The Cost-Effectiveness of the Minnesota Weatherization Assistance Program

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INTRODUCTION AND BACKGROUND

The Weatherization Assistance program is one of two major federal programs to assist low income households in meeting their energy expenses. The Weatherization Assistance program was begun in 1977 as an outgrowth of the Community Service Administration, Emergency Energy Conservation Services program.

The current Weatherization Assistance program is administered by the Department of Energy (DOE). DOE awards grants to states based on the number of poor households and number of heating and cooling degree days. States distribute funds to local governments and nonprofit organizations, with Community Action Programs (CAPs) receiving statutory preference to weatherize homes. In FY 81, Congress appropriated slightly less than $190 million for weatherization assistance. In FY 82, the program's budget was decreased to $144 million.

The Minnesota Weatherization Assistance program (WAP) is administered through the Department of Economic Security (DES). The program is primarily administered on the local level by Community Action Programs, but Indian Reservations and some county units also deliver services. Total funding for the Minnesota Weatherization Assistance program was $23.5 million in 1981 and $21 million in 1982. The program is funded by the DOE WAP, by the State of Minnesota and with Energy Assistance Program discretionary funds. By June 1983, 73,277 homes had been weatherized by the Minnesota WAP.

In comparison with other states Minnesota has consistently delivered a high level of services. According to a recent study[1], Minnesota was among the top 10 states both in total number and percent of eligible households weatherized. Given Minnesota's prominence among weatherization programs and the declining federal commitment to the program, it is important to evaluate the cost effectiveness of the Minnesota effort. This study is intended to provide such an evaluation. The results of this effort should help decision-makers arrive at appropriate funding levels and should assist program delivery personnel in spending dwindling program dollars most effectively.

Description of the Sample

This study is based on data collected by the engineering firm of Bakke, Kopp, Ballon and McFarlin, Inc. (BKBM)[2]. Because accurate energy consumption data was critical to the study, only households heated with natural gas were included in the the final sample. Primarily due to this criterion, there were only 306 useable cases of the original randomly drawn sample of 1200. The "natural gas" criterion also makes the sample more representative of Minnesota's urban areas than the state as a whole. Given this constraint, however, the 306 cases represent a relatively large and unbiased sample, and should allow fairly precise analysis.

Table 1, Column 1, displays the demographic characteristics of the sample. As can be seen, the head of household in the sample has an average age of 55.7 years, significantly older than the state average age. This is primarily due to the high proportion of elderly that are eligible for the program. More than 79 percent of the cases are single family homes, 12 percent are mobile homes and 9 percent are multi-family dwellings. Homes served are generally small, averaging only 838 square feet. The average number of occupants is 2.6 persons.

The average pre-weatherization consumption for our sample is 161.0 mcf per year, corrected for degree days. The typical weatherization job installed 5 measures; most frequently caulking and weatherstripping, attic insulation, glass repair, hot water heater wrap, and storm doors. The average total materials cost for a weatherization job was $371. Table 2 shows frequency and average costs of the various weatherization measures.

Average degree day-corrected post-weatherization consumption for the sample is 137.7 mcf per year, representing an average energy savings of 14.5 percent per year. A 95 percent confidence interval yields a range for savings of 12.5 to 15.3 percent. In comparison, an earlier study of the Minnesota program conducted by Raj Talwar, found a 10.95 percent savings in the experimental group. When calculating savings per dollar invested, the Talwar study reported a .28 percent saving per dollar invested, while the BKBM data shows a .39 percent savings per dollar invested.[4] Although this difference may be due to factors not controlled for, it suggests that current weatherization techniques are yielding both larger savings and a higher return on investment than earlier efforts.

Subgroup Analysis

In an evaluation of this type it would be desirable to explain variations in energy savings among different households gained by weatherization. Unfortunately, the BKBM data is not detailed enough to conduct multivariate regression analysis, lacking income, thermostat setting, and appliance data. As a result, preliminary regression results yielded adjusted R^2 of less than .1, indicating the equation provided little or no explanatory power. However, some initial insights into differences in rates of energy savings might be gained by comparison of the characteristics of "high-savings" vs "low-savings" households.

Columns 2 through 5 of Table 1 provide data for four subgroups:

1) Negative Savings, those households whose consumption actually increased after weatherization
2) Total Positive, all households in the sample who showed a decline in energy consumption after weatherization
3) Low Positive, the lowest 20 percent of households whose post-weatherization consumption decreased
4) High Positive, the 20 percent of households achieving the highest energy savings.

First, we thought it important to examine the characteristics of the group of households whose energy consumption actually increased after weatherization and compare these characteristics to the groups of households that had the expected outcome -- a reduction in energy consumption after weatherization.

A comparison of Columns 2 and 3 shows that the 26 members of the negative saving group were more likely to live in a single family dwelling but less likely to own their home than positive savers. Interestingly, while more weatherization measures were installed in negative savings households than in positive saving cases, less money was spent on the weatherization materials. In addition, pre-weatherization consumption is notably lower in the negative savings group. The two groups show little difference in age or number of occupants.

These comparisons offer no obvious explanation for why some households increased consumption after weatherization. However, the extremely low pre-weatherization energy consumption might lead one to conclude that the increase in consumption was the result of a change in home use or occupancy that was not related to weatherization. This conclusion is validated by DES staff's personal observation and experience. (For instance, one resident had been hospitalized during much of the pre-weatherization winter, so when she returned home, post-weatherization, her consumption increased.) However, it should be considered that at least some of these cases may reflect a poor weatherization job.

Within the set of positive savings households, the characteristics of the 20 percent of households reporting the lowest savings and the 20 percent of households reporting the highest savings are presented. As indicated in Columns 4 and 5 of Table 1, noticeable and consistent differences arise between these two groups.

Homes in the low savings group are smaller than those in the high savings group. Low savers are less likely to own their homes and more likely to live in single family dwellings than the high savings group.

Interestingly, pre-weatherization consumption is only 4 percent lower for the low savings group than the high savings households. Fewer weatherization measures were installed in the low savings group and, as would be expected, the materials cost for the weatherization was less than for the highest saving quintile. Not surprisingly, then, we can conclude the more money invested, and the more measures installed, the higher the energy savings that is achieved. However, the increase in savings (557%) is simply too large to be totally explained by the 35% increase in expenditures. Obviously other factors are at work as well.

Finally, in Table 3 we compare the characteristics of the three housing types. Notably, multi-family housing is smaller in floor space on average, yet has a higher average pre-weatherization consumption, indicating that these units are initially significantly less efficient than single-family dwellings. As a result, a smaller investment in materials and fewer implemented measures yields a much <u>higher</u> savings level for multi-family units than for single family dwellings or mobile homes. In contrast, mobile homes are larger than single family dwellings, yet have substantially lower pre-weatherization consumption. While fewer measures are implemented at a lower cost, percentage savings is also significantly less than single family dwellings.

In contrast to these findings, the owner status breakout, as displayed in Table 4, indicates that savings is higher for owners than renters, 14.4% and 11.8%, respectively. Thus, the higher multi-family savings is not apparently a result of higher rental incidence. It should be noted, however, that some of the difference in savings between owner and renter groups may be explained by the larger average number of occupants in the

TABLE 1

Sample and Subsample Characteristics

Variables	1 Total Sample (306)		2 Negative Savings (26)		3 Total Positive Sample (280)		4 Lowest Positive Quintile (56)		5 Highest Quintile (56)	
	Ave.	S.d.	Ave.	S.d.	Ave.	S.d.	Ave.	S.d.	Ave.	S.d.
A. Demographic										
1. Age	55.7	(19.4)	55.8	(19.6)	55.7	(19.4)	54.4	(19.0)	55.9	(18.6)
2. Housing Type										
- Single Family	79%		88%		79%		16%		4%	
- Multi-Family	12%		0%		9%		75%		84%	
- Mobile Home	9%		12%		11%		9%		12%	
3. Square Feet	838	(277.0)	883	(330.2)	833	(272.3)	834	(331.6)	846	(266.3)
4. No. of Occupants	2.6	(1.5)	2.5	(1.5)	2.6	(1.5)	2.6	(1.4)	2.4	(1.3)
5. Owner Status										
- Owns	80%		73%		81%		80%		86%	
- Rents	20%		27%		19%		20%		14%	
B. Energy										
1. No. of Measures	4.5	(1.5)	4.8	(1.5)	4.4	(1.4)	4.3	(1.6)	4.9	(1.4)
2. Cost of Materials	$371.	(168.8)	$344.	(181.6)	$373.	(167.7)	$317.	(182.9)	$428.	(146.0)
3. Pre-weatherization Consumption	161.0 mcf	(61.8)	137.5 mcf	(42.9)	163.2 mcf	(62.8)	160.1 mcf	(59.4)	165.9 mcf	(70.3)
4. Post-weatherization Consumption	137.7 mcf	(52.9)	151.7 mcf	(51.3)	136.4 mcf	(52.9)	153.1 mcf	(58.1)	114.7 mcf	(45.5)
5. % Savings	14.5	(12.2)	-10.2	(13.0)	16.1	(9.5)	4.5	(2.1)	30.5	(5.8)

TABLE 2
Measures Performed

Measures	Frequency	Cost Ave.	Cost S.d.
Attic Insulation	189	$154.00	(91.2)
Wall Insulation	79	109.00	(77.1)
Floor Insulation	52	75.00	(95.3)
Basement Insulation	92	61.00	(86.7)
Hot Water Heater Wrap	172	14.00	(6.2)
Glass Repair	191	23.00	(35.3)
Storm Windows	107	129.00	(120.0)
Storm Doors	118	119.00	(56.9)
Clock Thermostat	25	56.00	(3.1)
Caulking/Weatherstripping	294	53.00	(36.8)
Furnace Work	28	65.00	(41.5)

TABLE 3
Characteristics by Housing Type

Variable	Single Family (n=239) Ave.	Single Family (n=239) S.d.	Multi-Family (n=25) Ave.	Multi-Family (n=25) S.d.	Mobile Home (n=35) Ave.	Mobile Home (n=35) S.d.
Demographic						
1. Age	57.8	(18.7)	51.6	(20.3)	47.4	(21.1)
2. Square Ft.	837	(293.3)	717	(210.2)	867	(174.3)
3. No. of Occupants	2.5	(1.5)	2.8	(1.5)	2.7	(1.5)
4. Owner Status						
- Owns	83%		44%		94%	
- Rents	17%		56%		6%	
Energy						
1. Pre-Weather-Consumption	164.0 mcf	(60.8)	167.8 mcf	(59.8)	124.4 mcf	(33.0)
2. Post-Weather-Consumption	140.4 mcf	(53.4)	136.9 mcf	(51.3)	111.4 mcf	(28.6)
3. No. of Measures	4.7	(1.3)	4.4	(1.7)	3.2	(1.2)
4. Cost of Materials	$386.	(166.2)	$315.	(152.6)	$318.	(184.2)
5. % Savings	14.0	(12.8)	18.3	(9.9)	10.1	(9.2)

TABLE 4

Subsample Characteristics

Variables	Owner Status: Owns (n=246)		Owner Status: Rents (n=60)		Materials Costs: $0-199 (n=47)		Materials Costs: $200-399 (n=140)		Materials Costs: $400-599 (n=83)		Materials Costs: $600-900 (n=36)	
Demographic	Ave.	S.d.	Ave.	S.d.	Ave.	S.d.	Ave.	S.d.	Ave.	S.d.	Ave.	S.d.
1. Age	59.2	(18.8)	41.7	(15.3)	57.3	(19.3)	54.7	(18.9)	56.6	(19.7)	55.6	(21.3)
2. Square Feet	845.9	(277.4)	770.5	(269.8)	816.2	(227.4)	845.9	(276.4)	840.8	(277.0)	825.4	(331.7)
3. No. of Occupants	2.4	(1.4)	3.3	(1.4)	2.3	(1.4)	2.7	(1.5)	2.3	(1.4)	2.7	(1.5)
Energy												
1. Pre-Weatherization (mcf)	159.6	(61.8)	166.7	(61.6)	136.9	(36.5)	168.7	(62.5)	168.0	(73.8)	146.2	(42.6)
2. Post-Weatherization (mcf)	135.7	(53.1)	145.8	(52.7)	126.4	(36.7)	145.7	(56.3)	137.9	(58.5)	121.0	(35.6)
3. No. of Measures	4.5	(1.4)	4.3	(1.5)	3.0	(1.2)	4.5	(1.2)	4.8	(1.3)	5.5	(1.5)
4. Total Materials Costs ($)	$383.	(167.0)	$321.	(168.4)	$128.	(45.6)	$306.	(58.2)	$484.	(57.8)	$674.	(55.9)
5. % Savings	14.4%	(12.0)	11.8%	(13.3)	7.6%	(8.9)	13.4%	(13.5)	17.0%	(10.9)	16.6%	(10.9)

renter group. More occupants can increase non-heating energy use such as cooking and water heating, thus reducing the proportional effect of weatherization.

Benefit-Cost Analysis

Methodology: Although energy conservation is important, it must be compared to the cost incurred to achieve it. Several measures of cost effectiveness are presented in Table 5: simple payback (PB), discounted payback (DPB), internal rate of return (IRR) and net present value (NPV). Appendix A gives the formulas used to calculate each of these cost effectiveness indicators.

The internal rate of return, discounted payback and net present value calculations assume a 1 percent annual rate of decay in the effectiveness of the weatherization and project energy costs to grow at a real rate of 1.33 percent per year.[5] A real discount rate of 3 percent per year was used for the discounted payback and net present value calculations. Lifetime of the weatherization effort is assumed to be 15 years.[6]

In calculating the benefit of this program to society, one must be careful not to include any energy savings that might have been achieved by low income households independent of the program. In order to estimate this independent savings, we examined the change in consumption (per degree day) that occurred from the 79/80 to the 80/81 heating season, the two years of pre-weatherization consumption data for the 306 cases in the sample.

Average consumption per degree day actually increased by 2.6 percent over the period, from 19489 Btus/dd in the 79/80 heating season to 19999 Btus/dd in the 80/81 heating season. This increase occurred even in the face of an increase in natural gas prices of 39 percent over the same period. This finding reinforces the assessment that low income households cannot reduce energy consumption without government assistance.

As a result, the energy savings attributable to the weatherization program is assumed to be the total measured reduction in energy consumption from the pre-to post-weatherization heating seasons. This is, in fact, a conservative assumption. In calculating total program energy savings, Talwar actually added the percent increase in consumption experienced by the control group to the experimental group savings. In the present study, such an approach would increase the percent of average energy savings for the entire sample to 17.1 percent (14.5 percent + 2.6 percent). It is a weak assumption, however, to expect energy consumption to grow from 80/81 to 81/82 at the same rate it grew from 79/80 to 80/81. As a result, we will use the conservative assumption that no change in consumption would have occurred without the weatherization program.

A final methodological issue arose in calculating total average weatherization costs. Only materials costs, were available to BKBM. However, cost-effectiveness must be measured using total costs. The Department of Economic Security reported that material costs were 36.5 percent and labor and administrative costs were 63.5 percent of total program costs. The total cost can be estimated, then, by multiplying materials costs by a factor of 2.7. This is only an estimate, however, and especially in subsample analysis, must be assumed to reduce the accuracy of the results.

Cost effectiveness indicators are provided using two assumed costs of energy: 1) the weighted average price of the various fuel types and 2) the natural gas price. The weighted average price will reflect the overall program cost-effectiveness. Results of the weighted average price are presented in Table 5A. Using the weighted average price requires the asssumption that weatherization will have the same effect on houses heated with fuel types other than natural gas as it did with the natural gas sample. Again, we believe this is a conservative assumption. Oil and pro-

TABLE 5A

Benefit - Cost Indicators

Group	Simple Payback	Discounted* Payback	Internal** Rate of Return	Net Present*** Value
Weighted Average (price ($6.73)	6.4 years	7.1 years	13.8%	$ 920
House Type				
Single Family	6.6	7.3	13.2	903
Multi Family	4.1	4.4	24.1	1706
Mobile Home	9.8	11.5	6.3	215
Material Cost				
$0-199	4.9	5.4	19.5	518
200-399	5.3	5.8	17.6	1073
400-599	6.5	7.2	13.6	1177
600-900	10.7	12.8	4.9	257
Owner Status				
Owns	6.4	7.2	13.7	939
Rents	6.2	6.8	14.5	859

TABLE 5B

Benefit - Cost Indicators

Group	Simply Payback	Discounted* Payback	Internal** Rate of Return	Net Present*** Value
Natural Gas Price ($5.02)	8.6 years	9.9 years	8.4%	$ 432
House Type				
Single Family	8.8	10.2	8.0	409
Multi Family	5.5	6.0	17.1	1057
Mobile Home	13.2	16.4	2.1	-58
Material Cost				
$0-199	6.6	7.4	13.2	298
200-399	7.2	8.1	11.7	591
400-599	8.7	10.0	8.3	546
600-900	14.4	18.4	.9	-271
Owner Status				
Owns	8.6	9.9	8.4	438
Rents	8.3	9.5	9.2	420

Success Indicators: *DPB<15 years **IRR>3% ***NPV>0

Note: (Dollar amounts used in calculations are materials cost X 2.7 = Total Cost)

Calculations are carried out over an investment span of 15 years.

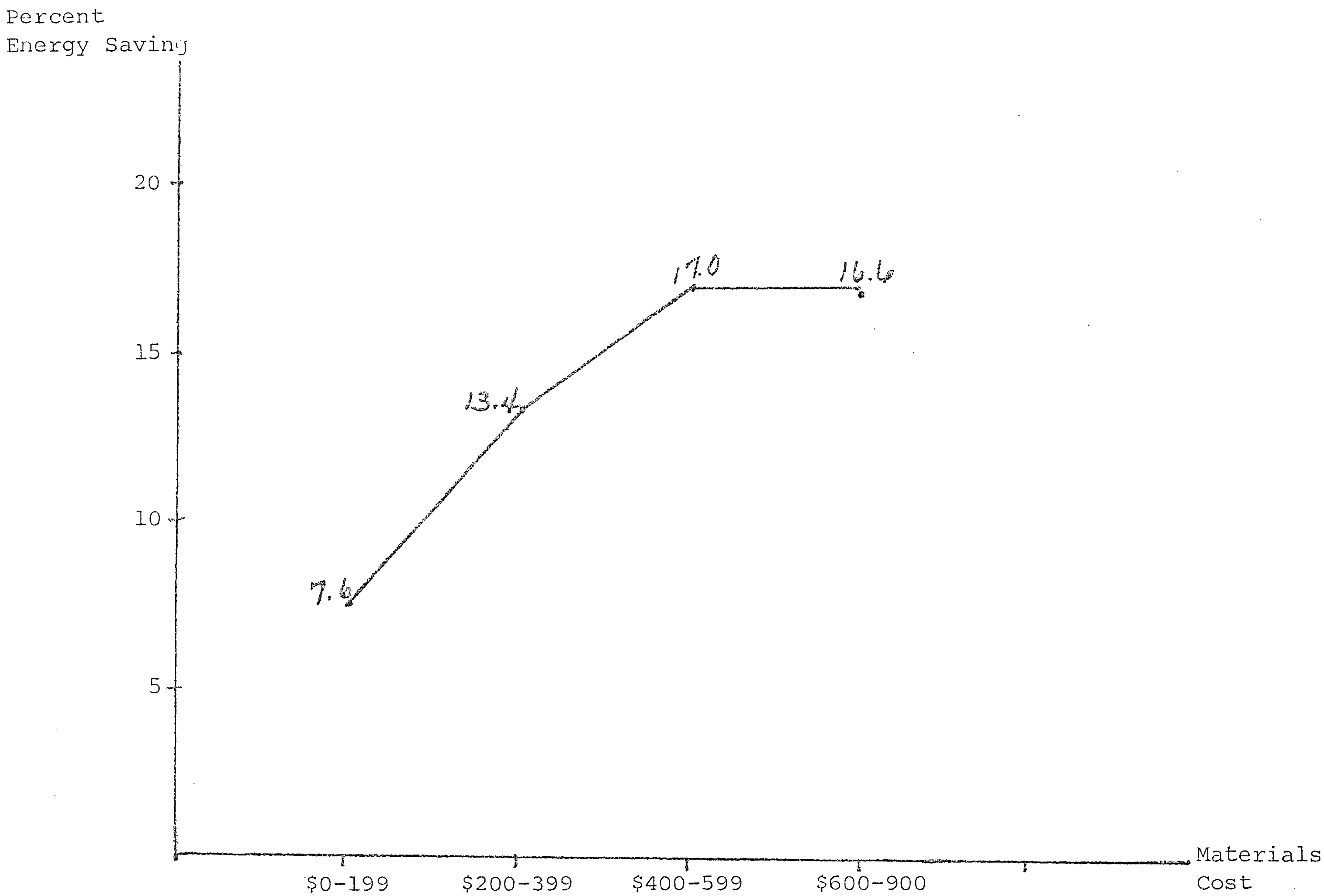
pane heated homes tend to be older and located further north. As a result, energy savings from weatherization should be higher for these homes than natural gas homes. The weights used were derived from the BKBM data, p. 10.[7]

Results: As can be seen in Table 5A the Minnesota Weatherization Program is clearly cost-effective. The total sample yields an internal rate of return of 13.8 percent and a net present value of $920 per unit weatherized. (Net present value is simply the value to society of the energy saved, less the cost to save it.) Thus total net present value of the homes weatherized during the 81/82 heating season by the Minnesota Weatherization Program is approximately $19 million dollars. In comparison, Talwar's study indicated that, although the program was cost-effective in 1979, it was much less so than current efforts. The NPV was $374 per home and IRR was 7.2 percent using Talwar's data.

Weatherization of multi-family dwellings yields the highest return per dollar invested of the three housing types, having a NPV of $1706 per unit and IRR of 24.1 percent. In contrast, mobile homes have a NPV of only $215 per unit and an IRR of 6.3 percent. With the weatherization techniques used at the time of the study, investment in mobile homes is not so cost-effective as other weatherization investments.

We also calculated cost-effectiveness indicators at various levels of investment in materials. Graph 1 plots savings versus costs for these levels of investment. As can be seen, higher levels of investment are yielding lower rates of return, declining from an IRR of 19.5 percent for weatherization with materials costs of less than $200 to only 4.9 percent for weatherization with materials costs of greater than $600. However, the NPVs for investment levels of $200-399 and $400-599 are actually higher than for $0-199 investment, the lowest category. The NPV for investments of $600 or more is less than $300, indicating such levels of investment are

GRAPH 1



NOTE: The above graph illustrates the relationship between % savings and dollar investment experienced for the conservation measures to which the program was limited.

cost-effective, but yield a lower return on investment than lower investment levels.

Table 5B provides cost-effectiveness indicators using the price of natural gas. In general, the cost-effectiveness indicators are lower, because natural gas is less expensive than other home heating fuels. This group shows an IRR for weatherization of 8.4 percent and NPV of $432 per unit. As with the entire sample, multi-family housing yields the highest internal rate of return and NPV, while mobile homes have the lowest IRR and NPV of the dwelling types. In fact, the IRR for mobile homes is less than 3 percent and NPV is negative. This indicates that weatherizing mobile homes heated with natural gas is not cost-effective.

As with the weighted average fuel price, rate of return on investment declines as cost for materials increases. However, the IRR and NPV for material costs of more than $600 indicate that such levels of investment are not cost effective in natural gas heated homes. The NPVs for the investment levels of $200-399 and $400-599 are higher than the lowest category, $0-$199.

Conclusions and Programmatic Recommendations

The Minnesota Weatherization Program has apparently improved its weatherization techniques since the late 1970s. This analysis shows higher savings are being achieved at a lower cost than at the time of Raj Talwar's study of the program. In order to continue improving the cost-effectiveness of the Minnesota Weatherization Program it will be important to direct investments where they yield the highest return. This analysis reveals two strategies for achieving this goal.

First, the analysis dramatically illustrates the need to deal with multi-family housing through this or other programs. Although smaller in square feet than the rest of the cases, multi-family units consistently used more energy than any other housing types. As a result, weatherization of these units yield extremely high rates of return.

Secondly, the study found that cost effectiveness decreases with increasing levels of materials expenditures. This is an expected finding, as any weatherization program should implement the most cost-effective measures first. In general, this finding suggests that if government funding is limited, the greatest benefit will be obtained by performing an initial weatherization of as many low income homes as possible, rather than pursue a goal of insulating fewer homes more comprehensively.

That is not to say, however, that such a program goal should be pursued at this time. With the exception of natural gas heated homes, all levels of investment are cost-effective. Thus, comprehensive weatherization through material costs of $600, or total cost of up to $2,000, should be considered socially desirable. (If the program expands allowable measures to include furnace replacement, even larger investments maybe cost-effective.)

Finally, another message may be implied from our inability to explain statistically the variation in energy savings. Pre-weatherization consumption, dwelling type and total cost of investment were all significant variables in the regression equation. However, in total, they explained very little of the variation in energy savings. This may be due to the variable quality of weatherization.

However, it may be that home use and lifestyle differences are significant factors in the potential for weatherization effectiveness. If this is true, educating low income households in the principles of efficient home energy use may increase program effectiveness.[8]

In general, we need to better understand the causes of variation in energy savings. Further research will be important in explaining the contributions to changes in energy consumption of individual weatherization measures, household consumption behavior, and other factors. Specific data needs include accurate labor costs for each unit weatherized, appliance and thermostat setting data, home use information and incomes. Understanding the effects of these factors will be the key to continuing to increase the effectiveness of Minnesota's and other states' weatherization efforts.

Notes and References

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2. J. Wheeler and P. Herzog. "A Study of the Effectivenss of the Weatherization Program in Minnesota," Bakke, Kopp, Ballou and McFarlin, Inc., 1983. (For a complete description of sample selection and data collection techniques.)
3. R. Talwar. "Evaluation of the Federal Weatherization Assistance Program in Minnesota," Mid-American Solar Energy Complex, Bloomington, Minnesota, 1979.
4. Talwar's study reported average total material costs of $301.80. Adjusting for inflation, this represents an average cost of $392 in 1981 dollars. The GNP price deflator was used for the inflation adjustment.
5. Minnesota Department of Energy, Planning and Development, Energy Division, Office of Data and Analysis price projections for natural gas, dated 3/22/83, were used to derive annual growth rate.
6. E. Gramlich, Benefit-Cost Analysis of Government Programs, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1981. (For a complete discussion of socially optimal discount rate, see pp. 95-106. For correction for a decaying function, see pp. 146-153.)
7. The weighted average price for fuel was determined from the "fuel type" data provided by BKBM, p. 10 as follows: ((.492 X $5.00) + (.358 X $8.00) + (.119 X $7.87) + (.03 X $15.38) = $6.73).
8. A study being conducted by Steve Kramer of the Urban Coalition is currently examining the effects of consumer education on energy consumption in low income households.

APPENDIX A

Cost-Effectiveness Indicators

Simple Payback

$$L = \frac{C_0}{B_1}$$

Discounted Payback

$$C_0 = \sum_{l=1}^{L} B_t \frac{(1+e)^t}{(1+i+d)^t} \qquad \text{Solving for L}$$

Internal Rate of Return

$$C_0 = \sum_{t=1}^{T} \frac{B_t\ (1+e)^t}{(1+r+d)^t} \qquad \text{Solving for r}$$

Net Present Value

$$NPV = \sum_{t=1}^{T} \frac{B_t\ (1+e)^t}{(1+i+d)^t} - C_0$$

Where

- C = Cost of Weatherization (including labor)
- B = Value of energy saving (mcf X $/mcf)
- L = Years to payback investment
- e = real growth rate of energy prices (.0133)
- i = real discount rate (.03)
- d = decay rate of energy savings (.01)
- r = internal rate of return