A REPORT EXPLORING THE DIFFERENCES AND SIMILARITIES
IN APPROACH, AND RESULTS OF DOCUMENTS CONCERNED WITH
ENERGY CONSERVATION IN EXISTING DWELLING UNITS

FINAL REPORT

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CHAPTER I

INTRODUCTION AND SUMMARY

This study involved a thorough evaluation of the state-of-the-art in home weatherization. It included a literature study followed by a careful evaluation of the methods and tactics found. The intent was to find the most cost-effective tactics and then to provide a methodology which could be used for selecting those most appropriate for a given house. The Project Retro-Tech manuals were used as the basic skeleton on which to build, although changes in both methodology and tactics are recommended.

The most fundamental change involved the inclusion of a procedure for determining the optimum weatherization package. This involves calculation of the payback period for most tactics and selection of those which are most favorable. Since reduction of infiltration is always necessary, a payback calculation is not required for it. While this selection requirement adds some complexity to the process, an attempt has been made to minimize the inspection and analysis paperwork required on each house. A procedure has been recommended which permits sample calculations to be made for representative buildings in a local area. These calculations can then be referenced for work on similar buildings rather than going through the identical process numerous times.

Several new tactics have been added to the recommended list. These include additional insulation steps, improvement of furnace performance and plumbing repair. A recommendation has been made to drop two tactics. The addition of storm doors is not cost-effective in most cases, nor is the addition of triple glazing. The recommended insulation levels have been modified to reflect weather conditions and are consistent with HUD's Minimum Property Standards.

In total, the changes recommended will result in a more optimum weatherization program which takes into account the cost of materials used, the energy savings achieved and the variations in climate. Chapter 5 includes page-by-page recommendations for changes in Retro-Tech. They are easy to incorporate and do not extensively disturb the original material.

CHAPTER 2

METHODOLOGY OF THE STUDY

The overall methodology of this study was to explore the various approaches and results achieved by the numerous documents concerned with energy conservation in existing dwellings. Once the evaluation was conducted, a plan for achieving an optimum weatherization program was developed. The Project Retro-Tech documents were selected as the baseline for comparison purposes. This approach was not intended to bias the effort toward the Retro-Tech methods, but rather to provide a convenient basis for comparison. The effort dealt with heating effects only, since comfort cooling is outside the weatherization effort.

The first step in the study was an extensive literature search. The largest source for literature on residential conservation was from the Atlantic Research Corporation library which contains over 200 relevant documents. Computerized information retrieval searches were also made to find additional documents. Using an interactive command terminal, a computer was used for classifying and retrieving information. Three computerized systems were used: Lockheed's DIALOG®, System Development Corporation's ORBIT®, and the Energy Line. In addition to the computerized searches, our staff's continuous involvement in the residential energy conservation area helped locate the existence of the most recent published and unpublished literature. Once the existence of a relevant document was found, the pertinent agency or distribution center was contacted to obtain it. The literature survey actually continued throughout the whole project as new documents were continually being obtained.

The foundation of the study was made up of ten basic documents which dealt with the selection of retrofit packages for residences. These are listed at the end of this report. One of these documents (Farmers Home Administration Proposed Standards) gave only recommended residence insulation levels, so there were actually only nine prime studies. Other documents were found which treated the subject of overall retrofit packages, but since they presented no new selection methodologies, they were not included in the basic comparisons which were used to evaluate retrofit packages.

Documents in the literature survey revealed information and data on energy conservation tactics not included in the basic documents. Data on costs, savings, and disadvantages were drawn from these documents to help evaluate the feasibility of tactics. Documents were also screened for different methods of determining residential heat losses, for different recommended tactic levels, and for different methods of finding costs and savings. The documents which provided most of the useful information are the following:

1. "In the Bank...Or Up the Chimney?"
2. "Retrofitting Homes for Energy Conservation - A Business Guide"
3. "Family Housing Energy Conservation Handbook"
4. "Keeping the Heat In"
5. "Project Retro-Tech"
6. "Tips for Energy Savers"
7. "NBS Technical Options for Energy Conservation in Buildings"
8. "Residential Energy Conservation Strategies"
9. "Energy Conservation in the Home"
10. "44 Ways to Build Energy Conservation Into Your Home"
11. "Measures for Reducing Energy Consumption for Homeowners and Renters"
12. "Heat Balance and Efficiency Measurements of Central, Forced Air, and Residential Gas Furnaces"
13. "A Regional Comparison of Savings from Various Residential Energy Conservation Strategies"
14. "Residential Energy Consumption, Single Family Housing"
15. "Insulation Refit Kit for Domestic Water Heaters"
16. "Retrofitting Existing Housing for Energy Conservation: An Economic Analysis"
17. "Retrofitting: Plan, Action, and Early Results Using the Townhouses at Twin Rivers"

After the basic literature survey and review was completed, a list of specific comparison parameters was developed. The comparison was broken down into four basic matrices as in the previous study.⁽¹⁾ These included:

(1) Comparison of Existing Methodologies for Determining Optimal Retrofit Packages, Prepared for Federal Energy Administration Office of Weatherization for Low-Income Housing, Office of Conservation and Environment, Booz, Allen and Hamilton, Inc., Report No. 13392-010-006, June 25, 1976.

a general matrix, an insulation matrix, a caulking and weatherstripping matrix, and a storm window and door matrix.

The parameters in the general matrix covered the methodology and the technical, financial, and economic aspects of the studies. The methodology parameters included a general description, the method for determining the tactic mix and level, the tactics discussed, and the major assumptions. The general description gave the basic steps used to find the heat loss and the savings. The method for selecting an optimum tactic mix and level was one of the important features of each methodology. The technical parameters considered included the assessment of the existing structure, the building environment, the effects of the possible retrofit action, and the life of the structure, as well as that of the retrofit tactics. Assessment of the structure included an estimate of the exposed area of wall and roof, the quality and type of insulation, the quality and quantity of windows, the heating system characteristics, as well as the condition of caulking, weatherstripping and glazing. The building environment included a climate factor. The financial and economic parameters included the cost of the materials used for retrofit, the cost of energy, the potential dollar savings, the payback, inflation rates, and the cost of capital. The cost of energy was very important and depended on the type of fuel. Another important parameter was the useful life of the tactic which helped determine the payback. Payback can be calculated several different ways and is dependent on the material cost, labor cost, the inflation rate, savings achieved, the cost of capital, and the useful life of the tactic. A thorough discussion of the payback calculation process is included in Chapter 4.

The parameters in the insulation matrix, the storm window and door matrix, and the caulking and weatherstripping matrix included the types of materials considered, the existing conditions, the computational framework, the major assumptions, the costs, and the type of recommendations made by the process. The computational framework treated the method used in calculating heat loss and potential heat savings.

Two sample houses were defined so that the computational results from the basic studies could be compared. The defined characteristics included the floor and attic area, the attic and wall insulation, the window area and glazing type, basement type, and the level of infiltration. One house represented a low-income dwelling and its characteristics were derived from the information in the study, "An Evaluation of Data Developed in a Study of Level of Retrofit for Energy Savings of Homes Owner-Occupied by Low Income Families, March 1975." The other house represented a dwelling occupied by low-income senior citizens. Table 2.1 summarizes these two dwellings. Using the tactic levels recommended by Project Retro-Tech, heat savings were calculated for each of the seven studies which gave savings computation methods. For the low income residence, heat savings were calculated for infiltration, ceilings, walls, and windows. For the senior citizen residence, similar calculations were made. These calculations were done for the two houses at two locations: Washington, D.C., and Minneapolis, Minnesota, which represent two distinct climates. The former has 4200 degree days, while the latter has 8400. The low income house calculations are given in Chapter 3 to illustrate the results.

To find the real-life problems associated with actually implementing the weatherization program, local weatherization agencies and officials were visited and called. From these conversations, a better understanding of the needs of the recipients, as well as the conditions of their dwellings, was developed. In addition, it provided insight into the types of problems encountered in the housing survey, in project administration, in the actual tactic installation, and in the type of labor force available. This information helped define the types of changes that were needed and would be acceptable to weatherization users. It was used extensively in defining the recommendations on the level of complexity and changes to Project Retro-Tech.

The present Project Retro-Tech tactics and methodologies were evaluated with respect to the other studies using information from the comparison matrices, the comparison calculations, and the data from agency visits. The tactics included infiltration correction; ceiling, floor, and

TABLE 2.1
CHARACTERISTIC HOUSES

	<u>HOUSE TYPE</u>	
	<u>LOW INCOME</u>	<u>ELDERLY</u>
Floor Area (ft ²)	850	1000
Attic Area (ft ²)	650	450
Attic Insulation	R-2	R-6
Window Area (ft ²)	23 (14.5%)	145 (14.5%)
Number of Stories	1	2
Glazing	Single	20% Double
Wall Insulation	None	None
Infiltration	Poor	Poor
Basement	None	Full

Reference: "An Evaluation of Data Developed in A Study of Level of Retrofit for Energy Savings of Homes Owner Occupied by Low Income Families," November 1975.

wall insulation; double glazing and triple glazing. Among the factors analyzed were the accuracy of the methods for calculating heat losses and savings, the ease and cost of performing the work associated with the surveys, and the relative savings and payback associated with each tactic. Differences among the study approaches and results were evaluated to determine the reasons for the different results, any demonstrated superiority of one approach over another, and the practical problems of implementing one approach over another. As an example, one approach may have proven to be more accurate than another, but it may have required a skill level that was not available so that the simpler approach is preferred. After thorough analysis, recommendations were made for changing, continuing, or deleting the present Project Retro-Tech tactics and methodologies. An example of a proposed change in Project Retro-Tech was that recommended insulation level should vary with the climate. The discussion of all tactics reviewed is included in Chapter 3.

From the nine basic studies, the reviewed literature and the agency visits, a list of potential new tactics was developed. These potential new tactics were screened on the basis of cost and energy savings. An analysis of each of these tactics, including the phenomena, advantages, disadvantages, and savings was written. These are included in Appendix A of this report. For candidate tactics, the payback period for materials only was compared to the payback period for the accepted Project Retro-Tech tactics. Material costs were obtained from a local retail building supply outlet, and the payback periods were done for the characteristic low-income residence located in Washington D. C. From the payback results and the previous analysis, certain tactics were selected for inclusion into Project Retro-Tech. These tactics were selected on the basis of low payback, low cost, easy installation, and compatibility with safety and building regulations. In summary, recommendations for improvements in Project Retro-Tech were developed which included changes in the current methodology as well as the inclusion for consideration of new energy conservation tactics.

CHAPTER 3

WEATHERIZATION TACTICS

Weatherization tactics are briefly discussed in this chapter. All those described were seriously considered but not all are recommended for implementation. More complete discussions of each, along with reference sources are included in Appendix A. The number in parenthesis following the tactic name indicates the sheet in Appendix A.

METHODOLOGY COMPARISON

As an aid in the tactic evaluation, the energy savings calculated by the seven basic documents were compared for infiltration, ceiling insulation, wall insulation and storm windows. This was done for the characteristic low-income home described in Chapter 2. Two cases were run. They were for Washington, D.C. (4200 degree days) and Minneapolis, Minnesota (8400 degree days). The results are summarized in Tables 3.1 and 3.2.

If one first looks at the savings gained from insulating the ceiling (see Table 3.1), one finds good agreement for all estimates except for the Navy Study which is three to four times that of the usual value and "In the Bank...Or Up the Chimney," which estimates a factor of 2 low. The Navy value is high in this and most other cases because it uses maximum design temperature in the calculations rather than average temperatures or degree days. These calculations will not be included in further comparisons. The "In the Bank...Or Up the Chimney," calculation is low because it assumes existing insulation in the ceiling. The other calculations assume none and since the first insulation is the most effective, one would expect a difference. The wall insulation values follow the same pattern.

There is some scatter in the values calculated for the effect of adding storm windows, but most values cluster around $1.4 \times 10^7 \pm 40\%$ BTU/hr. The principal differences are due to the varying effects of infiltration reduction in the total. 6.9×10^6 BTU/yr is attributed to conduction while the rest is due to infiltration. The Retro-Tech number is for conduction only.

The savings due to infiltration reduction have the widest scatter with values spread over a little less than one order of magnitude. One would expect wide variations in infiltration estimates between typical well-maintained homes and those of low-income families without resources for maintenance.

TABLE 3.1

CALCULATED HEAT SAVINGS FROM 7 STUDIES
LOW INCOME CHARACTERISTIC HOUSE
WASHINGTON, D.C.

	INFILTRATION	CEILING	WALLS	(BTU/YEAR)
RETRO TECH	3-4 Air Changes $2.7 \cdot 10^7$	R-2 + 20 $2.9 \cdot 10^7$	R-3 + 15 $2.1 \cdot 10^7$	$6.2 \cdot 10^6$
U.S. NAVY	$9.3 \cdot 10^7$	R-2 + 20 $8.9 \cdot 10^7$	R-3 + 15 $6.4 \cdot 10^7$	Plastic $1.8 \cdot 10^7$ Glass $1.9 \cdot 10^7$
LOW INCOME - NAHB	$7.6 \cdot 10^6$	R-1 + 20 $2.0 \cdot 10^7$	-	Storm $6.6 \cdot 10^6$ Outside Plastic $3.0 \cdot 10^6$
BUSINESS GUIDE	Weather Only $9.8 \cdot 10^6$ Caulk $1.9 \cdot 10^6$ $1.2 \cdot 10^7$	R-3 + 22 $1.8 \cdot 10^7$	$2.3 \cdot 10^7$	Storm $1.8 \cdot 10^7$
PROJECT CONSERVE	$8.3 \cdot 10^6$	R-2 + 20 $1.8 \cdot 10^7$	R-3 + 15 $2.7 \cdot 10^7$	Conduction $8.8 \cdot 10^6$ Infiltration $5.5 \cdot 10^6$ $1.4 \cdot 10^6$
IN THE BANK... OR UP THE CHIMNEY	$1.5 \cdot 10^7$	R-11 added $6.0 \cdot 10^6$	$1.2 \cdot 10^7$	Plastic w/o W.S. $1.3 \cdot 10^7$ with W.S. $9.5 \cdot 10^6$ Glass $9.5 \cdot 10^6$
NBS	Windows $4.0 \cdot 10^6$ Doors $1.9 \cdot 10^6$ $5.9 \cdot 10^6$	R-2 + 20 $1.8 \cdot 10^7$	R-3 + 15 $2.7 \cdot 10^7$	Conduction $8.8 \cdot 10^6$ Infiltration $4.0 \cdot 10^6$ $1.3 \cdot 10^7$

Not Calculated

TABLE 3.2

CALCULATED HEAT SAVINGS FROM 7 STUDIES
LOW INCOME CHARACTERISTIC HOUSE
MINNEAPOLIS, MINNESOTA

(BTU/YEAR)

	INFILTRATION	CEILING	WALLS	WINDOWS
RETRO TECH	3+1 Air Changes $5.4 \cdot 10^7$	R-2 + 20 $5.8 \cdot 10^7$	R-3 + 15 $4.3 \cdot 10^7$	$1.2 \cdot 10^7$
U.S. NAVY	$1.9 \cdot 10^8$	R-2 + 20 $1.8 \cdot 10^8$	R-3 + 15 $1.3 \cdot 10^8$	Plastic $3.6 \cdot 10^7$ Storm $3.9 \cdot 10^7$
LOW INCOME - NAHB	$1.4 \cdot 10^7$	R-3 + 22 $2.2 \cdot 10^7$	-	Storm $1.1 \cdot 10^7$ Outside Plastic $5.0 \cdot 10^6$
BUSINESS GUIDE	Weather Only $4.0 \cdot 10^7$ Caulk $\frac{3.8 \cdot 10^6}{4.4 \cdot 10^7}$	R-3 + 22 $3.7 \cdot 10^7$	$4.6 \cdot 10^7$	Storm $3.6 \cdot 10^7$
PROJECT CONSERVE	$1.5 \cdot 10^6$	R-2 + 20 $4.8 \cdot 10^7$	R-3 + 15 $5.0 \cdot 10^7$	Storm Conduction $1.6 \cdot 10^7$ Infiltration $\frac{1.0 \cdot 10^5}{2.6 \cdot 10^7}$
IN THE BANK... OR UP THE CHIMNEY	$2.1 \cdot 10^7$	Add R-11 $8.0 \cdot 10^6$	$1.6 \cdot 10^7$	Plastic w/o W.S. $1.7 \cdot 10^7$ with W.S. $1.3 \cdot 10^7$ Storm $1.3 \cdot 10^7$
NBS	Windows $8.0 \cdot 10^6$ Doors $\frac{3.7 \cdot 10^6}{1.2 \cdot 10^7}$	R-2 + 20 $4.8 \cdot 10^7$	R-3 + 15 $5.0 \cdot 10^7$	Storm Conduction $1.6 \cdot 10^7$ Infiltration $\frac{8.0 \cdot 10^6}{2.4 \cdot 10^7}$

- Not Calculated

The large energy savings shown on these charts may not actually be found after the weatherization process. Smaller savings may result from changes in occupant behavior or life style. For example, the increased warmth resulting from the weatherization may permit the occupants to use additional rooms which were previously too cold or permit the removal of outside clothing for the first time. While these changes reflect an improvement in the quality of life, they may have little energy conservation impact.

INFILTRATION REDUCTION (A-1)

Infiltration is frequently the largest source of heat loss in low income housing and is a source which is easily reduced. It represents 32% of the heating load of the characteristic low income house with an unheated basement. Tables 3.1 and 3.2 titled "Calculated Heat Savings from 7 Studies" show infiltration generally ranks as the largest source of heat savings. In low income housing, broken windows, sagging doors, holes, and structural cracks add greatly to the heating load. Reduction of these openings should be the first priority in any program. Without it, the effectiveness of many of the other tactics would be decreased substantially.

The caulking and weatherstripping materials used for infiltration reduction are inexpensive and easy to install. They are used on all windows and doors and all foundation cracks. Some siding may also be needed to fill holes. Heat savings which result from decreasing the number of air changes per hour in the characteristic very draft house from 3 to 1, as calculated by the Project Retro-Tech method, were $2.72 \cdot 10^7$ BTU's annually or \$141 for an oil furnace at 70% efficiency and oil at \$.50 per gallon. The payback would be on the order of a few months.

Installation of a fireplace plug (A-2) of wood and insulation to close the face opening is another method to reduce the infiltration losses. It reduces the heat loss up the chimney and cold air down it caused by a loose-fitting or missing damper. Material costs are small so that payback is rapid.

INSULATION

Recommended insulation levels for various parts of the house change for different regions of the country. These levels are brought about by the different climates across the country which economically justify higher levels

of insulation for colder areas. For example, the Department of Housing and Urban Development's "Minimum Property Standards for One- and Two-Family Dwellings," (May 1977), give recommended insulation levels of R-20 for ceilings of houses located in regions with district heating factors less than 2.0 and levels of R-25 for ceilings of houses in regions with higher district heating factors. (See Table 3.3, "HUD Recommended Insulation R-Values.")

Ceiling heat losses are generally high in the housing considered (25% in the characteristic house with an unheated basement) and can be reduced substantially by insulation installation (A-3). In unfloored attics, the installation is generally simple. Fiberglass batts or blown-in insulation material may be installed. Floored attics pose more of a problem though insulation can still be blown in under the floorboards. Finished attics pose the largest problem and attic insulation in that case may not be economically practical. Heat savings from attic insulation for the characteristic house insulated to the Project Retro-Tech recommended R-20 level were $2.9 \cdot 10^7$ BTU's annually or \$151 for an oil furnace at 70% efficiency and oil at \$.50 per gallon. Payback for materials only is on the order of one year.

Walls are another area of generally high heat loss (20% in the characteristic house with an unheated basement) in the houses considered. Wall insulation (A-4) will reduce the heat loss substantially but installation is expensive for closed walls. Access to the wall interior has to be provided at least once every 16 inches and insulation either blown in or foamed in place. Proper installation requires a fairly high degree of skill and experience. Heat savings from wall insulation for the characteristic house insulated to the Project Retro-Tech recommended R-15 level were $2.1 \cdot 10^7$ BTU's annually or \$109 for an oil furnace at 70% efficiency and oil at \$.50 per gallon. Payback for materials and installation would be on the order of 6-10 years which would prove to be economically unattractive when compared to other tactics. Note installation costs were included in this analysis because of the labor-intensive nature of the tactic.

Floor heat losses are less than ceiling and wall losses (14% in the characteristic house with an unheated basement) but still are appreciable for the houses considered. Floors above unheated rooms or crawl spaces that cannot be sealed off are best insulated by batts placed under the floors (A-5).

TABLE 3.3

HUD RECOMMENDED INSULATION R-LEVELS*

<u>Component</u>	<u>District Heating Factor</u>	<u>Recommended R-Levels</u>
Ceiling	Less than 2.0	20
	Greater than 2.0	25
Frame Wall	All D.H.F.	12.5
Floor over Unheated Area	.25	3.1
	.50	3.8
	.75	5.3
	1.00	8.3
	1.25 or greater	12.5

* HUD recommendations are for degree day values. Conversion has been made using 4000 degree days = 1.0 district heating factor.

Reference: "Minimum Property Standards for One- and Two-Family Dwellings,"
2900.1 - May 1977, Department of Housing and Urban Development.

Closed crawl spaces under floors can also be efficiently insulated by installing insulation on the walls and the adjacent ground (A-6) and vapor barrier on the ground to prevent moisture problems. Heat savings from floor insulation for the characteristic house with a 650 square foot floor above an unheated area insulated to R-14 were $1.1 \cdot 10^7$ BTU's annually or \$58 for an oil furnace at 70% efficiency and oil at \$.50 per gallon. Payback for materials only would be on the order of 2 years. Heat savings for a 650 square foot floor above a 3 foot crawl space with walls insulated to R-14 were $6.0 \cdot 10^6$ BTU's annually or \$31 for an oil furnace at 70% efficiency and oil at \$.50 per gallon. Payback for materials only would be on the order of 3 years.

Heating duct losses can be appreciable through cold areas of the house such as basements, crawl spaces, and attics. Wrap-on insulation (A-7) can lessen this loss appreciably at a low cost. Recommended insulation levels range from 2 inches (R-7) to 6 inches (R-19), depending on the area of the country. A typical example of savings for insulating ducts through a basement with no insulation in the Washington, D.C. area is \$.53 per foot annually based on oil heat, at \$.50 per gallon and 70% efficiency. Payback for materials only would be on the order of 1.1 years.

Hot water heater stand-by losses average about 25% of the heater input. The addition of insulation jackets (A-8) reduce this conduction loss from storage by a reported 24 to 30%. For a 40-gallon gas water heater at 140°F, reported savings were 28% or 36 therms a year, a savings of \$11 at \$.30 per therm. For a 40-gallon electric water heater at 140°F, reported savings were 30% or 362 Kw/hr, a savings of \$13 at \$.035 per Kw/hr. Payback for this easily installed tactic was 1.7 years for the electric heater and 2.0 years for the gas water heater.

STORM WINDOWS

Heat losses through and around single glazed windows are appreciable (10% in the characteristic house with an unheated basement) in the house considered. In better insulated houses, the percentage of window heat loss becomes considerable, up to 25-30%. The heat losses come from cracks around the windows which allow infiltration and through the glass itself due to its

low thermal resistance. With proper weatherstripping in place and with infiltration controlled, storm windows are normally taken as reducing conduction heat losses by one-half. However, in many of the houses under consideration, the windows are likely to be in such poor shape that weatherstripping will not satisfactorily reduce infiltration. Storm windows (A-9) would then take on that added advantage.

Storm windows can be made from plastic or from glass. Both types give approximately the same heat loss reduction. Plastic storm windows are temporary and are installed only for the cold season. Experience has shown that for the type of housing involved in weatherization programs, the plastic windows are often destroyed after one season and replacement is needed for the next season. Thus, though they have a low cost, they give only one season of benefit. On the other hand, though the permanent glass storm windows are much costlier, once they are installed they give effective heat loss reduction for many seasons.

Heat loss savings for storm windows for the characteristic house considering only conduction reduction is $6.2 \cdot 10^6$ BTU's annually or \$32 based on oil heat at 70% efficiency and oil at \$.50 per gallon. Payback for plastic window materials in such a case is about .8 years. For a permanent triple track glass storm window, payback for materials only is about 9 years. When the windows are in such poor enough condition that storm windows are also needed to reduce infiltration, the extra heat loss savings is $7.8 \cdot 10^6$ BTU's annually. Based on oil heat at 70% efficiency and oil at \$.50 per gallon, the total savings would be \$72. This would make the plastic storm window payback about .4 years and the glass storm window payback about 4 years.

STORM DOORS (A-10)

Heat loss through doors comes from two sources: infiltration and conduction. Infiltration losses come from loose-fitting doors and this problem can often be corrected by weatherstripping. Storm doors then reduce conduction losses and these losses are not large enough to justify storm doors unless the climate is very cold and the primary door is mainly glass - an infrequent combination. Heat loss savings for the characteristic house considering conduction and infiltration reduction is $8.6 \cdot 10^5$ BTU's annually or \$4 based on oil heat at 70% efficiency and oil at \$.50 per gallon. Pay-back for materials would be on the order of 15 years. When the main door is in such poor condition that infiltration cannot be corrected by weatherstripping, more satisfactory results are usually attained by replacing the main door instead of adding the storm door. The heat savings are similar, the cost is comparable, and a more durable door is the result.

CLOSING UP UNUSED ROOMS (A-11)

Unused or infrequently used rooms waste energy during the heating season. By sealing off these rooms and turning off any interior heating devices such as a radiator or a register, the heat lost by these areas can be reduced. Readily available materials such as old rugs or blankets can be tacked over entrances or put under doors so that costs will be minimal and installation easy. Plastic sheet may be put up like a storm window to shut off these rooms. However, in very cold climates this may cause moisture problems in the room. Savings from this tactic vary depending on the size of the rooms, their location in the house, and the area temperatures. As an approximation, for a 10-foot by 10-foot outside room in a one-story house with an average outside temperature of 35°F, the expected savings for oil heat at 70% efficiency and oil at \$.50 per gallon would be about \$18 per year.

FURNACE WEATHERIZATION

There are a number of furnace related weatherization tactics which have been reviewed. All offer significant fuel savings but most require skills not possessed by the usual local agency. Each tactic will be briefly discussed and possible operating procedures for acquiring the skilled labor will be presented.

Furnace Cleaning (A-12)

Replacing the filter in a forced air furnace is important not only for the energy savings it provides but also from the reduction of air-borne dust. Unless the existing filter is visually clean, it should be replaced by the weatherization crew. A second area which may need cleaning is the heat transfer surface inside the furnace itself. Soot deposits reduce the efficiency of the furnace and often indicate the need for burner servicing. These conditions should be noted for servicing by a qualified mechanic.

Furnace Adjustment (A-12, A-13)

Correct air-fuel mixtures are important to efficient furnace operation, as noted in "Maintenance and Adjustment Manual for Natural Gas and No. 2 Fuel Oil Burners," 1977. Adjustment of oil and gas burners require a trained serviceperson with test equipment. Another fuel saving adjustment is that of the control switch settings on the air blower. Reducing these temperature settings result in the delivery of more energy from the furnace to the house. Details of these changes are given in Appendix A. This adjustment requires a trained serviceperson.

Heat Recovery From Flue (A-14)

When the furnace is operating, more than 1/4 of the total energy in the fuel is exhausted up the flue. There are devices on the market which can recover some of this heat. The devices are generally expensive, must be carefully installed and some models have safety/building code problems. Use in the weatherization program is not recommended at this time.

Flue Vent (A-15)

Heat is lost up the flue even after the burner goes off. Placing a valve in the flue which closes whenever the burner is off could prevent such losses. Safety-approved devices of this type are now becoming available but their cost is generally high (over \$100). Installation must be performed by a qualified serviceperson. The high cost, the possible safety hazards and the limited experience with approved devices makes flue vents unsuitable for the weatherization program at this time.

Pilot Light Shutoff (A-16)

The natural gas used by a furnace pilot light is wasted during the warm months. Turning off approximately 20 pilot lights during the summer will save enough gas to heat a typical house for an entire winter. Turning off the pilot is not cost-effective, however, if a trained serviceperson has to be called to relight it in the fall. It is recommended that the weatherization crew show the homeowner how to turn off the pilot and relight it if he believes that the homeowner is likely to understand the process. No other action is recommended.

Furnace Service Implementation

Cleaning and adjusting a typical oil furnace can result in energy savings on the order of 10%. In addition, there is a reduction in the danger to inhabitants from chimney fires and from carbon monoxide release. Such servicing must be performed by a trained serviceperson. Two possible scenarios exist for securing these services: The first would be to list all furnaces requiring service as the basic weatherization process is accomplished. When this list is large enough to require a full week of servicing, (20-30 homes possibly), it could be sent out to local contractors for a fixed price quotation. It is hoped that clustering the work and permitting it to be performed at a time convenient to the contractor will result in a low per home cost. A second possible scenario would be to find a local heating contractor who would accept a CETA employee as an apprentice. The contractor could use the employee as he was being trained. When the trainee had acquired sufficient skill, the furnace weatherization tasks would be accomplished. Finally, the trainee would be able to join the regular work force and the process would start all over again.

PLUMBING WEATHERIZATION

Hot Water Heater Turndown (A-17)

A reduction in water heater setting to 120°F can save 10-20% of the energy used. If occupant families are not so large that this reduction would cause frequent exhaustion of the hot water supply, it should be done by the weatherization crew.

Shower Flow Restrictor (A-18)

A plastic shower flow restrictor can be installed in a few minutes and costs less than \$1. This device saves the energy used to heat hot water and reduces the total amount of water used. Installation should be performed in all dwellings unless the condition of the plumbing is so bad that damage might result.

Leaking Faucet Repair (A-19)

A leaking hot water faucet wastes energy and water. The cost of a washer is quickly recovered. If the occupant witnesses the process, he or she may be able to fix it the next time. However, the faucets in low-income homes are often very old and repair parts are very difficult to find. If washer replacement is attempted, it is probable that some number of entire faucet assemblies will have to be replaced. Unless the local group contains plumbing skills, this tactic should be omitted. As an alternative, this work could be included in the tasks undertaken by the heating contractor.

CHAPTER 4

WEATHERIZATION TACTIC SELECTION

When one seeks to optimize the tactics to be used in the weatherization process, there are three inter-related concerns that must be addressed. The first is purely technical/financial and involves finding the most cost-effective energy savers. The second concerns the real needs of the recipients whose homes are to be weatherized. Priorities are different from those of typical middle-class homes. The third concern includes implementation problems of the local agencies who are to perform the work. These agencies frequently use CETA personnel who have low skill levels and whose turnover is high. The following analysis uses the first concern as a framework and discusses the implications and complications caused by the other two. Table 4.1 presents a short summary of how tactic selection is made in the basic source documents.

COST-BENEFIT ANALYSIS

Analysis of costs and benefits is basic to the selection of retrofit tactics. The method chosen can have various degrees of complexity. The simplest method would be to sum the cost of weatherization materials used, calculate the annual energy cost savings and then divide the first number by the second to determine the time required for payback. Even this seemingly simple process takes on significant complexity when one considers that the value of money changes with time (inflation and cost of borrowing money) and that future costs of energy are unknown. In addition, one must forecast the useful life of the tactic being considered. Thus, the payback period may be correct for one set of assumptions about the future but these assumptions are subject to considerable discussion. As the complexity of this process increases, so does the difficulty in taking, processing and interpreting the information. This complexity increases the burden on the implementation agencies.

Most of the manuals examined use a simple payback calculation. Project Conserve⁽¹⁾ calculates both payback and the rate of return on weatherization investments. It does not consider inflation in calculating paybacks.

TABLE 4.1
TACTIC SELECTION

1. "Project Retro-Tech" - Areas of highest heat requirements are taken as logical areas for weatherization. Owner's comments on heating are also taken as a guide to necessary tactics. The residence is checked to see if the tactics can be applied. The procedure is not rigorous by tactic.
2. "Project Conserve" - The homeowner selects tactics based on the tactic's cost and its payback.
3. "Retrofitting Existing Housing for Energy Conservation: An Economic Analysis," NBS Study - Tactics selected based on marginal economic savings from two conditions:

$$1) \text{ MS} = \text{MC}, \quad 2) \frac{\text{MS}_1}{\text{MC}_1} = \frac{\text{MS}_2}{\text{MC}_2}$$

(MS = marginal savings, MC = marginal cost)
4. "Keeping the Heat In" - Weatherstripping and caulking is given first priority, insulation second, storm windows third. For insulation, parts of the house closer to the standard are given lower priority, and ease and cost of installation is considered.
5. "U.S. Navy Energy Conservation Handbook" - Elimination of air leakage is given highest priority. Savings from the various methods are calculated, but not definite selection criteria is given.
6. "A Business Guide" - Tactics are originally put into Basic and Better Packages and Custom and Supplemental Options for each zone of the country. Tactics are finally selected based on the initial cost, the payback period, and the resident's budget.
7. "Study of Level of Retrofit for Low Income Families" - Tactics are selected from the savings to cost ratio. There are minimum, typical, and maximum levels, each with a different savings-to-cost ratio.
8. "In the Bank...Or Up the Chimney" - First, tactics are selected based on what can be afforded. Then, those tactics with the highest net savings are performed.
9. "A Community Planning Guide to Weatherization" - Caulking and weatherstripping is given first priority. Other tactics and their level are determined directly from a table by funds available and heating index.

The Business Guide⁽²⁾ includes the future price of energy but does not include a figure for the time value of money. The NBS Study⁽³⁾ considers the time factors but they use a real energy price increase due to inflation of 1%/yr and a real money value rate of 1%, so the effects cancel. If that study had used an energy price increase rate of 3% and left other values the same, payback on an item with a 20-year life could have been reduced 17%. A short life tactic is affected to a smaller extent. Furthermore, if one were tempted to forecast future energy costs, it is expected that the rate of change would also vary with the fuel. For example, natural gas prices will probably climb faster than those of oil.

A thorough analysis of payback could include the following factors:

- initial retrofit costs - materials and labor
- lifetime of tactics
- period of analysis
- increased value of home when sold in the future
- annual cost of money
- estimated annual energy saving at present prices
- annual rate of change of price of energy
- estimated annual cost of necessary repairs and maintenance, if any

The application of such a rigorous technique is not justified because

- 1) heat loss calculations and therefore energy savings are only estimates,
- 2) user agencies would find the analysis very difficult to deal with, and
- 3) detailed calculations are not needed because of the characteristics of the program.

The weatherization program has limited funds and a large number of dwellings to treat. The present level of weather protection in these homes is very low so that only the most cost-effective measures can be implemented. As a result, the payback period of tactics used will generally be less than two years based on materials cost only. See Table 4.2 for sample calculations. With such a short payback period, one can safely ignore the annual rate of change of costs. A second consideration which makes this effort less sensitive to the complexities of the situation results from the fact that the effort makes comparative judgements over the population of treated homes. The process compares similar units. Therefore, the only items which might

TABLE 4.2

PAYBACK COMPARISON

Payback periods for several weatherization tactics were calculated as examples. A low income house located in Washington, D.C. was used. The results for payback which follow include materials priced at local cost on 1 February 1978.

	<u>Payback Period</u>	<u>Cost</u>	<u>Heat Loss Savings (BTU/YR)</u>
Infiltration Reduction	Oil .2 year	\$30	$2.7 \cdot 10^7$
	N.G.* .2 "		
Shower Restrictor	Very fast	\$ 1	$7.7 \cdot 10^6$
Furnace Servicing	Oil .6 year	\$35	$1.2 \cdot 10^7$
	N.G. .7 "		
Storm Windows (10) (Plastic)	Oil .4 year	\$30	$1.4 \cdot 10^7$
	N.G. .5 "		
Furnace Pilot Turn-Off	.8 year	\$10 (labor)	$3.0 \cdot 10^6$
Ceiling Insulation (adding R-19)	Oil .9 year	\$130	$2.9 \cdot 10^7$
	N.G. 1.0 "		
Duct Insulation (Basement)	Oil 1.1 year	8" D-\$.59/ft	$1.0 \cdot 10^5/\text{ft}$
	N.G. 1.3 "		
Hot Water Heater Insulation	Electric 1.7 year	\$22	$1.2 \cdot 2.5 \cdot 10^6$
	Gas 2.0 "		

* N.G. - Natural Gas

Gas \$.30/therm - 70% furnace efficiency

Oil \$.50/gallon - 70% furnace efficiency

Electric \$.035/Kw/hr

even be considered, are the differences in payback factors between houses. These differences should be very small. For example, will the cost of energy rise significantly more in one area than another? When one considers the short time involved for payback and the fact that one need only make comparisons, it is clear that a simple calculation is most appropriate.

Having recommended a simple payback calculation, one must now consider what to include in the cost of weatherizing a house. Everyone would agree that the cost of materials should be included but including the cost of labor is less certain. Actual installation labor is often provided by sources outside the weatherization program and is difficult to accurately cost. However, if the cost of labor is not considered at all, incorrect selections may be made. For example, let us first examine two possible tactics: Installation of 6 inch insulation in an open attic versus installation of 3 inches of insulation in the walls. A single story, 850 ft^2 house would have approximately 1000 square feet of walls and 850 square feet of ceiling. Insulating the ceiling to 6 inches would require 425 ft^3 of insulation material while insulating the walls would require only 250 ft^3 . It is obviously better to insulate the walls from a material cost viewpoint. Even when one takes into account the greater energy savings from insulating the ceiling, the wall option still looks better. However, when one considers that the ceiling can often be insulated quickly with little or no construction skills while installing wall insulation requires creating access openings to the walls at least once every 16 inches and then closing these up, it is clear that a crew can do many more ceilings than walls in a given time. It is therefore recommended that a labor factor be included.

Project Retro-Tech⁽⁴⁾ currently does not include an installation charge in its weatherization tactic cost calculation. The other documents which treat contractor installation include labor costs, and three of these documents break out labor costs separately. Project Conserve⁽¹⁾ includes contractor cost based on zones using the postal zip code. It includes data on labor dollars per storm door or window and dollars per square foot of different thickness of ceiling insulation. The National Bureau of Standards study⁽³⁾ includes average national installation costs. It has data on insulation cost in dollars per first inch of insulation and each succeeding inch, and overall materials and labor cost for storm windows and doors. "In the Bank...Or Up the Chimney"⁽⁵⁾ gives contractor installation costs for attic

and floor insulation in dollars per square foot for various insulation or R values. For wall insulation, it gives dollars per linear foot.

In calculating a labor installation charge for any weatherization tactic, two variables must be defined: the number of labor hours to perform the job, and the cost per labor hour. There are two basic ways to attack the definition of these variables. The first is to have an agency surveyor estimate the number of labor hours associated with each tactic and then multiply this value by the applicable labor rate to find the total labor charge. This requires more skill on the part of the surveyor, but at the same time, if he is skillful, the result should be accurate since each case is handled on an individual basis. The second is to have a labor-time schedule, similar to those used in the aforementioned studies, which could be multiplied directly by the tactic amount to find the total labor charge. This would tend to be less accurate than the first method because it gives a standard charge for all cases and neglects the varying degrees of difficulty in installation.

There are several characteristics of the weatherization process that determines how one treats labor cost effects. First, the hourly cost of labor is generally low and tends to be reasonably constant across the country. Second, since it is only necessary to make comparisons between tactics, a relative labor factor is all that is required. If one uses unity as the factor on most tactics where it is appropriate, it is only necessary to use an additional factor if a significant labor penalty exists. For example, wall insulation would use a factor of 3* on materials while ceiling insulation would use a factor of 1.2 if all the joists are covered, thereby making it difficult to install insulation. This procedure requires no additional estimating skills of the weatherization surveyor and only requires one additional multiplication step.

OPTIMIZATION IMPLEMENTATION

If one accepts the basic computational framework described above, the next problem is how to apply it. From a purely financial point of view, one should perform the cost benefit calculation based on each weatherization

* This factor was generated by using the NBS Study⁽³⁾ cost figures and extracting a relative labor intensity figure.

tactic for each dwelling and then select only those tactics which pay back in some reasonable time period, for example less than three years. However, performing all the calculations for each home exceeds the capability of most implementation groups unless an excessive amount of supervision is devoted to this aspect alone. In addition, the characteristics of the dwellings to be treated make many of the calculations unnecessary.

One does not have to make a calculation to determine that keeping cold air from blowing into a house is the highest weatherization priority. In well-constructed, well-maintained homes this heat loss is called infiltration but it is not clear that the term applies to missing windows, leaky walls and broken doors. The CSA Weatherization Guide⁽⁶⁾ sets the proper perspective when it states "...the first and most basic point to remember is that the problems of infiltration which you are likely to encounter must be solved before any other energy conservation measures are undertaken. Cracks, broken windows, holes in floors and roofs, etc., must be repaired first, because no combination of other more expensive home improvements can be effective until the rapid loss of heated air through these basic flaws is stopped."

Once the infiltration process has been reduced to acceptable levels, one can then move to selecting an optimum tactic mix for buildings. This is done by calculating the payback for each tactic applicable to the house and then selecting the most effective ones. Many houses in a given area are similar and repeating the same calculation process for each one is not cost effective. Therefore, it is recommended that the optimization calculation be carried out for typical sample dwellings in an area and that the work on all similar homes refer to these carefully documented calculations. This is possible because the weatherization process is carried out at the local level and there are often numerous similar buildings in a given area. Houses which differ significantly from the samples should have individual calculations performed. This procedure will minimize the analysis and calculations while maintaining a high level of cost-effectiveness in the program.

CHAPTER 5
IMPLEMENTATION PLAN

This chapter describes the changes recommended to the Project Retro-Tech Home Weatherization Manual "C". The changes are presented on a page by page basis.

Page 9 - Inspection of Building

The local weatherization unit should have typical sample house calculations made and filed. If the house examined is essentially the same as one of the samples on file, the inspector should be able to skip all the inspection and analysis steps and go directly to the Summary Table and Job Sheet "A" for the list of materials needed. A note is to be made on the cover of the Job Book that this short procedure has been used and the file number and date of the sample calculation recorded.

Page 11 - Note 3

A sentence should be added which encourages replacement of the primary door if the existing one cannot be properly weathersealed. A less durable alternate is to use a storm door.

Page 12 - Comment 7

Remove the last sentence: "This is one of the less effective measures of reducing heat loss; however, it may help in a loosely constructed building."

Page 12 - Comment 8

Add the following: Calculate the cost of the energy saved using local fuel rates. This value is to be put in column 4.

Instructions should be added which require the inspector to calculate the cost savings from each of the tactics except infiltration. The latter is always included in the weatherization process. In addition, there are other

items such as water flow restrictors which are always recommended. A reference to the list of such pre-approved items should be made.

Page 12 - Comment 10

Instructions should be added which require calculating the cost of weatherization materials for each tactic. This cost should be divided by the cost savings to determine tactic payback. Selection should be made based on the best payback figures.

Page 12 - Comment 12

This calculation of total payback can be eliminated.

Page 13

A note is to be added on the Job Book cover if a pre-calculated sample was used in lieu of actual inspection.

Page 16 - Infiltration

The comment across from the item "Walls" and under the column headed "Two" which says, "building needs paint" should be removed. It is not pertinent to this effort.

Page 17 - Floors

The text needs to be modified to indicate that insulation of floors directly or insulation of crawl space perimeters are possible alternatives. A table indicating the HUD recommended insulation values by district heating factors, as listed below, should be added.

<u>Floor Over Unheated Area</u>	
<u>District Heating Factor</u>	<u>Recommended R-Level</u>
.25	3.1
.50	3.8
.75	5.3
1.00	8.3
1.25 or greater	12.5

Page 18 - Ceilings

The potential savings calculation should be modified to permit use of recommended insulation values based on district heating values. For District Heating Factors less than 2.0, R-20 is recommended; for factors greater than 2.0, R-25 is recommended.

Page 20 - Double Glazed Windows

This page can be deleted because improvement from double glazing to triple glazing is outside the scope of the weatherization program.

Page 21 - Walls

Recommended wall insulation for all District Heating Factors is R-12.5. Several additional notes are needed. The first concerns the difficulty of insulating walls if they are closed in. The second should warn about moisture condensation problems that are possible if care is not exercised with moisture barriers. The last one should indicate that although R-12.5 is recommended for walls, as a practical matter, if any insulation is done in the walls, it will be to full stud thickness.

Page 22 - Summary Table - A revised sample is shown in Figure 5.1.

(This is always filled out even if the sample house method is used.)

1. Additional columns need to be added for local energy cost per heating unit and dollar savings expected for each tactic.

2. The row titled "Conduction through doors and double-glass windows" can be eliminated.

3. A column for tactic cost should be added, as should one for cost/saving ratio (or payback).

Notes should be added that (a) costs are calculated on Job Sheet "A", (b) selection of tactics is to include infiltration prevention as priority one, installation of the recommended item from the list of pre-approved items as priority two and all subsequent items to be selected from the best (lowest) cost/saving values.

4. Pre-calculated cost/saving ratios should be included for duct insulation where it is necessary (1.2/yr), and hot water heater insulation (1.8/yr).

FIGURE 5.1

REVISED SAMPLE PAGE

Use the instructions on page 11 of the Home Weatherization Manual to assess which potential savings can be obtained most successfully.

Fill out the following Summary Table by entering the "Heating Units Required" and the "Potential Heating Savings" from the corresponding tables at the bottom of pages 4-9. Then, write in the "Proposed Changes" and "Heating Units to be Saved" by such changes.

Summary Table

Heat Requirement Estimates (Annual Heating Units Needed)

Type of Heat Loss	From	Heating Units Required	Potential Heating Savings	Proposed Changes to Structure	Heating Units to be Saved	Cost per Unit	Cost Saving	Total * Cost of Change	Cost/Saving Ratio
Infiltration	Page 4								
Conduction Through Floors	Page 5								
Conduction Through Ceilings	Page 6								
Conduction Through Single-Glass Windows	Page 7								
Duct Insulation only if Ducts are in Cold Areas									1.2
Water Heater Insulation									1.8
Conduction Through Walls	Page 9								
Total									

*See Sheet A

Use the space below to calculate the quantities and cost of materials needed to make the proposed changes to the building.

Page 23 - Job Sheet "A"

An additional column should be added for labor factors which are multiplied by the material cost to arrive at total cost. The labor factor is one (1) for all cases except insulation of closed-in walls (factor is 3.0) and ceiling insulation when attic has complete floor (factor is 1.2). Figure 5.2 is a revised job sheet.

Page 24

Delete and replace with a list of pre-approved tactics. This list can include the following:

- Hot Water Heater Temperature Turndown
- Shower Flow Restrictor
- Closing Up Unused Rooms if Occupants Agree

The furnace and plumbing related items should be discussed, but no recommendation is made at this time.

Page 27 - Installation of Materials

Instructions should be added for the following tactics:

1. Floor insulation
2. Crawl space perimeter insulation
3. Fireplace plugs
4. Glass storm window installation
5. Hot water heater insulation
6. Leaking faucet repair
7. Shower flow restrictor installation
8. Closing up unused rooms
9. Furnace pilot light extinguishment and relighting.

FIGURE 5.2
REVISED JOB SHEET

Job Sheet A

This Page
Is Removable for
Use at Job Site

Name _____ Address _____

Type of Materials	Quantity Required	Estimated Cost	Labor Factor*	Total Cost	Location Where Materials Are To Be Installed (Walls, Ceiling, etc.)	Installation Figure No	Special Instructions

(Insert Carbon Paper Under Table at Top of Page Only)

* Labor factor is 1.0 for all cases except the following:

Insulation of closed walls - 3.0

Insulation of ceilings when attic has floor - 1.2

Map or directions for locating home:

**FILL IN
AT JOB SITE**

Work record

Activity	Date	Supervisor	Comments
Order materials	_____	_____	_____
Install materials	_____	_____	_____

REFERENCES

BASIC DOCUMENTS STUDIED

- (1) "Project Conserve - Functional Requirements Document," Applied Urbanetics, Inc., Federal Energy Administration, June 1977.
- (2) "Retrofitting Homes for Energy Conservation - A Business Guide," NAHB Research Foundation, Inc., December 1975.
- (3) "Retrofitting Existing Housing for Energy Conservation: An Economic Analysis," Building Sciences Series 64, Center for Building Technology, National Bureau of Standards, December 1974.
- (4) "Project Retro-Tech," R. Hill, et al., University of Maine, Federal Energy Administration, May 1976.
- (5) "In the Bank...Or Up the Chimney," ABT Associates, Inc., Federal Energy Administration and U.S. Department of Housing and Urban Development, April 1975.
- (6) "A Community Planning Guide to Weatherization," Community Services Administration, September 1975.
- (7) "Family Housing - Energy Conservation Handbook," Naval Facilities Engineering Command, March 1974.
- (8) "Keeping the Heat In - How to reinsulate your home to save energy and money (and be more comfortable too)," Energy, Mines and Resources Canada, Office of Energy Conservation, August 1976.
- (9) An evaluation of Data Developed in "A Study of Level of Retrofit for Energy Savings of Homes Owner Occupied by Low Income Families," NAHB Research Foundation, Inc., March 1975.
- (10) Farmer's Home Administration's Proposed Thermal Performance Standards

APPENDIX A

WEATHERIZATION TACTICS

APPENDIX A
WEATHERIZATION TACTICS

A-1	INFILTRATION REDUCTION	Recommended
A-2	FIREPLACE PLUGS	Recommended
A-3	CEILING INSULATION	Recommended
A-4	WALL INSULATION	Recommended
A-5	FLOOR INSULATION	Recommended
A-6	CRAWL SPACE INSULATION	Recommended
A-7	DUCT INSULATION	Recommended
A-8	HOT WATER HEATER INSULATION	Recommended
A-9	STORM WINDOWS	Recommended
A-10	STORM DOORS	Not Recommended
A-11	CLOSING UP UNUSED ROOMS DURING HEATING SEASON FROM THE REST OF THE HOUSE	Optional
A-12	OIL OR COAL FURNACE SERVICING	Recommended
A-13	LOWERING FURNACE FAN SWITCH SETTING	Optional
A-14	HEAT RECOVERY FROM FLUE	Not Recommended
A-15	FLUE VENT	Not Recommended
A-16	FURNACE PILOT LIGHT	Optional
A-17	HOT WATER HEATER TEMPERATURE TURNDOWN	Recommended
A-18	SHOWER RESTRICTOR	Recommended
A-19	LEAKING FAUCET REPAIR	Optional

INFILTRATION REDUCTION

Strategy:

Caulk and weatherstrip doors and windows and foundation cracks.
Repair all wall and roof holes.

Phenomena:

Infiltration is often the largest single source of heat loss^(1,2), often up to 30 to 40% of the total. Through cracks, holes, and crevices, cold air enters the house and heated air escapes. Closing these openings substantially reduces the heat loss.

Advantages:

Heat loss is reduced and fuel is saved.
Repair is simple and straightforward.
Materials are inexpensive.
Payback is fast.
Its use aids the effectiveness of other tactics³.

Disadvantages:

Some cracks are due to structural problems which still must be corrected.

Savings:

Savings depend on the house condition and the local weather. Savings from infiltration reduction are usually the largest of any tactic. Using the Project Retro-Tech method⁴, heat savings for the characteristic low income house located in Washington, D.C. from reducing air changes per hour from 3 to 1 were 2.72·10⁷ BTU's annually or \$141 for an oil furnace at 70% efficiency and oil at \$.50 per gallon. Payback for materials only is on the order of a few months.

Recommendations:

This tactic should be given first priority due to the high heat savings, low cost, and benefit for other tactics.

References:

1. "Family Housing - Energy Conservation Handbook," Navy Facilities Engineering Command, March 1974, p V1-2.
2. "Keeping the Heat In," Energy, Mines and Resources, Canada, August 1976, pp. 35-36.
3. "A Community Planning Guide to Weatherization," Community Services Administration, September 1975, p. 17.
4. "Project Retro-Tech," R. Hill, et al, University of Maine, Federal Energy Administration, May 1976, p. 16.

FIREPLACE PLUGS

Strategy:

Install an insulated plug in the fireplace.

Phenomena:

Even with the damper closed, a great deal of heat can escape up the chimney. Installation of an insulated plug when the fireplace is not in use seals off this area and prevents this heat loss.

Advantages:

Heat loss through the fireplace is reduced so the house heating load is reduced.

Disadvantages:

Covering of the fireplace may not be aesthetically pleasing to inhabitants.

Cost:

Cost can be small by constructing plug from plywood and fiberglass insulation.

Savings:

Savings have not been quantified but the heat loss by a fireplace with a missing damper can be appreciable.

Recommendations:

Fireplace plugs should be installed when acceptable to the inhabitants.

References:

1. "Keeping the Heat In," Energy, Mines and Resources, Canada 1976, pp. 88-89.

CEILING INSULATION

Strategy:

Insulate unfinished ceiling below roof.

Phenomena:

Large amounts of heat are lost by conduction through poorly insulated ceilings¹. Insulation of this area greatly reduces the heat loss.

Advantages:

Fuel costs are reduced by lessening the house heat load.
Paybacks are generally fast.

Disadvantages:

Roof leaks must be repaired to prevent wetting the insulation which can lead to structural damage.

Savings:

Savings depend on the amount of insulation present and the area of the country. Ceiling heat loss typically runs from 5 to 25 percent of the total house heat loss². Assuming an 850 square foot house with a 650 square foot attic in the Washington, D.C. area with an attic insulation of R-2, insulating to R-20 using the Project Retro-Tech³ calculation method would save about 2.93×10^7 BTU's annually. At 70% furnace efficiency, this savings equals \$125 in natural gas at \$.30 per therm or \$151 in oil at \$.50 per gallon. At \$.20 per square foot of insulation material, the payback is about one year for either case.

Recommendations:

This option should be adopted for consideration due to its high heat savings and fast payback.

References:

1. "Retrofitting Existing Housing for Energy Conservation: an Economic Analysis," NBS, 1974, pp.44-45.
2. "Keeping the Heat In," Energy, Mines, and Resources, Canada, August, 1976, pp. 34-36.
3. "Project Retro-Tech," R. Hill, et al., University of Maine, Federal Energy Administration, May, 1976. p. 18.

WALL INSULATION

Strategy:

Insulate walls

Phenomena:

Large amounts of heat are lost by conduction through uninsulated walls¹. Insulation in this area greatly reduces this heat loss.

Advantages:

Reduces fuel costs by lessening house heat load

Disadvantages:

Expensive contractor installation is required for closed walls.
Payback time can be long.
There can be moisture condensation problems in the wall.

Savings:

Savings depend on the amount of insulation present, the type of wall, and the area of the country. Wall heat loss typically runs from 10 to 40 percent of the total house heat loss². Assuming an 850 square foot house in the Washington, D.C. area with uninsulated walls, insulation to R-15 using the Project Retro-Tech calculation method³, would save about 2.14×10^7 BTU's annually. At 70% furnace efficiency, this loss equals \$92 in natural gas at \$.30 per therm, or \$110 in oil at \$.50 per gallon. Assuming \$.60 per square foot of blown-in insulation installed, paybacks are about 6 years.

Recommendations:

This option should not be adopted due to the high cost resulting from the need for contractor blow-in insulation which results in long payback times, especially compared to other tactics.

References:

1. "Retrofitting Existing Housing for Energy Conservation: An Economic Analysis," NBS, 1974, p. 45-46.
2. "Keeping the Heat In," Energy, Mines and Resources, Canada, August, 1976, pp. 35-36.
3. "Project Retro-Tech," R. Hill, et al., University of Maine, Federal Energy Administration, May, 1976, p. 21.

FLOOR INSULATION

Strategy:

Insulate floor of heated areas above unheated rooms or crawl space that cannot be sealed off.

Phenomena:

Large quantities of heat can be lost by conduction through floors from heated areas into unheated areas. Insulation of these floors reduces this heat loss.

Advantages:

Reduces fuel costs by reducing heat loss
More effective than wall insulation except for sealed crawl spaces

Disadvantages:

Could lead to freezing of pipes in certain areas

Savings:

Savings depend on the amount of insulation present, the area of the country, and the type of space beneath the heated area. For a house in the Washington, D.C. area with a 500 square foot floor above a basement (all above ground), increasing the floor insulation from R-3 to R-14 saves 8.6×10^6 BTU's annually. At 70% furnace efficiency, this loss equals \$37 of natural gas at \$.30 per therm or \$45 of oil at \$.50 per gallon. For insulation materials at \$.15 per square foot, the payback is about 2 years for materials only.

Recommendations:

This option should be adopted for consideration due to the appreciable heat savings and fairly fast payback times.

References:

"In The Bank...Or Up The Chimney," AET Associates, Inc.,
Federal Energy Administration and U.S. Department of Housing
and Urban Development, April 1975, pp. 21-23.

CRAWL SPACE INSULATION

Strategy:

Insulate walls and adjacent ground of crawl space that can be tightly sealed.

Phenomena:

Heat is lost by conduction from heated areas through the floor through the crawl space walls. Insulation of these walls reduces this heat loss.

Advantages:

Fuel costs can be reduced by lessening the house heat load. Insulation of these walls is the most economical and efficient place to reduce this heat loss.

Disadvantages:

No insulation should be added when there is some already present. It may be difficult to get into the crawl space to do the work in certain situations. Crawl space must be well ventilated during warm weather.

Savings:

Savings depend on the type of crawl space, its accessibility, and the area of the country. For a house in the Washington, D.C. area with a 500 square foot floor above a 3 foot crawl space area, increasing the wall R value from 3 to 14 with insulation, saves 4.6×10^6 BTU's annually. At 70% furnace efficiency, this loss equals \$20 of natural gas at \$.30 per therm or \$24 of oil at \$.50 per gallon. For insulation materials at \$.15 per square foot, the payback is between 2-3 years for materials only.

Recommendations:

This tactic should be adopted due to the heat savings and fairly fast payback times.

References:

"In The Bank...Or Up The Chimney," AET Associates, Inc.
Federal Energy Administration and U.S. Department of Housing
and Urban Development, April 1975, pp. 21-23.

DUCT INSULATION

Strategy:

Insulate air ducts through cold areas of the house such as basements, crawl spaces and attics.

Phenomena:

Air ducts lose heat in cold areas during the winter and gain heat from warm areas during the summer (if used for air conditioning). Some of the heat lost may go into the conditioned house, but much of it does not. Insulation lessens these effects.

Advantages:

Decreases heating load and thus fuel usage.
Inexpensive and generally easy to install.

Disadvantages:

None.

Savings:

One source¹ estimated losses at up to 40% of total heat load if ducts are uninsulated or leak. It recommends at least one inch of board-type or 1.5 inches of wrap-on insulation. Other sources^{2,3} recommend two to three inches of wrap-on insulation for exposed ducts. One source⁴ states that using two inches of flexible insulation instead of one inch of insulation reduces heat loss by 3400 BTUH per foot or about a 30% increase in efficiency. Taking this as an example, with natural gas at \$.30 per therm, a 70% furnace efficiency, a 180-day heating season and a 25% on-cycle, a savings of \$1.58 per foot of ducting would be realized during the winter. For oil, the savings would be about 21% higher (oil at \$.50/gal), for electricity about 46% higher (at \$.035/Kwhr). Another source⁵ using a 4200 degree day climate, puts the savings at \$1.01 per linear foot for trunk (greater than 8-inch diameter) ducting in an attic with attic insulation, \$.64 per linear foot in a basement with no insulation, and \$1.01 per linear foot in a basement with floor insulation. Another source⁶ puts the savings from installing one inch of insulation on uninsulated ducting at \$22 per 10 feet of ducting for gas and \$28 for oil.

Recommendations:

This tactic pays for itself slightly over a year so it should be added to the weatherization process.

References:

1. "Energy Conservation in the Home," University of Tennessee
2. "In the Bank...Or Up the Chimney," HUD, p. 63
3. Slide 54 - Home Energy Savers Workshop - Virginia Energy Office
4. "44 Ways to Save Energy," Owens Corning
5. "Retrofitting Homes for Energy Conservation - A Business Guide," NAHB, p. 53, 55
6. "Family Housing Energy Conservation Handbook," U.S. Navy, p. XIII-3

HOT WATER HEATER INSULATION

Strategy:

Install insulation on the hot water heater.

Heating hot water accounts for about 10-20% of residential energy use.

Phenomena:

Insulation will reduce the heat loss by conduction from the hot water heater. This loss averages about 25% of the input to the heater, though one source¹ reports losses of 20% for a 50 gallon electric heater and 35% for a 40 gallon LPG water heater.

Advantages:

Reduces hot water heating load under most circumstances. The insulation is inexpensive and generally easy to apply.

Disadvantages:

Under certain circumstances, the heat loss may be beneficial to the residence.

Cost Savings:

Reported cost savings range from 24% to 30% of the storage losses for electric and gas water heaters. Approximate dollar savings on electric water heaters were \$12-28^{1,2,3} per year at \$.035 Kw/hr depending on assumed initial energy usage. Reported dollar savings on 40/50 gallon^{1,2} gas water heaters were approximately \$10-12 per year at \$.30/therm. This figure leads to paybacks of 1-2 years for self-installation. The above savings are for cases in which the heat loss did not help the house heat balance. If the initial heat loss contributed to the winter heating load, the savings would be diminished considerably. In some instances, the use of insulation is negated by the need for more space heating if the heater heat loss had entered the house.

Examples:

Reported savings² on 40 and 52 gallon water heaters at 140°F were 30% (projected 362-439 Kw/hr/yr) and 28% (projected 36 therms/yr) for a 40/50 gallon gas water heater at 140°F. For an 82 gallon³ electric water heater with R-7 insulation added and with a 50 gallon per day usage rate, savings were reported at \$28 annually for electricity at \$.035 per Kw/hr. The temperature was 140-160°F.

Recommendations:

For houses in which the heater loss would not contribute to the house load, this measure should be adopted due to its fast payback.

References:

1. "Insulation Refit Kit for Domestic Water Heaters," Johns-Manville Sales Corporation, 1977.
2. "Tips for Energy Savers," Federal Energy Administration, p. 18.
3. "Retrofitting: Plan, Action, and Early Results Using the Townhouses at Twin Rivers," Harrje, David T., Center for Environmental Studies, Princeton University, June 1976, p. 14.

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STORM WINDOWS

Strategy:

Install storm windows on single glazed windows.

Phenomena:

Large amounts of heat are lost by conduction and by infiltration through single glazed windows. Weatherstripping effectively reduces infiltration except in cases of very loose windows. In those cases, storm windows will reduce infiltration as well as conduction.

Advantages:

Heat loss is reduced thereby saving fuel.
Cold drafts around windows are reduced.
Window moisture problems are reduced.

Disadvantages:

Plastic storm windows have to be replaced each heating season. Experience has shown that some residents destroy plastic storm windows after one heating season and will not replace them. Triple track glass storm windows are expensive.

Savings:

Savings depend on the condition of the weatherstripping and local weather. Plastic and glass storm windows have similar heat loss reduction properties. Heat losses from windows from the characteristic low income house were about 10% of the heating load, though for more insulated houses, the loss is usually 20-30%¹. In cases in which infiltration is corrected by weatherstripping, storm windows are taken as reducing conduction losses by one-half^{2,3,4}.

Heat loss savings from storm windows for the characteristic low income house in Washington, D.C., considering only conduction reduction, is $6.2 \cdot 10^6$ BTU's annually or \$32 based on oil heat at 70% efficiency and oil at \$.50 per gallon. Payback for plastic storm window materials in such a case would be about .8 year; for permanent triple track glass storm windows, it would be about 9 years. For the case in which the windows are in poor enough condition that weatherstripping does not control infiltration, the extra heat savings from controlling that source is $7.8 \cdot 10^6$ BTU's annually. Based on oil heat, the total savings is \$72. This would make the total plastic storm window payback about .4 year and the total glass storm window payback about 4 years.

Recommendations:

Plastic storm windows are always effective and should be installed. For cases in which funding permits, triple track glass storm windows should be installed to take advantage of the benefits from reducing heating losses for many years.

References:

1. "Keeping the Heat In," Energy, Mines, and Resources, Canada, August 1976, pp. 35-36.
2. "Project Retro-Tech," R. Hill, et al., University of Maine, Federal Energy Administration, May 1976, p.7.
3. "Retrofitting Existing Housing for Energy Conservation: An Economic Analysis," NBS, 1974, pp. 63-65.
4. "Project Conserve - Functional Requirements Document," Applied Urbanetics, Inc., Federal Energy Administration, June 1977, Appendix A.

STORM DOOR

Strategy:

Install storm doors on house outside doors.

Phenomena:

A storm door reduces the thermal conductance through the primary door's wood and glass areas by setting up dead airspace resistance. It also reduces infiltration losses through the primary door, though this reduction is less than from weatherstripping¹ for well-fitted doors and the same as weatherstripping for average/poor-fitted doors.

Advantages:

Heat loss is reduced through primary doors, leading to home heating fuel reduction.

Disadvantages:

Storm doors are costly and often have a long payback period. Weatherstripping can accomplish nearly the same savings at a much lower cost.

Costs:

Storm door costs range from \$75² to \$125⁴.

Savings:

Infiltration savings are the same or less than those which can be accomplished with weatherstripping. For well-fitted doors, weatherstripping reduces infiltration by 50%¹, storm doors by 30%. For average or poor-fitted doors, either measure reduces infiltration by 50%.

The thermal conduction loss reduction from storm doors is not great. Using the NBS Technique¹, for a 20% glass, 80% wood door (1.5 inches thick), a storm door reduces the thermal conduction loss by 38% or .4 million BTU's per door, for a Washington, D.C. area house. For an all-wood door, the thermal conduction loss is reduced by 25% or .2 million BTU's per door for Washington, D.C. The NBS³ results recommended that storm doors be installed only for heating costs of \$1.50 (electricity at \$.05 KW/hr) per 100,000 BTU's for a house in the Washington, D.C., area. The primary door had 20% glass. The U.S. Navy⁴ report calculated infiltration heat savings from storm doors for a Washington, D. C., house as being 42 gallons of oil per year (\$21 at \$.50/gal) or 5410 cubic feet of gas (\$16 at \$.30/therm).

Recommendations:

Storm doors should only be considered in high fuel cost, cold climate conditions for primary doors that are partly glass. In other situations, weatherstripping (at a much lower cost) accomplishes nearly the same heating savings.

(Storm Doors - Continued)

References:

1. "Retrofitting Existing Housing for Energy Conservation: An Economic Analysis," NBS, 1974, pp. 66-67.
2. Ibid, p. 50.
3. Ibid, p. 31.
4. "Family Housing - Energy Conservation Handbook," Navy Facilities Engineering Command, 1974, p. XII-12.

CLOSING UP UNUSED ROOMS DURING HEATING SEASON FROM THE REST OF THE HOUSE

Strategy:

Separate off unused rooms during the winter by putting up a thermal barrier around the door or entrance and turning off any inside heating devices such as radiators. Blankets can be tacked up in entrances or rugs put under doors. Plastic can be hung over door like a storm window.

Phenomena:

Heat and consequently fuel is saved from shutting off unused rooms from the rest of the house during the winter.

Advantages:

Heat is saved, thereby reducing the fuel bill.
Installation is simple and easy.
Method is inexpensive.
No discomfort is experienced by occupants.

Disadvantages:

Occupants may object to loss of space.
Moisture problems may result in very cold areas.

Costs:

Minimal.

Savings:

Savings vary widely depending on the size of shut off rooms, their location, and the temperature involved, but there is always some savings involved. As an approximation, for a 10 foot by 10 foot outside room in a one story house, savings per heating season in an area with an average 35°F temperature could be expected to range from \$15 for natural gas at \$.30 per therm to \$38 for electricity at \$.035 per kw/hr¹.

Recommendations:

This measure should be adopted with occupants approval due to its benefit with little cost.

References:

1. "ASHRAE Guide and Data Book, Fundamentals and Equipment," 1963.

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OIL OR COAL FURNACE SERVICING

Strategy:

Have oil or coal furnace serviced annually.

Phenomena:

Annual servicing^{1,5} of an oil or coal furnace including cleaning of heat exchanger surfaces, burner adjustments and replacement of filters which allows the furnace to operate at high efficiency.

Advantages:

Maintaining high furnace efficiency eliminates unnecessary fuel consumption. Payback is generally fast.

Disadvantages:

If the furnace is already operating efficiently, servicing will not increase efficiency appreciably.
Skilled service person usually required.

Savings:

Reduction in fuel consumption of about 10%^{1,2,3,4} is expected. With servicing costing about \$25-35, the payback is usually less than one year.

Recommendations:

For houses with no recent furnace servicing, this measure should be utilized.

References:

1. "In The Bank...Or Up The Chimney, HUD, April 1975, pp. 60-61.
2. "Family Housing - Energy Conservation Handbook," Navy Facilities Engineering Command, March 1974, pp. X-1-X-3
3. "Measures for Reducing Energy Consumption for Homeowners and Renters," Federal Power Commission, 1975, p. 7.
4. "Technical Options for Energy Conservation in Buildings," NBS Technical Note 789, 1973, p. 41.
5. "Maintenance and Adjustment Manual for Natural Gas and No. 2 Fuel Oil Burners," Bureau of Natural Gas, FPC and DOE, 1977.

LOWERING FURNACE FAN SWITCH SETTING

Strategy:

Lower the furnace fan switch setting on hot air systems to lower temperatures.

Phenomena:

Fan switch settings¹ are generally set at high furnace bonnet temperatures for "fan on" and "fan off" operation to keep discharge air temperatures high. On gas furnaces, the "fan on" temperature is generally 125° to 140°F and the "fan off" temperature 100°F. By lowering these temperatures, for example 90-95°F for "fan on" and 75-80°F for "fan off", more of the heat generated by the furnace is delivered to the house thereby resulting in a higher furnace efficiency and a fuel savings.

Advantages:

Furnace efficiency is higher, resulting in fuel savings.

Disadvantages:

1. The furnace control system has to be reset to allow longer blower operation.
2. Electricity is required to keep the blower operating, thus decreasing cost savings.
3. Ducted air will be cooler at the end of cycles. If blown directly on inhabitants, it may be uncomfortably cool.

Costs:

They are due to resetting or modification of the furnace control system and to higher electricity usage for the fan.

Savings:

Savings will vary with the type of furnace, its size, and the house location. Savings generally increase the colder the climate.

A computer simulation run^{1,2} for 4 cities with an increasingly higher number of degree-days measured the difference in efficiencies between a normal fan switch cycle (140°F "on", 100°F "off") and an adjusted cycle (on at 10°F above room temperature, off at 5°F above room temperature). Two furnace sizes were used, one correctly sized and the other doubly sized. Savings were calculated, taking into account the fuel savings from the higher furnace efficiency and the higher electricity costs from longer fan operation. Annual savings ranged \$3.30 in San Diego for a doubly sized furnace to \$20.50 in Minneapolis for a doubly sized furnace. The double size furnace values are reported because most units are oversized to that extent.

(Lowering Furnace Fan Switch Setting - Continued)

Recommendations:

For cases in which only a minor adjustment is necessary, this measure should be adopted. For cases in which more modification is necessary, it is doubtful whether the payback would justify this measure.

References:

1. "Heat Balance and Efficiency Measurements of Central, Forced-Air, Residential Gas Furnaces"; Oak Ridge.
2. "A Regional Comparison of Savings from Various Residential Energy Conservation Strategies;" J. C. Dalena, et al., Oak Ridge, February 1976, pp. 36-39.

HEAT RECOVERY FROM FLUE

Strategy:

Put heat exchanger in furnace flue to recover waste heat.

Phenomena:

Up to 30 percent¹ of the energy available from fossil fuels can be lost as heat in the flue gas from house furnaces. Temperatures can range from 450°F to 800°F in the stack gases. By inserting a heat exchanger in the stack, part of this waste heat can be recovered, thereby increasing the overall efficiency of the furnace.

Advantages:

Heat that would otherwise be lost can be reclaimed by the heating of air or water. This reclaiming increases overall furnace efficiency and decreases fuel usage, leading to dollar savings.

Disadvantages:

Waste heat reclamation from furnace flues is prohibited in many areas by local building codes and regulations. The flue gas contains noxious gas which could leak through a heat exchanger stack opening. Cooling down of the flue gases by heat reclamation could cause poor draft in the stack which could lead to release of carbon monoxide also.

The heat recovery devices are fairly expensive and can be difficult to install.

The stack temperature of gas furnaces is not high enough to use these devices safely.

Savings:

There are several devices on the market for flue gas waste heat recovery. Reported recovery rates range^{1,2,3} from 3 to 12 percent of the fuel burned. One source² reported savings of 125 therms per year (12% savings), which for natural gas at \$.30 per therm is \$38.

Recommendations:

Due to safety and code problems, and possibly expensive installation, this measure is not recommended.

References:

1. Consumer Reports article, January 1977.
2. "Residential Energy Consumption, Single Family Housing," R.W. Anderson, Hittman Associates, pp. 51-53.
3. "Heat Balance and Efficiency Measurements of Central, Forced-Air, Residential Gas Furnaces," E.C. Hise, et al., Oak Ridge, pp. 46-49.

FLUE VENTS

Strategy:

Install flue vents in the furnace stack.

Phenomena:

After the furnace turns off, a lot of heat is still lost up the stack. These losses amount to 10-15% of the furnace fuel consumption. Flue vents installed in the stack could be closed when the furnace turns off, stopping this escape of heat. However, if the flue does not open when the furnace comes on again, toxic carbon monoxide may be circulated in the house. Approved flue vents for retrofit have just appeared on the market.

Advantages:

Heat usually lost up the stack after the furnace is turned off is retained, thereby resulting in energy savings.

Disadvantages:

If the vents do not open when the furnace turns on, the toxic carbon monoxide fumes may be circulated through the house.
Building codes often prohibit flue vents.
Cost is high.
Installation requires skilled service person.

Recommendations:

This measure should not be adopted due to the potential safety problems and high cost at present.

Reference:

1. "Control of Overall Thermal Efficiency of Combustion Heating Systems," Bonne, U., et al., 16th International Symposium on Combustion, MIT, Cambridge, Massachusetts, August 15-21, 1976.

FURNACE PILOT LIGHT

Strategy:

Turn off gas furnace pilot light during the non-heating seasons.

Phenomena:

Pilot lights of furnaces are generally lit year round. During the non-heating season the fuel used is wasted. Thus by extinguishing this light the fuel is conserved.

Advantages:

Fuel is conserved and thus cost savings are realized.

Disadvantages:

Pilot light must be relit before the heating season. Furnace could not be used in case of an unseasonable cold spell. Savings are small.

Cost:

None - if occupant can perform relighting.
Small - having serviceman turn off and on the pilot light.

Savings:

For a gas furnace, the pilot light monthly consumption¹ is generally 750-1000 cubic feet of gas. For a 5-month shutoff period, the savings at \$.30 per therm is about \$11-\$15.

Recommendations:

If this measure can be safely and easily done by the homeowner, it should be adopted due to its savings.

References:

1. "Heat Balance and Efficiency Measurements of Central, Forced-Air, Residential Gas Furnaces," Wise, et al., Oak Ridge, pp. 12-14.

HOT WATER HEATER TEMPERATURE TURNDOWN

Strategy:

Turn down the hot water thermostat to 120°F.

Heating hot water accounts for about 10-20% of residential energy use, so any percentage savings can be appreciable.

Phenomena:

Most hot water uses in the home require only 110°F water, so a turndown of the temperature from the usual 140°F or higher temperature to 120°F will still give satisfactory results and save fuel also. Only a dishwasher and clothes washer need 140°F water, and laundry detergents are available for lower temperature water. Hot water storage losses are generally taken as 25% of the total energy requirements, though one source quoted losses of 20% from a 52 gallon electric water heater and 35% from a LPG water heater.

Advantages:

Reduced heat losses and consequent fuel savings.

Disadvantages:

High temperature hot water (140°F) is not available if necessary for dishwasher and clothes washer use.

Occupants may run out of hot water more often.

Some training is required.

Cost:

None.

Savings:

Savings result from this no-cost change, if occupants permit its use

For a temperature reduction from 140°F to 120°F, savings of 6% to 30% are estimated⁽¹⁻⁶⁾. Reductions of 10°F would give estimated savings from 4% to 15%^(2,6,7). One source estimated savings of 9% for electric water heaters and 15% for gas heaters for a reduction from 140°F to 110°F⁽⁶⁾. For a water heating bill of \$15 per month, annual savings of 6% to 30% would give annual savings of from \$11 to \$55.

Example:

From a NSF study, an electric 50 gal⁽⁶⁾ water heater saved 4.5% per 10°F reduction while a 40-gallon fossil fuel heater saved 5.8% per 10°F reduction.

References:

1. "In the Bank...Or Up The Chimney," p.63
2. "Tips for Energy Savers," p.18
3. "RBS Technical Options for Energy Conservation in Buildings," p. 102-103
4. "Measures for Reducing Energy," FPC, p.9
5. Slide 67 - Home Energy Savers Workshop - Virginia Energy Office
6. "Energy Conservation in the Home," University of Tennessee
7. "Retrofitting: Plan, Action, and Early Results Using the Townhouses at Twin Rivers," Harrje, David T., Center for Environmental Studies, Princeton University, June 1976.

SHOWER RESTRICTOR

Strategy:

Install a shower restrictor to save hot water.

Phenomena:

A shower may use up to 8 gallons per minute of water. For hot showers, about half of this flow is hot. By installing a shower restrictor the flow^{1,2} can be cut to 3-4 gallons per minute, saving hot water and still giving a satisfactory shower.

Advantages:

Hot water flow in the shower is restricted, leading to hot water and fuel savings. Shower restrictors are inexpensive and easy to install.

Disadvantages:

Some users may object to reduction of shower rate.
Some plumbing tools required.

Savings:

Cutting the shower head rate from 8 gallons per minute² to 3 gallons per minute and assuming 2 showers of 5 minutes each leads to a savings of 30 gallons per day of hot water. Assuming a \$.30 per therm cost for natural gas with 70% heater efficiency gives a savings of \$33 per year. For electricity at \$.035 per Kw/hr, the savings would be \$79 per year. A restrictor costs less than \$1.00.

Recommendations:

This measure should be adopted due to its benefits and minimal cost.

References:

1. "Tips for Energy Savers," Federal Energy Administration, p. 23.
2. "Energy Conservation in the Home," University of Tennessee, ERDA, 1977, p. 158.

LEAKING FAUCET REPAIR

Strategy:

Repair leaky hot water faucets.

Phenomena:

Leaky hot water faucets waste hot water. Repairing these leaks reduces energy waste.

Advantages:

The water wastage is eliminated, thereby leading to fuel and water conservation.

Disadvantages:

The cost of repair can vary substantially. Repair of old faucets might necessitate replacement of all the hardware which would be costly. On the other hand, only low cost washers might need to be replaced. Some skills and tools are required.

Savings:

Nearly continuous drops from a leaking faucet were estimated to result in a loss of about a gallon per hour. Taking natural gas at \$.30 per therm with a 70% heater efficiency, this loss results in a fuel cost of \$.51 per week. For electricity at \$.035 Kw/hr, the loss would be about 2.4 times^{1,2} greater. A leakage rate of one drop per second results^{1,2} in estimated losses of 54 to 192 gallons monthly or a fuel loss of \$.16-.57 a month, based on natural gas. One source³ states that for a leakage rate of 200 gallons per month, annual fuel wastage would be 16.5 gallons of oil (\$8.25 at \$.50 gallon), 2150 cubic feet of gas (\$6.45 at \$.30 therm), and 710 Kw/hr of electricity (\$24.90 at \$.035 Kw/hr). Payback on repairs of faucets can vary widely because of the age and condition of existing plumbing.

Recommendations:

Due to the large variation in repair costs, this measure should be considered only in extreme cases of hot water leakage.

References:

1. "Measures for Reducing Energy Consumption for Homeowners and Renters", Federal Power Commission, 1975, p. 9.
2. "Technical Options for Energy Conservation in Buildings," NBS Technical Note 789, 1973, p. 104.
3. "Family Housing - Energy Conservation Handbook," Navy Facilities Engineering Command, March 1974, p. V-8.