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LOW COST FURNACE EFFICIENCY IMPROVEMENTS

Sun Power Consumer Association

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ABSTRACT

The potential energy savings of weatherization programs is vastly greater than the savings we have seen thus far. Furnace efficiency adjustments and modifications can bring these programs more in line with their potential.

In this paper, furnace efficiency work on over 400 low income households is studied. Funded by LIEAP these modifications are described in detail and compared to other furnace and weatherization options.

The client group was recruited from a general list of LIEAP recipients for this program which was sponsored by the Colorado Office of Energy Conservation.

Monitoring of actual changes in gas usage over a year's time is reported for a pilot group of homes. When corrected for weather changes this shows a 12% reduction on an average annual heating bill of $724. The program cost less than $150 per home.

The training, delivery, inspection and monitoring system of this extremely cost effective program are described. Institutional and economic barriers to widespread implementation of the program are discussed.

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Most weatherization programs fall far short of their potential energy savings, because they fail to incorporate low cost furnace efficiency modifications. Furnace efficiency modifications alone have shown to have an ongoing heating savings of 12% at a total cost of only $150 per unit. Some weatherization programs at a cost of $1,000 per unit have shown savings in the 13-14% range.

The high savings associated with this low cost program makes it one of the most cost effective weatherization options in existence. If the low cost furnace efficiency modifications were combined with a few other very cost effective measures, we would have a weatherization program of lower cost to the taxpayer and much higher return in energy savings.

INTRODUCTION

The Low Income Energy Assistance Program (LIEAP) provides that States may use a portion of their LIEAP allotment for low cost residential weatherization. In the Summer of 1982 two furnace efficiency programs were undertaken with LIEAP funds in Colorado. They were both administered on the state level by the Colorado Office of Energy Conservation. This paper reports on one of these programs, run by the Westside Energy Co-op (WEC) with technical assistance by Sun Power Consumer Association. During the same time period the local utility, Public Service Company of Colorado (PSCo) ran a similar furnace program with different results. The PSCo program report, "Furnace Inspection and Tune Up 1982-1983 Heating Season, Field Program Data" provides a point of comparison. Both programs utilized the same basic client base, except the PSCo program was limited to owner occupied dwellings.

DISCUSSION

Program Development

Sun Power Consumer Association was founded in 1979 to reduce low income people's dependence on purchased energy. It helped found the Westside Energy Co-op in 1981. In cooperation with WEC, Sun Power has started programs which concentrate on prioritization of energy expenditures to maximize energy savings. Through the WEC, the "barnraising" model was developed in which neighbors work on weatherizing each other's homes. These barnraisings concentrate on four areas: air infiltration, furnaces, windows, and domestic hot water. Analysis of actual fuel use changes for these programs generally showed a simple payback

time of less than one year. All paid back in less than two years. This is especially significant because these homes are heated with a relatively low cost fuel - natural gas.

Based on this history, the State of Colorado Office of Energy Conservation asked Sun Power to develop a low cost furnace program with a payback of less than two years. The furnace program was to be a complement to the low cost weatherization program the State already had in place. The program was limited to a total cost of $150 per unit. Other low cost spin-offs from the WEC barnraising experience are possible.

Program Goal

The goal of the WEC was to save over 10% annually on heating use for at least five years at an initial program cost not to exceed $150 per unit. In order to accomplish this goal a program was designed which would operate with the following philosophy.

1. Maximize energy savings with minimum cost. This insures that the client and the taxpayers get maximum benefit from the program.

2. Utilize local community people to do the work not requiring a heating contractor's license.

3. Insure energy savings by review of 100% of work done by a technically competent individual.

4. The majority of the savings should be long range - not just for a single year.

This program combined long term adjustments and modifications, safety repairs, tune ups and client education in one low cost package. This package was applied to every furnace to the extent it was applicable. Since July of 1982 over 587 furnaces have been treated under this WEC program.

Selection of Program Components

A large number of possible program components were evaluated prior to initiation of this program.

Furnace derating to reduce cycling losses in oversized furnaces has been suggested. Mechanical derating by reduction in orifice size, etc., does not meet local codes or AGA approval. When mechanical derating is used a reduction of both primary and secondary air is necessary in order to maintain steady state efficiency. Adjustment of secondary air on modern gas forced air furnaces is not generally accepted. Electrical derating by duty cycling appears to increase the risk of corrosion in the gas vent and heat exchanger.

Automatic vent dampers and intermittent ignition devices both increase the probability of reliability problems. In addition both devices tend to be somewhat expensive for the savings they achieve when applied "across the board". If additional funding were available an electronic automatic vent damper would have been included in a small percentage of furnaces where the probable savings would justify the cost. This would include situations where a large diameter gas vent or chimney removed heat from an intentionally heated space.

Many other furnace programs have actually been repair programs for "broken" furnaces. They generally do not result in improved furnace efficiency. While deficiencies uncovered in the course of the WEC program were corrected, the primary emphasis had to be on efficiency improvements. Therefore much of this program concentrated on correcting problems which were present when the furnace was originally installed.

Adjustments and Repairs. See Appendix A for a breakdown of adjustments and repairs discussed in this section.

Long Range Adjustments. Fan temperature adjustments reduce cycling losses. Work done on improving the delivery system to eliminate dumping heat into basements and crawlspaces is another long term adjustment. By various means the heat rise was reduced on 73.4% of the furnaces in the WEC program. This adjustment effects both delivery and steady state efficiencies.

Tune Up Items. Cleaning the blower and filter are known to effect the system efficiency. However these items need to be repeated year after year. The Westside program attempted to attack this in two ways. First the homeowner was encouraged to assist in the blower cleaning to see how bad it is needed and how to do it. Second all furnaces had a washable filter added with a clogged filter whistle.

Derating. The items which the WEC program did not include in this area probably contributed significantly to the success of the program. The WEC did not derate furnaces because of the detrimental effect it can have on steady state efficiency. The utility company viewed it as necessary to derate furnaces as specified by the manufacturer for the 5000 + ft. altitude. The PSCo program adjusted the gas pressure in 39% of the furnaces. Twenty percent of the furnaces were also derated. In many cases the steady state efficiency probably suffered in the PSCo program.

Safety. Significant safety items were discovered and repaired as a result of this program. In one case, (Case 26), the client had caulking and weatherstripping done both by family and by a low income weatherization program. As the home became tighter she showed increased dizziness, headaches and nausea. When the installer from the WEC program worked at the residence, a clogged flue and numerous gas leaks were discovered and corrected.

The clogged or disconnected gas vents were the most serious safety problems. Draft/gas vent problems were found and corrected in the WEC program in 16.2% of the units. The utility program found half that many vent problems.

While ten furnaces were originally suspected of having cracked heat exchangers, an accurate chemical test showed that only two were actually cracked. Similar results outside of this program have shown that homeowners often pay for new furnaces they don't really need.

Program Savings

The first 50 furnaces in the WEC furnace program are part of a longitudinal study of savings generated by the program. Methodology of the study is explained below. After four months, the program showed a heating only savings of 15% for an N of 37 units. Based on this data the program continued.

After 11 months the savings was recalculated based on the same methodology. This resulted in an average savings of 11.78% for an N of 28 units. (Other units had inadequate data or had changed occupancy.) The results for the same period were recalculated for units which had no other weatherization in either the base or the post change period. The eleven units which fit this category showed an average annual heating savings of 12%.

The 3% degredation over seven months is probably attributable to individual furnaces not being maintained on the strictly tune-up items (blower and filter maintenance).

By way of contrast, the PSCo program sampled 26 of the units contained in their program. This data analysis did not eliminate any changes in base use for hot water. All these units also received basic low cost weatherization during the same time period. The average savings on those units was 7.98%.

Savings Methodology. Accurate analysis of savings is achieved as follows.

1. The prechange actual CCF usage is totaled.
2. Daily degree day information is totaled for identical time period. (To Base 65°F)
3. Base (non-heating gas) use is subtracted.
4. Remaining use is divided by actual degree days giving CCF/degree day.
5. Multiply the CCF/degree day by the local average degree days, resulting in the total CCF use in a standard year.
6. Items 1 thru 5 are repeated for the post-change period. The difference in CCF use is multiplied by current gas cost to obtain savings.
7. Percent savings is also computed and savings in base (non-heating) use is printed separately. Both pre and post test periods must be for a 10 - 14 month period and exclude changes in occupancy.

Program Economics

The WEC furnace program is one of the most cost effective weatherization programs developed thus far. The total local program cost including training, outreach, administration, form review, inspection, installation and follow up is $150 per furnace. The 12% annual savings on an average heating bill of $724/year gives a simple payback time of 1.7 years. The long range adjustments will last as long as the furnace is in place. The 12% savings associated with those changes should therefore last beyond 10 years.

Barriers To Implementation

The primary barrier to widespread implementation of this cost effective program is the widespread belief that "business as usual" is the best policy on weatherization. In spite of the fact that Project Retrotech has proven to be unreliable in prioritizing weatherization expenditures, program directors are hesitant to use available flexibility to include furnace options outside the specified addition of furnace efficiency devices. The weatherization community does not generally see the difference between an hour spent by a heating contractor whose emphasis has been repair and a tightly controlled program built around efficiency increases. Personnel who are already trained specifically in furnace efficiency are not available in the phone book. They must be trained for this task.

METHODOLOGY - PROGRAM OPERATION

Personnel

The personnel in this program were as follows:

1. Installers - Community members were recruited and specifically trained on furnace efficiency. Later programs have used installers who already work on other weatherization programs. Installers' work is limited to the items on the flow sheet. The flow sheet is the "Bible" of the program.

2. Inspector, Form Reviewer and Program Coordinator - These tasks can be performed by a single person in programs doing less than twenty furnaces per week. This individual must be the most technically competent individual who was originally trained as an installer. It is a position installers can move into.

3. Heating Contractor - A "willing to learn" individual with the proper licenses is required to repair gas leaks, replace electrical components and replace other furnace components which novices cannot be rapidly trained to do. These items also must be done by a licensed contractor according to building code. This individual extends the program's ability to deal with any possible problems.

Training

The Westside program was designed to maximize the use of local individuals not previously trained in furnace work. It was able to bring these individuals to a level of knowledge sufficient to accomplish all but the items that local code required be accomplished by a licensed heating contractor.

The most important part of the training is that each individual come out of it with the attitude that they are going to find a way to make each furnace as efficient as it can be.

Installer Training. The installer begins with four hours of classroom instruction on the operation of gas forced air furnaces and the opportunities available for increasing their efficiency. Also included is a description of program procedures and philosophy. This day concentrates on the "typical" furnace. The installers spend the afternoon with experienced trainers rotating through stations which each address a different portion of the efficiency program in a "hands-on" manner. The first day of training closes with a group discussion and answer session.

On the second morning two installers accompany a trainer to a furnace and perform the procedures they learned the previous day. They follow the flow sheet and prepare the report form. The form is discussed during the afternoon. The afternoon discussion session expands on their experience with the furnaces of that day and begins to introduce the exceptions to the "typical" furnace.

During the third day each installer completes a furnace of their own with a trainer present. The results are discussed at an evening meeting of all the installers.

Subsequently the installers obtain feedback in three ways:

1. Installer forms returned with comments from the form reviewer.

2. Periodic meetings of all installers with the trainer and form reviewer.

3. Notes and personal feedback from inspector.

The training requires a lot of attention by the installers. About half of the individuals who begin the training stick with it to actually do furnaces. The majority of the fall out is in the first day.

Inspector Training. The inspector is trained first as an installer. They then receive 1/2 day of additional training, and constant feedback on inspections.

Form Reviewer Training. The technical form reviewer receives eight hours of side-by training and feedback as required.

Heating Contractor Training. The heating contractor receives 1/2 day of training plus feedback.

Program Coordinator Training. The program coordinator receives approximately twelve hours of training, plus weekly feedback.

Outreach

During the course of the program two methods of contacting LIEAP recipients have been used. Initially the available LIEAP lists did not contain telephone numbers. Therefore a bilingual letter from the Westside Energy Co-op was sent to 500 LIEAP recipients. The result was an 18% response rate. This exceeds the response rate that the State of Colorado got when soliciting for Public Service Company.

The Colorado LIEAP lists now contain phone numbers fro the majority of the clients. Using these lists, phone solicitation has shown a better response for less total time.

All contacts were grouped by zip code to reduce travel time for all personnel.

Table 1. Outreach response rate.

Westside Energy Co-op		State of Colorado for PSCo	
letter	Phone	Letter	Phone
18%	31%	10%	13%

The overwhelming reason for non-participation by phoned clients is that they do not have a forced-air furnace. The second most prevalent reason is that either they were previously served by the program or their furnace was otherwise recently serviced.

Installation

The installers spend an average of 3 1/4 hours per furnace and follow the flow sheet.

1. Entry interview:
   a. Any heating problems known to client.
   b. What will be accomplished in the visit and reiterate the fact that the service is free.
   c. Cycle the furnace by turning up the thermostat to insure it works properly before work is begun.

2. Efficiency and safety inspection, recording all data for later review by technical form reviewer.
   a. Check fan on/off temperatures.
   b. Check draft.
   c. Check high limit switch.
   d. Check heat rise through heat exchanger.
   e. Check for gas leaks.

3. Work is prioritized for each house dependent on the efficiency inspection. All work done is recorded on the report form attached as Appendix C.
   a. Adjust blower speed.
   b. Adjust fan on/off temperature.
   c. Replace frayed belts.
   d. Clean and oil blower.
   e. Adjust anticipator.
   f. Tape ducts and plenum.
   g. Install permanent filter with whistle.
   h. Unclog flue.
   i. Open or adjust dampers.
   j. Move furniture blocking registers.
   k. Reconnect ducts if new duct materials not needed.

4. Repeat all efficiency checks and record final condition of furnace.

5. Conduct a self-help session with homeowner regarding their furnace, teaching them ways to maintain the efficiency of their system.

The installers are paid $25 - $30 per furnace for these services.

The PSCo program broke the jobs down into similar categories. The initial checks by their personnel averaged one hour and eight minutes and cost $28.33 per furnace (not charged). The second phase was adjustments and repairs made by their service people. This cost about $41.06 per furnace. These utility program costs do not include travel, office personnel, computer time, etc.

Form Review

Every week, <u>every</u> report form was reviewed to determine what additional work might be necessary. This review results in four possible actions:

1. Return to furnace by installer.

2. Written comments to installer.

3. Furnace determined to be completed.

4. Follow up by heating contractor.

This form review is the key to assuring each furnace is brought to peak efficiency.

Follow Up

52% of the furnaces needed follow up by the licensed, insured, heating contractor. This follow up included: replacing fan/limit switch, repairing duct work, replacing thermostats, repairing gas leaks, reconnecting the flue, fixing roll out, performing a heat exchanger test, replacing pulleys, installing fusetron, rewiring, replacing blower

motors, blowers, gas valves, and thermocouples. The work by the heating contractor cost an average $59.92. In the PSCo program the average cost of the heating contractor phase was $57.70.

Inspection

Based on review of the forms, one out of every four furnaces by each installer was selected for inspection. Inspections verified the final data on the form and insured that all materials and client information was properly delivered. 7.5% of the inspections failed. These mistakes were corrected by the installer and an additional inspection of another furnace by the same installer was made.

RECOMMENDATIONS

Individual weatherization items should be applied to low-income housing based on their cost effectiveness. This is based on cost per lifetime BTU's saved or delivered. Such a policy faithfully followed and accurately monitored would greatly increase the effectiveness of existing programs. The same policy would result in heating system efficiency work becoming an early and consistent component of all weatherization programs. Most weatherization, especially those using Project Retrotech, do not meet this criteria.

Based on the experiences of this program, any weatherization program that influences air infiltration should at a minimum include a check of the flue for safety.

REFERENCES

"Furnace Inspection and Tune Up 1982-1983 Heating Season Field Program Data", Public Service Company of Colorado, May 1983.

"Weatherization in Colorado", Colorado Energy Advocacy Office, August, 1983.

"Recommendations for Improving the Effectiveness of Federal Low Income Weatherization & Energy Assistance Programs", Alliance to Save Energy, 1983.

APPENDIX A

Adjustments, Repairs and Replacements

A sample of 158 furnaces completed between February 1983 and June of 1984 was analyzed. Results from the 370 furnaces in the PSCo program is presented for comparison.

Table II. Adjustments, repairs and replacements (by % of occurrence)
(N.R. = Not Reported)

	WESTSIDE	PSCo
Fan on/off adjusted down	79.1	
Heat rise lowered	73.4	43
and previously cycled on limit	17.1	N.R.
Delivery Problems		
Taped plenum or ducts	70.9	
Disconnected ducts reconnected	17.1	(13.2)
Duct work added	9.5	
Anticipators reset higher	60.7	N.R.
Blowers cleaned		
Found dirty	53.2	
Found filthy	27.8	(26.5)
Found clean	5.7	
Blowers oiled	51.9	N.R.
Filters replaced		
Found dirty	51.9	
Found clogged	21.5	(37.3)
Found clean or had none	25.3	
Fan/limit switch replaced or moved		
For better fan control	19.0	
For limit control	7.0	(12.2)
Belts replaced	17.6	38.2
Thermostats replaced	8.9	4.9
Gas leaks repaired	7.6	8.1
Draft/gas vent problems		
Minimal draft corrected	5.7	
Clogged vents cleared	3.2	(8.1)
Disconnected vents reconnected	1.3	
Other vent problems corrected/checked	6.3	
Electrical repair and replacement	7.0	6.5
Roll out fixed	2.5	N.R.
Blower motor replaced	1.9	2.4
Blower fixed/replaced	1.3	2.2
Gas valves replaced	1.3	4.9
Thermocouple	1.3	5.4
Cracked heat exchanger	1.3	4.9

The PSCo program also included the following checks and adjustments not contained in the WEC program:

1. Adjust gas pressure and derate furnace.
2. Clean and adjust burners.
3. Adjust thermostat.
4. Perform adjustments on burner or pilot.
5. Carbon monoxide test.

The carbon monoxide test is now done on every furnace in the program.