Glass	●	o	o	o	o		o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
AR8 Storm Doors	●	o	o	o	o	o		o	●	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
AR9 Wall Insulation	o	o	o	o	o	o	o		o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
AR10 Vestibules	●	o	o	o	o	o	o	o		o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
SH2 Set Back Thermos	◐	◐	◐	◐	◐	◐	◐	◐	◐		o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
SH3 Auto.Flue Damper	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐		o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	●	o	o	o	o	o	o	o	o	o	o
SH4 Flue Heat Recov.	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐		o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
SH5 Elec.Auto.Pilots	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	o		o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
SW2 Flow Restrictors	o	o	o	o	o	o	o	o	o	o	o	o	o		o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
SW3 New DHW Heaters	o	o	o	o	o	o	o	o	o	o	o	o	o	o		o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	●	o	o	o	o	o
SW4 Upgrade Plumbing	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o		o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
SL2 Auto.Light Level	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o		o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
SL3 Auto.Timer Contr	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o		o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
SL4 Conv.to Fluoresc	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o		o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
SL5 High Eff.Ballast	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o		o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
CR1 Room Control	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o		●	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
CR2 Zone Control	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o		o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
CR3 Pump Control	+	+	+	+	+	+	+	+	+	o	o	o	o	o	o	o	o	o	o	o	●	●		●	●	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
CR4 H.W. Reset Contr	+	+	+	+	+	+	+	+	+	o	o	o	o	o	o	o	o	o	o	o	●	●	o		●	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
CR5 Part Load Pump	+	+	+	+	+	+	+	+	+	o	o	o	o	o	o	o	o	o	o	o	●	●	o	o		o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
CA2 Reduce Sup. Air	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o		o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
CA3-5 Upgrade Air Syst	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o		o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
CA7 Zone Reset Contr	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o		o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
CA9 Heat Recovery	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o		o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
CH4 Auto Cycling	+	+	+	+	+	+	+	+	+	o	o	o	o		o		o	o	o	o	◐	◐	◐	◐	◐	o	o	o	o		●	o	o	●	o	o	o	o	o	o	o	o	o	o	o
CH5 Lead/Lag Control	+	+	+	+	+	+	+	+	+	o	o	o	o		o		o	o	o	o	◐	◐	◐	◐	◐	o	o	o	o	o		o	o	●	o	o	o	o	o	o	o	o	o	o	o
CH6 Reduce Burner Sz.	+	+	+	+	+	+	+	+	+	o	o	o	o		o		o	o	o	o	o	o	o	o	o	o	o	o	o	o	o		o	o	o	o	o	o	o	o	o	o	o	o	o
CH7 Modulat'g Burner	+	+	+	+	+	+	+	+	+	o	o	o	o		o		o	o	o	o	◐	◐	◐	◐	◐	o	o	o	o	●	●	o		o	o	o	o	o	o	o	o	o	o	o	o
CH8 Part Load Boiler	+	+	+	+	+	+	+	+	+	o	o	o	o		o		o	o	o	o	◐	◐	◐	◐	◐	o	o	o	o	o	o	o	●		o	o	o	o	o	●	o	o	o	o	o
CH9 Auto.Breech Damp	◐	◐	◐	◐	◐	◐	◐	◐	◐	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o		o	o	o	o	o	o	o	o	o	o
CH10 Flue Heat Recov.	◐	◐	◐	◐	◐	◐	◐	◐	◐	o	o	o	o	o	o	o	o	o	o	o	◐	◐	◐	◐	◐	o	o	o	o	o	o	o	o	o	o		o	o	o	o	o	o	o	o	o
CH11 Fuel Conversion	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o		o	o	o	o	o	o	o	o
WS1 Hydro-Pneu Syst.	o	o	o	o	o	o	o	o	o	o	o	o	o	◐	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o		●	o	o	o	o	o	o
WS2 Var. Speed Pump	o	o	o	o	o	o	o	o	o	o	o	o	o	◐	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o		o	o	o	o	o	o
WS3 Sep. DHW Heater	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o		o	o	o	o	o
CC2 Ambient Control	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o		o	o	o	o
CC3 Timed Control	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o		o	o	o
EL1 Timed Switching	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o		●	o
EL2 Photo Switching	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o		o
EL3 Sod-Vapor Conve	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	◐	

Legend:
- ● Downgrades Savings Significantly
- ◐ Downgrades Savings
- o No Effect
- + Increases Savings

9.6 Economic Analysis

Based upon the information gathered and analyzed as indicated in previous sections, an economic evaluation was performed for each applicable ECO to determine whether it provided adequate economic benefit or whether it was only marginally effective in reducing energy consumption and costs.

There were a number of investment decision methods considered to determine ECO economic feasibility, including simple and discounted payback, net present worth and internal rate of return. The discounted payback method was selected for economic evaluation of energy conservation opportunities. This method takes into account the time value of cash flows and is used as an indicator for prioritizing investment decisions. This method is also used in existing HUD policy to determine economic worth. Its diasdvantage is that it ignores benefits which accrue after the payback date and therefore does not reflect the total net benefit for the life of the project.

The discounted payback period is the number of years, k, it takes for the following conditions to be satisfied:

$$Co = \sum_{t=1}^{k} \frac{B_o \times (1 + i_f)^t - M_o \times (1 + i_g)^t}{(1 + i_d)^t}$$

where

Co = Initial capital cost of ECO including material and labor costs

k = Number of years to payback

t = Year

B_o = Fuel savings in first year

= (Annual BTUH saved) x (Rate) + (Annual KWH saved) x (Rate)

i_f = Fuel escalation factor

i_g = Inflation rate

m_o = Maintenance costs in first year

i_d = Discount rate

In other words, it is the time period in years for an investment to pay for itself through yearly savings taking into consideration yearly fuel escalation, maintenance costs, general inflation, and the discount rate. An Energy Conervation Opportunity (ECO) is considered feasible if its payback is less than its useful life.

It should be noted that this algorithm is a simplification of a complete discounted payback analysis which takes into account income tax, tax credits and energy credits. It was decided that since the Public Housing Stock is an ongoing HUD administered program not subject to taxes, sale or eligible for tax credits, these features did not apply. In addition, salvage value was ignored, since by definition discounted payback only considers ECOs feasible if they payback in less than their useful life.

If in certain cases, such as wall insulation, there were no annual maintenance costs, the equation simplifies as follows: solving for k,

$$C_o = \sum_{t=1}^{k} \frac{B_t \, (1 + 1_f^t)}{(1 = i_d)^t}$$

To reflect short-term and long-term projections of fuel escalation and general inflation, the following values were used:

Fuel escalation	=	12% above inflation for the first two years of analysis, 8.8% thereafter
General inflation	=	11% for the first two years, 9% thereafter
Discount rate	=	10% constant

Due to the rapidly changing economic and fuel cost picture, these rates might not coincide exactly with recent rates, but it is felt that they represent an adequate forecast for the analysis.

In general, if fuel escalation was less than used in this analysis the discounted payback of the ECOs would be longer than shown. This would put some of the marginal ECOs, those with 13 or 14 year paybacks, over the 15 year cutoff and would tend to shift the energy savings and capital costs of each payback category lower. This, however, would produce approximately the same curve as obtained in this analysis showing the effect of savings versus capital investment. This curve would then produce the same relationships of cost to benefits and a similar recommended level of investment would be derived.

9.6.1 Combined Analysis

Detailed energy savings and capital cost analyses were performed on each prototype (22) for applicable ECOs (58). Resulting savings and cost with corresponding payback period for each ECO are arranged by prototype in order of best-to-worst payback. These individual ECOs are then grouped in the following three categories:

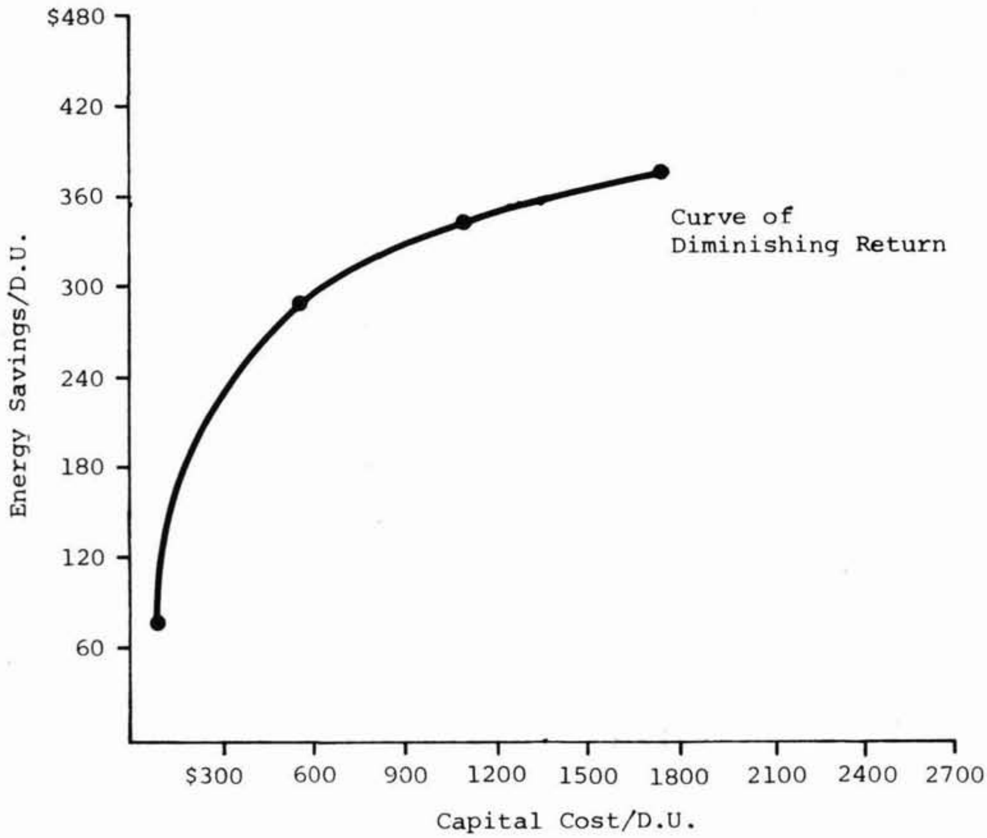
1. Less than 5 years discounted payback
2. Less than 10 years discounted payback
3. Less than 15 years discounted payback

Since some ECOs are mutually exclusive and interdependent, total energy savings and cost would therefore result in less than a total for the ECOs taken independently. To take this into account, each payback group is reanalyzed to show diminishing returns of combined ECOs resulting in three final totals for each prototype corresponding to the payback groupings.

The final results of this analysis can be plotted on a graph with capital cost investment per dwelling on the bottom axis and dollar savings per dwelling unit on the vertical axis as shown in Illustration 9.2.

Illustration 9.2

Curve of Diminishing Return



By connecting these points through an approximate linear regression a curve can be derived illustrating the function of capital cost investment to energy savings. This curve will show diminishing return as higher capital cost investments yield smaller energy savings. The magnitude of this curve will vary between prototypes, illustrating their unique cost/benefit relationships. From these curves the appropriate level of investment can be estimated.

Curves were developed for the eight major building types and for the national total.

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