The Environmental Benefits of Low-Income Weatherization

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ABSTRACT

Low-income weatherization programs have been operated by most states in the U.S. for over two decades. There have been many impact evaluations, both local and national, intended to identify the energy savings and economic and social benefits of such programs. Relatively few have quantified the environmental benefits of such programs. Some evaluators have more recently begun to identify the environmental gains from home weatherization programs; in particular, they have studied benefits associated with reductions in air pollutants and greenhouse gas emissions. A major national evaluation of home weatherization programs conducted by Oak Ridge National Laboratory led in this area.

In 1998, several inter-related evaluations of Ohio's Home Weatherization Assistance Program (HWAP) were completed for the state's Office of Energy Efficiency. One of these studies, an environmental impact analysis, is the focus of this paper.

The environmental analysis aimed to quantify the reductions in air emissions due to the operation of HWAP. In addition to quantifying results specific to Ohio's HWAP, the report aimed to explain the methodological issues surrounding identification and valuation of environmental benefits to audiences interested in the benefits of low-income weatherization programs.

Engineering analysis was used to establish the physical reduction in air emissions. The dollar value of emissions reductions from the weatherization program was estimated by using projections of market values for emission reductions.

Introduction

Low-income weatherization programs have been operated by most states in the U.S. for over two decades. There have been many impact evaluations, both local and national, intended to identify the energy savings and economic and social benefits of different such programs. More recently, some of these evaluations have also attempted to quantify the reductions in air emissions from low-income weatherization programs. Identification of environmental benefits is increasingly important in view of the Kyoto protocol to the UN Framework Convention on Climate Change that was recently signed by representatives of the U.S.

In 1998, several inter-related evaluations of Ohio's Home Weatherization Assistance Program (HWAP) were completed for the state's Office of Energy Efficiency. These included an energy impact and cost-effectiveness evaluation, a report of site visits to treated homes, a process evaluation, an economic/employment analysis, and an environmental impact study. This paper focuses on the environmental analysis.

The environmental analysis aimed to quantify the reductions in air emissions due to the operation of HWAP. As such, the environmental analysis built off the energy impact analysis and its estimation of the volumes of gas, electricity, and other fuels saved through HWAP during the program year studied. In addition to quantifying results specific to Ohio's HWAP, the report aimed to explain the methodological issues surrounding identification and valuation of environmental benefits to audiences interested in the benefits of low-income weatherization programs.

Research Questions

Two sets of research questions presented themselves, one relatively straightforward, the other more complex. The straightforward questions involved the physical reductions in air emissions. The less straightforward questions involved how to estimate the value of emissions reductions in dollar terms.

Research Design & Method

Billing analysis was used to establish the physical reduction in air emissions. One set of reductions comes from fuels burned in houses, such as gas and oil. Emissions coefficients based on prior research were used to establish the total emissions reductions based on the amount of such on-site fuel saved. Another set of reductions comes from electricity, where fuel is burned at the mix of power plants in the state. Here, characteristics of the state's power plants and assumptions about the pattern of reduction in demand were used to establish electricity-related emissions reductions.

The other set of questions involved how to value emissions reductions in dollar terms. Clearly there are direct and indirect benefits to human and environmental health from emissions reductions. Yet there is no single established methodology for monetizing these benefits. In our analysis, we use projections of market values for emissions reductions.

Neither of these research questions required an explicitly statistical analysis method. Both analyses are explained in further detail below.

Air Emissions Reductions

Energy Savings. The impact evaluation of HWAP conducted for the 1994 program year found average annual fuel savings for single family gas heated households of 326 hundred cubic feet (ccf) for gas heated households, and 1757 kilowatt hours (kWh) for electric heated households. Additional electricity savings for households with natural gas primary heating was estimated at 300 kWh per year. These estimates were based on a weather normalized analysis of utility billing data conducted by Proctor Engineering Group (Blasnik 1998).

Representing a smaller proportion of HWAP's total client base are households using non-utility bulk fuels [liquid propane gas (LPG), fuel oil, kerosene and fuel wood] as their primary heating fuel. Overall, these households account for around 14 percent of the clients served in 1994. For non-utility heating households, we assumed equivalent energy savings to those realized by natural gas heated homes in each program year. This assumption is supported by data from the program's building weatherization report (BWR) database, which show relatively little variation in the reported average final efficiency of heating systems for the fossil based primary heating fuels (ranging from 78 percent for gas to 80 percent for liquid propane gas (LPG). Table 1 summarizes the savings impacts estimated by fuel type.[1]

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[1] These figures are weighted average fuel savings for single and multi family homes. Single family homes tend to have higher absolute average savings per unit (Blasnik 1998).

Table 1. Average Estimated Annual Savings per Household by Primary Heating Fuel Type

Fuel Type	Annual Savings/HH
Natural Gas	295 ccf
	271 kWh
Electricity	1,287 kWh
LPG	380 gallons
Fuel Oil	237 gallons
Wood	4,951 lbs.
Kerosene	270 gallons

This set of estimated energy savings was mapped to the appropriate end-use or energy conversion devices. Emissions coefficients for each were used to translate the estimated energy savings into total amounts of avoided pollutants.

Emissions Coefficients. Two sets of emissions coefficients were used in our analysis. One was applied to direct end-use fuel combustion by households for space heating, while the other contained emissions estimates for electric generating plants. Table 2 shows emissions factors for CO_2, total NO_x, SO_x, CO, Methane (CH_4), and Particulates, in pounds per million British thermal units (lbs/Mbtu) of fuel input for residential space heating equipment according to fuel type.

Table 2. Air Emissions Coefficients for Residential Space Heating Devices

Fuel:	Emission Coefficient lbs / Mbtu of input					
	CO_2	NO_x	SO_x	Particulates	CO	CH_4
Natural Gas	121	0.02 to 0.10	0.001 to 1.09[2]	0.003 to 0.020	0.006 to 0.026	0.002 to 0.003
Fuel Oil	172	0.07 to 0.17	1.01 to 2.71	0.020 to 0.026	0.032 to 0.047	0.013
LPG	152	0.09 to 0.10	0.001	0.021	0.022	0.002
Kerosene	166	0.01 to 0.12	0.91	0.001 to 0.161	0.001 to 0.24	na
Wood	na[3]	0.09 to 0.98	.029 to .073	0.50 to 3.05[4]	0.15 to 25.8	0.085 to 4.65

Source: SEI-B & UNEP 1995.

Some of the non-CO_2 pollutant and fuel combinations in Table 2 have significant ranges between the low and high coefficient estimates. These are attributable to variations in combustion equipment, fuel characteristics, and testing methods. In our analysis, except where noted, the lower of the simple average and median of available emissions coefficient estimates was used.

For carbon dioxide, which is the air pollutant with the greatest total physical emissions and greatest total valuation, emissions coefficients are derived from the estimated carbon content of the

[2] For SO_x emissions from natural gas household devices, the low end of the estimated emissions range was applied.

[3] Fuelwood raised on a sustainable basis produces no net emissions of CO_2.

[4] The median value of estimated particulate emissions from wood burning space heating devices was used in this analysis.

fuel, and percent of the fuel oxidized during combustion. Emissions coefficient estimates for CO_2 are therefore relatively straight forward, and subject to much less variability than the coefficients for the other pollutants.

The estimated average air emissions factors for electric generating stations were computed using emissions data for five Ohio electric utilities as reported by the National Resources Defense Council. These data were derived from data from the Environmental Protection Agency's 1995 Acid Rain Database and utility reports to the Energy Information Administration on generation and fuel use. Factors impacting the emissions profile from any one plant include the type of fuel combusted, the environmental controls in place, and the efficiency of the boilers.

We calculated a weighted average for CO_2, NO_x and SO_x emissions based on each utility's share of the total customers enrolled in a payment assistance program that are served by these five utilities. Emissions estimates for other pollutants were also based on EPA and EIA data. Table 3 presents the estimated avoided emissions of each pollutant per megawatt hour of electricity saved by the program (annualized 1995 result from PY 1994 program activity).

Table 3. Estimated Air Emissions Coefficients for Electric Generating Stations

	Emission Coefficient lbs / MWh					
	CO_2	NO_x	SO_2	PM-10	CO	CH_4
Electricity (lb/MWh)	2,145	7.58	18.57	0.31	0.33	0.02

Source: EPA 1997; EIA 1997.

Avoided emissions for NO_x and SO_x per mWh were projected to decrease from 1995 levels due to improving control technologies and compliance with Phase II targets of the Clean Air Act. As a result of compliance actions, the emission coefficient for NO_x decreases from 7.58lbs/mWh in 1995 to 4.00lbs/mWh in the year 2000 and beyond. This estimate assumes an average heat rate of 10,000 Btu/kWh, and is consistent with the rough average Phase II emission limitation standards for wall-fired and tangential-fired boilers (Tellus Institute 1996a).

The emissions of SO_x per mWh are also projected to decline from an average of 18.57 lbs/mWh in 1995 to 12.00 lbs/mWh in the year 2000 and beyond. The level in year 2000 and beyond is estimated based on the overall Phase II limit for SO_2 of 8.95 million tons, and approximately 1.2 lbs. of SO_2 per MBtu.

Avoided Emissions. The estimated annual total gross air emissions reductions attributable to HWAP weatherization activities are presented in Table 4. The measures installed through the program will save energy for many years to come, and therefore the annual emissions reductions need to be multiplied by an expected measure lifetime to estimate the full environmental impact of program savings. The second row in Table 4 presents the estimated lifetime emissions reductions based upon an average measure lifetime of 20 years[5], with full persistence, and no changes in the mix of avoided energy consumption and emissions.

[5] The national Weatherization program impact evaluation (Brown et al. 1993) estimated an average measure life of 25 years. Narum, Pigg, and Schlegel (1993) found the net energy savings from low-income weatherization increasing with time. Other studies have found evidence of savings degradation. In one case, (Seattle City Light's Home Energy Loan Program) the savings degradation was as high as 27% over a five year period. (See Proceedings of the Sixth International Energy Program Evaluation Conference, 1993. p. 386-394.)

Table 4. Annual and Lifetime Total Air Emissions Reductions

	Pollutant					
	CO_2	NO_x	SO_x	Particulates	CH_4	CO
PY 1995 Annual Tons	24,228	29	66	3	6	39
Total Lifecycle Twenty Yrs. Tons	484,557	433	1066	60	120	780
Average Annual Reduction lbs. Per household	4,039	3.6	8.9	0.50	0.84	6.45

The source of emissions reductions from the program is primarily avoided combustion of home heating fuels. Avoided electricity generation accounts for roughly ten percent of the total reductions of carbon dioxide, and one third of the total reductions in NO_x and SO_x emissions.

To put the CO_2 emissions reductions in context, an annual average per capita reduction of more than 1350 lbs is approximately 2.6 percent of the average US per capita emissions for 1990 as reported in the Kyoto Protocol. The Kyoto target for the US is 7 percent reduction from 1990 levels within the 2008-2012 time period. Therefore, the average CO_2 emissions reductions result in each participant reaching more than one quarter of a "personal" target for emissions reduction. This shows that low-income weatherization programs can help the U.S. meet the carbon reduction goals to which it is tentatively committed.

Value of Emissions Reductions

In this analysis we estimate values for avoided emissions of CO_2, SO_x, and NO_x based upon projections of market values. A national market for SO_x already exists as a result of the cap and trade based trading system for SO_2 emissions allowances that was created under Title IV of the 1990 Clean Air Act Amendments. In Southern California, the Regional Clean Air Initiatives Program has created a marketable permits program for emissions of SO_x, and NO_x. The values for trading in California reflect the poor air quality conditions in the region and are likely to be significantly higher than values in other regions, at least initially. A demonstration program for trading discrete emissions reductions credits for NO_x had also taken place in the Northeast (Tellus Institute 1996b)[6]. There is also a possibility that trading for carbon emissions reductions credits will emerge as a direct result of the Kyoto conference.

SO_2 Emissions Allowance Trading . When the trading system for SO_2 emissions allowances was being established, estimates of prices for each emission allowance (allowing one ton of emissions in any particular year) ranged from $500 to more than $1,000. In 1993, the national evaluation of the weatherization assistance program valued avoided emissions of SO_2 at $860/ton. Due to the increased market availability of low sulfur coal, and banked allowances created through early control actions, market prices for emissions allowances have been much lower. We used historical values ranging from

[6] A fledgling market now exists for NO_x allowances as a result of this program, but it is fairly new, not all states are participating, and allowance prices are fairly high-- approximately $5000/ton (Tatsutani 1999).

\$130 to \$110/ton for the period of 1995 through 1997, and projected that prices will escalate to roughly \$165/ton by 2010[7]. This estimate was based upon the Phase II nationwide emissions cap of 8.95 million tons of SO_2 per year after 2000, and projections of the price premium for low sulfur coal. Compared to scrubber control costs this method provides a conservative profile of values. After 2010, the value per ton escalates at a more rapid rate, trending towards a scrubber based control cost of \$1,075/ton by the year 2020 (*Electric Utility Week* 1997).

NO_x Valuation . We also projected that markets for avoided NO_x emissions will emerge starting in the year 2000 in response to the Phase II limits of the 1990 Clean Air Act Amendments, and the EPA's new Ozone standards, for which a final rule was to be issued by September of 1998.We assumed control levels that will result in emissions of approximately 0.4 lbs. per Mbtu for utility boilers (Tellus Institute 1996a). This level of emissions is consistent with the installation of low NO_x burners, and overfire air technologies. We used the control costs of these technologies as a basis for estimating a value for avoided emissions of \$400/ton. The need to install more expensive technologies (selective catalytic reduction) would result in higher valuations. We projected the value of \$400/ton will remain constant through 2014.

CO_2 Valuation. The valuation for CO_2 is the dominant determinant for the program's total environmental benefits. Three CO_2 valuation scenarios were examined. Under the scenario which placed the lowest value on CO_2 (\$2 to \$10 per ton of CO_2 in the 2008-2014 time frame), CO_2 accounts for more than seventy percent of the total environmental benefit. In this scenario emissions increase to twelve to twenty-four percent relative to 1990 levels. We also looked at a scenario where the growth rate of carbon emissions slows to stabilization, so that by 2010, emissions are from zero percent to 12 percent above 1990 levels. CO_2 is valued in this scenario from \$6.20 to \$12.40 per ton of CO_2. In the third scenario, carbon emissions are reduced to six to ten percent below 1990 levels by 2010. In this last scenario, CO_2 is valued at \$25 per ton of CO_2. As CO_2 valuation levels increase, the share of total environmental benefits derived from CO_2 becomes as high as ninety-six percent. Therefore, a discussion of the valuation of the environmental benefits of HWAP must be grounded upon consideration of Kyoto targets and market valuations for CO_2 emissions reductions likely to emerge as policy responses to the Protocol are defined.

Results

We recommended that a total discounted value of \$264 per participant household be assigned to the program's environmental benefits at this time (Table 5). This is consistent with the valuation of avoided CO_2 emissions at \$12.40/ton, and scenarios that project the stabilization of U.S. carbon emissions at 1990 levels by 2010. Assigning this level of credit to environmental benefits is the result of what we considered to be a moderate approach in light of the sources we reviewed and the analyses conducted during this study.

[7] The current price of SO_2 allowances is \$215/ton (Tatsutani 1999).

Table 5. Recommended Environmental Benefits

	Recommended Environmental Benefits			
	Total Discounted Benefit	Levelized Annual Benefit per household	Total Discounted Benefit per household	Share of Total
NO_x	$122,838	$0.69	$10	2%
SO_x	$135,899	$0.76	$11	2%
CO_2	$2,906,842	$32.84	$242	96%
Total	**$3,165,579**	**$34**	**$264**	100%

Conclusions

The analysis presented in this report did not resolve many questions pertaining to the exact values to apply when determining the environmental benefits of the home weatherization program. Rather, the methods developed and applied in this study present a framework for tracking, and estimating the value of, avoided emissions created by HWAP activities. A recommended set of values was proposed based on what we considered to be reasonable estimates of emerging market values. We recognize that it will be useful to revisit the valuation of environmental benefits as the scope and details of carbon reduction policies become more clearly defined. In the interim, no matter what market values emerge for emissions reductions, the HWAP program is making a real contribution to the attainment of goals for carbon reduction established at the international level.

Implications

The environmental benefit results were incorporated into an overall summary report on HWAP prepared by the Office of Energy Efficiency (OEE). In an era of uncertainty in HWAP funding levels, the OEE is concerned that all documentable program benefits be recognized in the policy debates around the future of HWAP.

Comparison to Other Environmental Valuation Results

We can compare these levels of environmental benefits to other research on the environmental benefits of low-income weatherization programs. Skumatz and Dickerson (1997) estimated annual environmental benefits for Pacific Gas and Electric's Venture Partners Pilot Project of $3 to $20 per household. The national impact evaluation of the Weatherization Assistance Program conducted by Oak Ridge National Laboratory in 1993 estimated environmental benefits at roughly $13 per household per year (Brown et al 1993).

Two primary factors contributed to our recommended valuations exceeding those of the previous studies:

- The ORNL study's estimated value of $13 per household did not include valuation of avoided CO_2 emissions and is based upon valuation of NO_x and SO_x only. The valuation of avoided CO_2 emissions accounts for more than 90% of our recommended values.

- The estimated environmental benefits for the PG&E program are derived through an environmental adder based on 15% of the program's calculated avoided costs. In contrast, our approach is based directly on estimates of avoided emissions and the range of market values that may be applied.

For these reasons it is not surprising that our recommendations are higher than previous estimates of the environmental benefits attributable to weatherization activities.

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