A CASE STUDY IN PROGRAM IMPROVEMENT: THE DEVELOPMENT AND EVALUATION OF A NEW WEATHERIZATION MEASURES SYSTEM IN MICHIGAN

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ABSTRACT

This paper presents the results of a comparison of a new weatherization measures prioritization system with the old measures system previously utilized in the Low Income Home Weatherization Program in Michigan. The new measures system was developed as a result of several years of research and evaluation conducted by the Michigan Energy Administration.

The new system features additional conservation measures not previously included in the Michigan Weatherization Program (e.g., wall insulation, clock thermostats, low-flow showerheads) as well as some new installation techniques for previous measures like ceiling insulation and infiltration reduction. This study represents the first quantitative evaluation of the effectiveness of that new system.

The study utilized a comprehensive evaluation methodology, including the analysis of: (1) agency records detailing the nature and cost of the weatherization services provided to each home; (2) telephone interviews covering demographic information and client reactions to the service; and (3) monthly utility natural gas consumption records for one heating season before and after receiving service. Homes included in the study were randomly sampled from 9 different Local Weatherization Operators from around the state.

Results revealed that the new system achieved an average 18% reduction in space heat fuel use versus 11.7% for the old system -- a more than 50% improvement. This was accomplished without increasing total materials and labor cost.

This paper summarizes the background research leading to the program design change and presents the results of this study.

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INTRODUCTION

This paper presents the results of an evaluation of a new measures prioritization system implemented in the Michigan Low-Income Home Weatherization Program. This study, which compares the new measures system to the old U.S. Department of Energy (DOE) Project Retro-Tech measures system previously utilized, is the culmination of four years of program evaluation and research conducted by the Michigan Energy Administration (now part of the Michigan Public Service Commission) for the Bureau of Community Services of the Michigan Department of Labor (BCS/MDOL). The following brief review summarizes the history of evaluation and research which led to the current study.

Background

The Michigan Low-Income Home Weatherization Program began operation in late 1974. The program was administered by BCS/MDOL and was a very typical example of the state-run federal Weatherization Assistance Program (WAP). Participating homes received a standard package of conservation measures, principally including R-38 ceiling insulation, storm windows, and infiltration reduction measures (primarily caulking and weatherstripping). Through 1983, a total of 82,629 homes had been served. No actual energy savings evaluation of the program had ever been conducted.

During 1983, however, an energy policy debate developed within the state regarding the question of how best to weatherize low-income homes. As a result, it was ultimately decided that the Michigan Energy Administration (MEA) would perform an evaluation of the Michigan Weatherization Program. A study was conducted which assessed the program, along with a lower cost service alternative and a low-cost/no-cost volunteer conservation program. The results showed that the regular Weatherization Program achieved an average space heat fuel savings of 14.7% while the lower cost alternative saved 9.2% (slightly less cost-effective on a dollar per dollar basis) and the volunteer program achieved no measurable savings. (See Kushler & Witte, 1985, for a full report.)

In 1984 a second MEA study was performed on the Michigan Weatherization Program which documented a similar savings level of 12.0%, and furthermore, determined that savings achieved in homes from the first year study persisted through a second full year after the service. In addition, a small sample of homes which received wall insulation in addition to regular weatherization measures achieved a very impressive 28.8% savings. (See Kushler & Witte, 1986a, for a full report.)

These two studies demonstrated a reasonably satisfactory energy savings impact by the Michigan Weatherization Program. However, results such as those from the small sample of homes receiving wall insulation suggested that improvements could be achieved. Furthermore, during 1984 and 1985, the DOE made substantial revisions to the federal WAP rules. Central to these revisions was the specification of a greatly expanded list of eligible conservation measures. This opportunity to consider new measures also suggested that improvements could be made to the existing system. Unfortunately, although the expanded measures list was intended to provide more flexibility for the states and to allow for the inclusion of additional conservation measures into WAP that might be cost-effective, states lacked information on which measures to include and in what order of priority they should be installed.

Therefore, in the spring of 1985, BCS/MDOL contracted with MEA to perform a comprehensive review of the Weatherization program home energy audit procedures. The purpose of this review was to (1) assist BCS/MDOL in deciding what method should be used for identifying and prioritizing the measures to install in houses served by the Michigan Weatherization Program; and (2) determine the relative cost-effectiveness in Michigan of all applicable conservation measures on the expanded DOE eligibility list. This information could then be used by BCS/MDOL to develop a revised weatherization measures priority system for the Michigan Weatherization Program.

In January of 1986, MEA presented to BCS/MDOL its findings regarding the prioritization methods and relative cost effectiveness of a total of 33 different conservation measures. (See Kushler, 1986.) From these findings, BCS/MDOL developed a new measures priority system to potentially replace the old measures list previously utilized. (See Table 1 for a comparison of the two measure priority listings.) This information was presented to Local Weatherization Operators (LWO's) in the spring of 1986.

Because the LWO's were naturally reluctant to quickly embrace a major change in the method of operation which they had been using for nearly ten years, BCS/MDOL proposed a pilot study to test three major concerns: (1) could the LWO crews and contractors sucessfully install the new measures; (2) could the new priority measures be delivered within existing federal cost limitations; and (3) could LWO production rates be maintained with the new measures system? BCS/MDOL contracted with MEA to conduct a pilot study to examine these issues. Volunteers were solicited and a total of 19 out of the 35 LWO's expressed their willingness to participate. Ten agencies were selected in such a manner so as to provide a good geographic distribution and a good mix of agencies utilizing crews and private contractors. (Nine of these agencies ultimately completed service delivery in time to be included in the study.) The results of this pilot study revealed positive findings on all three questions examined (see Kushler & Witte, 1986b), so the decision was made by BCS/MDOL to move to statewide implementation of the new measures system in the spring of 1987.

Table I. A comparison of old and new measure priorities.

Old Priorities	New Measure Priorities
	Addressed in all homes:
1. Complete Infiltration (Esp. exterior caulking & weatherstripping)	1. Electric water heater insulation & wrap 6' of pipe
2. Ceiling Insulation (Add up to R-33, or R-38 in Northern Michigan)	2. Low flow showerhead (optional)
3. Floor Insulation (or perimeter insulation)	3. Ceiling Insulation (Add R-19 if less than R-8 existing)
4. Storm windows	4. Wall insulation
5. Electric water heater insulation	5. Duct Insulation (in unconditioned space)
	6. Floor insulation (in vented crawl space)
	7. Major infiltration (Esp. attic bypasses,interior caulking, etc.)
	Other Optional Measures: (once above are addressed)
	8. Clock thermostat
	9. Gas water heater insulation and wrap 6' of pipe
	10. Band joist insulation
	11. Floor insulation (over unheated basement)
	12. Oil furnace flame retention burner
	13. Gas furnace thermal vent damper
	14. Storm windows

The Current Study

Despite this history of positive and productive research and evaluation, however, one final task remained. In the course of developing the pilot test covering costs and implementation concerns, BCS/MDOL promised the LWO's that it would also contract for a follow-up energy savings study to determine if the new measures system in fact saved more energy -- as was expected. Therefore, in 1987 BCS/MDOL contracted with the Michigan Public Service Commission (MPSC) (into which the MEA had been merged) to perform an energy savings evaluation of the new system.

The purpose of this paper is to provide the results of that evaluation, which compared the energy savings achieved in a sample of homes receiving the new measures system to a sample of homes which received the old measures (a no-service control group was also included). The remainder of this document presents the methods utilized and the results obtained in that energy savings evaluation.

METHOD

Sample

Households targeted for inclusion in this evaluation were identified through the nine LWO's which participated in the earlier new measures pilot test (which examined the costs and installation of the new measures system). As described in a previous report (Kushler & Witte, 1986b), this group of agencies was well representative of the statewide population of LWO's. (In addition, on a more pragmatic note, these agencies were the only LWO's which had completed homes with the new measures system at the time of this study. Selecting different agencies would have meant delaying the study for a year.)

Despite these positive features, this choice of LWO's did present one problem. Since these agencies had volunteered for the original pilot project, the issue of self-selection on the part of the service implementors did arise. However, for a variety of reasons, that self-selection does not appear to be a substantive threat to the validity of the results of this study. (This issue will be explored later in the Discussion section.)

The next step in the process was to determine which households would be included in each of the three service groups ("new measures", the regular "old service", or the control group). This allocation was essentially predetermined by the date of service. The new measures system was implemented in these nine pilot LWO's in approximately June or July of 1986. Homes completed from that point up until October of 1986 were randomly selected for the new measures group. (Although not intended as a strict probability sample, the number of homes selected from each agency was roughly proportional to the annual total number of homes weatherized by each agency, and ranged from a low of 8 to a high of 49.) In order to reduce evaluation expenditures and still have homes as comparable as possible, households in the old service group were randomly selected from the regular weatherization clients served by five of these same agencies in the two months immediately preceding the new service (i.e., April or May of 1986). Control group homes were randomly selected from homes served by those same agencies after the winter of 1986/87 (i.e., after April 1987). In this manner, all three groups were composed of similar low-income, weatherization-eligible homes.

In determining the specific households to be examined, a number of criteria were established. Requirements included: 1) use of natural gas as the main heating fuel; 2) no use of a major supplemental fuel; 3) residence in an individually metered single family dwelling unit; 4) occupancy in that dwelling for at least one year prior to the study period; and 5) having usable fuel consumption histories available from their utility company.

Approximately 32 percent of the homes in the initial random samples were screened out through these criteria (due primarily to the use of heating fuels other than natural gas or the lack of sufficient natural gas billing data). No attrition bias was detected when cases screened out were compared with cases remaining in the sample on key descriptive variables (e.g., size of the home, total cost of weatherization materials installed) obtained from agency service records.

After screening for the above criteria, the following sample sizes were available for the energy savings analysis for this study.

Table II. Sample sizes for the energy savings analysis.

	New Measures	Old Service	No Service Control
Sample Size	173	65	68

Data Collection and Analysis

Three major data sources were used to evaluate the effects of the new measures pilot: 1) existing agency service records; 2) a telephone survey; and 3) fuel consumption data. Each of these data sources contributed unique information to the study.

Agency Service Records. The participating agencies used a form called the 'Building Check and Job Order Sheet' (BCJOS) to document the work that was completed in each home. This form provided detailed information describing the home, its prior condition, the conservation measures installed and the cost of the installed measures. The form used for the new measures service was a slightly modified version of the traditional BCJOS used for the old service program. The new measures BCJOS prioritized the measures to be installed in each home. If the priority measure was not installed, it was required that a reason be listed to justify that decision.

Copies of the agency service records were obtained for all new measures and old service cases. Information from the records was coded onto optical scanning sheets for entry into the state's mainframe computer.

Telephone Survey. A telephone interview was designed to obtain client responses regarding their reaction to the service received as well as to determine client household and demographic information not available on the agency service records (e.g., number of occupants, age and education of the customer, etc.).

The interviews were conducted in July and August of 1987 by experienced evaluation staff and averaged about 20 minutes in duration. The interview completion rate was approximately 60 percent for each group -- well within expectations for this low-income target population. (The potential for non-response bias was examined by comparing interviewed with non-interviewed cases on fuel use data. There were no significant differences on either prior fuel use or percent savings.) The information obtained from these interviews was also coded onto machine readable optical scanning sheets.

Fuel Consumption Data. Natural gas consumption records were requested for each dwelling from the four major utility companies providing service to the households included in this study. In order to make a comparison of fuel consumption for the periods before and after the weatherization service, these utilities were asked to provide the MPSC with the following information for each of the households in the samples:

1. Monthly meter read dates for the period of June, 1985 to August, 1987; and
2. Ccfs, number of days and a bill code for each of these months.

After these data were received, each record was carefully examined. Cases having unusable consumption information (e.g., insufficient actual meter reads, client moved, etc.) were eliminated from the gas consumption analyses. Fuel data for the remaining cases were coded onto optical scanning sheets. Daily heating degree day information was also obtained (from the National Weather Service) for the time period and regions analyzed.

Pre- and post-consumption periods were determined for each case based on the job completion date. Total consumption (in Ccfs), number of days and heating degree days were coded for each actual meter reading in both the pre- and post-service periods. For the majority of cases, the utility's estimate of baseload (in Ccf/day) was coded to represent the amount of natural gas consumed for purposes other than heating the home. For cases not having this utility estimate, the average post-service July and/or August consumption per day was used as the baseload. The baseload estimate was then multiplied by the number of days in each consumption period and subtracted from the total gas consumption during those periods. The resulting space heat fuel consumption estimates for the pre-and post-service periods were adjusted for weather differences by dividing by the number of heating degree days in each respective time period. Change in consumption (Ccf/hdd) from the pre-to post-weatherization periods was determined by subtracting the pre-service estimate from the post-service estimate. The difference was then divided by the pre-service consumption. This figure represented the percentage change in pre-service heating fuel usage that resulted from the weatherization work done to the home.

RESULTS

Demographic and Descriptive Data

The demographic and descriptive data gathered in this study served two major functions: 1) to describe the households and homes in the sample, and 2) to determine the comparability of the new measures and old service groups on variables that could possibly affect fuel consumption. This comparison was particularly important in the current study since the households were not randomly assigned to the two groups, but rather, pre-determined by the date of service.

The new measures and old service groups were compared on a total of 11 demographic and descriptive variables, including: age, education, income, employment status, owner vs. renter status, number of occupants, number of bedrooms, status of basement, use of supplemental fuels, water heater fuel, and age of home. There was only one statistically significant difference between the two groups (the old service group was less likely to have a head of household who was a high school graduate). Overall, as would be expected given the source of the households in the sample, the two groups were very similar.

In terms of a general description, the households in each group in the study closely reflected what one would expect for participants in the Low-Income Weatherization Program. Education, employment and income levels were very low and the housing stock was typically old and in great need of weatherization improvements. (More complete data, in tabular form, is presented in Kushler & Witte, 1988.)

Participants' Reactions to the Services

Table III presents the results for two survey items used to measure participants' reactions to the service they received. As the data indicate, the vast majority of participants in both the new measures and old service groups reported they were satisfied with the service they received. In addition, most reported noticing a difference in their homes after the service was completed. (The most commonly reported differences were "feeling warmer in the winter" and having "lower gas bills.") There were no significant differences between the two programs on either of these two survey questions.

Table III. Participants' reactions to service.

Item	New Measures	Old Service
Satisfaction with Program		
Positive comment	75%	70%
Qualified positive	16%	25%
Negative comment	9%	5%
Noticed Difference in Home		
Yes	83%	85%
No	4%	8%
Not sure	14%	8%

Cost of Service

In order to make a complete comparison between the new measures and old service programs, it was important to determine the costs associated with each.

Table IV provides average total direct costs (material plus labor) incurred by the two programs. The distribution of costs for the two groups were very similar. There were no significant differences between average material, labor or total costs for the new measures and old service groups. It should be noted that these are direct costs only and do not include other operational costs such as program administration, pre- and post-inspections, client intakes, etc.

Table IV. A comparison of average direct service costs.

	New Measures	Old Service
Material Cost	$392	$414
Labor Cost	$549	$564
Total direct costs	$941	$978

In regard to individual measure costs, two conservation measures were of particular interest. The first was ceiling insulation material cost, because the new measures system reduced the required R-value from R-38 to R-19. The second was the infiltration materials cost, because the new system revised the way in which infiltration items were addressed -- focusing on "major infiltration" problems rather than comprehensive exterior caulking and weatherstripping. The data reveal that the new measures system resulted in substantial reductions (statistically significant at $p<.001$) in the average material costs for both ceiling insulation and infiltration (see Table V).

Table V. Average materials cost for ceiling insulation and infiltration: new vs. old measures.

	New Measures	Old Service
Ceiling Insulation	$145	$195
Infiltration	$ 76	$114

Fuel Savings

Fuel consumption records were analyzed for participants in all three groups (new measures, regular old service, and the no-service control group). The results for this analysis can be found in Table VI.

Table VI. Space heat natural gas savings by type of service.

	Sample Size	Average 'Pre' Usage[a] (Ccf/HDD)	Average 'Post' Usage (Ccf/HDD)	"Gross" Percent Change Pre to Post	Signif.[b]	"Net" Percent Change vs. Comparison Group[c]
New Measures	173	.2002	.1642	-18.0%	p<.001	-19.4%
Old Service	65	.1981	.1750	-11.7%	p<.001	-13.1%
No-Service Comparison	68	.2151	.2182	1.4%	N.S.	----

a There was no significant difference between the groups on this variable.
b Two-tailed T-Tests with n-1 degrees of freedom.
c Determined by taking the nominal ("gross") percent change for each category of service and subtracting the gross percent change of the comparison group (i.e. + 1.4%). The "net" savings figure was also estimated through the use of regression analysis, including an adjustment for pre-program fuel use level. This analysis resulted in a net savings of 20.4% for the new measures group and 13.9% for the old service group.

The results indicate that the old service group achieved a significant fuel savings of 11.7%. (Note that this savings figure is very comparable to the figure cited in the most recent evaluation of the Michigan Weatherization Program i.e., Kushler and Witte, 1986a, which found a 12% savings). However,

space heat fuel savings for the new measures group was approximately 18% -- representing a more than 50% improvement over the old service group. The control group actually showed a slight but non-significant increase in fuel consumption of 1.4%, resulting in a net savings of 13.1% for the old service group and 19.4% for the new measures group.

The next step in the analysis process was to compare the energy savings achieved with the costs incurred to produce these savings.

Comparing Savings and Costs

Table VII indicates the cost-effectiveness of the two programs by projecting actual dollar savings and a simple payback for each of the service alternatives. This Table assumes that the pre-service fuel consumption level is the same as that of a typical Michigan Weatherization participant (i.e., computed using the average level of pre-service consumption for the households in the samples in this study).

Table VII. Relative savings and direct costs of weatherization services as applied to a typical home[a]

	Pre "Normalized" Space Heat Fuel Use[a]	NET SAVINGS			Average Total Direct Cost[c]	Simple Payback
		Percent	Ccf	Dollars[b]		
New Measures	1345 Ccf	19.4%	261	$144	$941	6.5 years
Old Service	1345 Ccf	13.1%	176	$ 97	$978	10.1 years

a Using an overall average value for the households included in this study.
b Based on a retail residential gas price of $.55 per Ccf.
c From Table IV.

Table VIII illustrates the relative cost-effectiveness of the two programs as defined by the commonly used index known as the "cost of conserved energy".* In order to provide a representative range of analyses, two different social discount rates (3% and 7%) are included in the table.

* In lay terms, the cost of conserved energy is what it costs to conserve a unit of energy. It is usually expressed in dollars per million Btu's, which can be compared to the cost of purchasing fuel to supply the same amount of energy. Arithmetically, the cost of conserved energy is the annualized cost of the retrofit divided by the annual energy savings. (e.g., see Kushler & Witte, 1988, for the actual formula).

Table VIII. Cost of conserved energy by type of service.

	NET SAVINGS		Direct	Life of	Cost of Conserved Energy[e]	
	Ccf[a]	MMBtu[b]	Cost[c]	Measures[d]	3% discount	7% discount
New Measures	261	26.1	$941	15 years	$3.03/MMBtu	$3.95/MMBtu
Old Service	176	17.6	$978	15 years	$4.67/MMBtu	$6.10/MMBtu

a From Table VII.
b Millions of Btu, assuming 1000 Btu per cubic foot of natural gas.
c From Table IV.
d Value obtained from an estimate of typical weatherization measures reported in a review by Lawrence Berkeley Lab. (Goldman, 1983)
e A 3% discount rate is reflective of the low social discount rate often assigned to public expenditures for some socially desirable program or project. A 7% discount rate is more reflective of the true cost of capital for private sector expenditures.

The above data indicate that the new measures weatherization service was more cost-effective than the old service. The new system produced a net average annual space heating fuel savings of $144, providing a "simple payback" of direct costs in 6.5 years and a "cost of conserved energy" of $3.03 to $3.95 per million Btu. In contrast, net annual savings for the old service averaged $97 per household, resulting in a 10.1 year simple payback and a cost of conserved energy of $4.67 to $6.10 per million Btu. (Note that at a typical current retail price of $.55 per ccf, purchasing natural gas from the utility company costs approximately $5.50 per million Btu.)

DISCUSSION

The purpose of this study was to assess the effectiveness of a new weatherization approach and to compare it to the existing method. Toward that end, samples of homes were chosen from a group of LWO's intended to encompass the broad range of LWO's in the state (e.g., in terms of such factors as agency size -- i.e., annual production rates; geographic location; and use of private contractors or agency crews). The study design was not intended to incorporate a strict probability sample of the statewide program (although the group of LWO's chosen was quite representative).

One issue raised earlier was the potential for self-selection bias due to the fact that the nine LWO's included in this evaluation volunteered for the original pilot study. Several factors act to mitigate any possible problem in this regard, however. First, it is useful to note that over half of the LWO's in the state volunteered for the original pilot study anyway. So "volunteering" is more characteristic than uncharacteristic of the statewide program. Second, it was the agency directors, not the contractors or crews, who volunteered. Thus, there is no reason to attribute special motivational qualities to the people doing the actual service. Third, the same

LWO's were the source of the old service and no-service comparison groups, which eliminates self selection as it may relate to both area-specific housing factors and general quality of work by the installers. Lastly, this group of nine LWO's was very representative of the total population of LWO's in terms of geographic distribution, the use of contractors or crews, and historical production costs (labor, materials, total direct costs -- see Kushler & Witte, 1986b). For all of these reasons, it is felt that self-selection by the service implementors is not a substantive threat to the validity of the results of this study. (Neither is self-selection by program participants -- due to the design of the study and the source of the old-service and no-service comparison groups.)

As a final observation, it should be noted that the effectiveness of the new measures system turned out to be quite robust over the broad range of LWO characteristics built into this study. There were no significant differences in energy savings due to agency size, geographic region, or contractor versus agency crew installation.

CONCLUSION

The study presented in this paper represents the culmination of several years of longitudinal research and program evaluation conducted for the Low-Income Home Weatherization Program in Michigan. This study, which compared a new weatherization measures priority system developed by BCS/MDOL with the old system then in use, has produced several important findings.

First, in terms of customer reactions to the service, it was found that clients rated both services very positively. There had initially been some speculation that clients might be less favorable toward the new service because of its much less frequent use of storm windows. However, almost no such complaints were received in the customer telephone surveys conducted for this study. Overall, there was essentially no difference in the degree of positive client ratings between the two service types.

Second, this study clearly demonstrated that it was possible for the LWO's to successfully implement a wide range of new cost-effective conservation measures now allowed by DOE. For example, in comparison to the old service which did not include these measures, the new service system resulted in 60% of the households receiving wall insulation, 15% receiving a low-flow shower head and 23% receiving a clock thermostat. Furthermore, both private contractors and agency crews were able to successfully implement the new measures system, and there was no significant difference in energy savings achieved in homes served by contractors versus those served by crews.

Third, this study was able to document that the new system actually produced an average direct cost (materials plus labor) slightly less than the old system ($941 vs. $978, not statistically significant). While this comparison may vary from agency to agency depending on such factors as the local cost of labor, the LWO policy on installations beyond the minimum measures, etc., it is quite noteworthy that, overall, major improvements in energy savings were obtained by the new measures system at no additional cost.

Fourth, this study was able to document the magnitude of those major improvements in savings. The new measures system achieved an average 18% reduction in space heat fuel usage versus 11.7% for the old service -- a more than 50 percent improvement in energy savings impact. Net savings relative to a no-service comparison group were 19.4% and 13.1% respectively. (While it is not possible to identify which new conservation measures installed accounted for what portion of that overall improvement, it is clear from the available data -- see Kushler & Witte, 1988 -- that wall insulation was the single largest contributor to the improvement in energy savings.)

Fifth, the results revealed a substantial improvement in cost-effectiveness. Although the old service was still likely to be a worthy investment from a societal perspective (particularly if secondary benefits such as improved client comfort and health and increased local employment were to be taken into consideration), the new measures system is clearly much more cost-effective. This was demonstrated through the use of such common techniques as the "simple payback" and "cost of conserved energy" criteria, where direct fuel savings were compared to direct (labor plus materials) costs.

Finally, this study has also produced important results in terms of illustrating the usefulness of program evaluation. The time and resources invested in evaluation and research on behalf of the Michigan Weatherization Program seems to have resulted in very beneficial impacts. The findings of this study have shown that the new measures system produced significantly greater energy savings, while remaining essentially equivalent to the old system in terms of both client response to the service and in direct costs. Implementing a paradigm of baseline evaluation, followed by targeted research, followed by program revision, followed by outcome evaluation, appears to have resulted in a much more cost-effective weatherization service.

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