ENERGY, ECONOMIC AND ENVIRONMENTAL IMPACTS OF THE DELAWARE LOW-INCOME WEATHERIZATION ASSISTANCE PROGRAM

FINAL REPORT

TO

OFFICE OF COMMUNITY SERVICES
DEPARTMENT OF HEALTH AND SOCIAL SERVICES
STATE OF DELAWARE

Center for Energy and Environmental Policy
University of Delaware

February 2006

ENERGY, ECONOMIC AND ENVIRONMENTAL IMPACTS OF THE DELAWARE LOW-INCOME WEATHERIZATION ASSISTANCE PROGRAM

Final Report

to

Office of Community Services
Department of Health and Social Services
State of Delaware

Project Advisors
Young-Doo Wang, Associate Director, CEEP
John Byrne, Director, CEEP

Researchers
Jyoti Kulkarni
Abhijit Banerjee
Jae Hyun Shim
Wang Jin Seo
Ju Hyeon Cho
Kamala Muhovic-Dorsner

Center for Energy and Environmental Policy
University of Delaware

FEBRUARY 2006

TABLE OF CONTENTS

LIST OF TABLES

ACKNOWLEDGMENTS

The authors express their appreciation to the Delaware Department of Health and Social Services for initiating and supporting this project, especially Mr. Kenneth Davis, Weatherization Assistance Program Manager, Office of Community Services. We are also grateful for the cooperation of Mr. Leonard Beck of Delmarva Power and Light Co. and Ms. Teresa P. McCann of the Delaware Electric Cooperative, Inc. for providing energy consumption data of their respective utility customers; Mr. Edward Minch of the Energy Services Group for providing data on weatherized dwellings; and Ms. Michelle A. Marean of Princeton University for patiently providing technical support for the PRISM software used in this study.

EXECUTIVE SUMMARY

Funded by the U.S. Department of Energy (DOE) and administered by state governments, the low-income Weatherization Assistance Program (WAP) is one of the largest energy efficiency programs in the country. The program provides assistance to improve the energy efficiency of dwellings occupied by vulnerable low-income[1] households, including the elderly, the disabled and families with children.

The State of Delaware administers its WAP initiative through the Office of Community Services (OCS), which oversees weatherization of an average of 500 low-income family homes a year. The weatherization package includes advanced diagnostics, infiltration reduction, upgrading of thermal values, energy saver kits, and client energy conservation education. Under contracts with the State, weatherization services are provided by Neighborhood House, Inc. (NH), First State Community Action Agency, Inc. (FSCAA), and Energy Services Group (ESG).[2]

Monthly household electricity and/or natural gas consumption and billing data for the period 2002 to 2005 was provided by Delmarva Power (for New Castle County) and Delaware Electric Co-op (for Kent and Sussex Counties), respectively. Daily temperature readings for all three counties in Delaware for a fifteen-year period (1990 – 2004) were obtained from the National Weather Service of the National Oceanic and Atmospheric Administration (NOAA). Weatherization cost estimates and data on household socioeconomic characteristics were provided by OCS. The household sample consisted of 99 households heating with electricity (50 receiving weatherization and 49 receiving only fuel assistance), and 54 households heating with natural gas (27 receiving weatherization and 27 receiving fuel assistance alone).

Energy savings were calculated using two methods. The first involved pre- and post-evaluation of energy consumption with a widely used software package, the PRInceton Scorekeeping Method (PRISM), that automatically calculates weather-adjusted annual energy savings per household. Whereas PRISM assumes that the energy-consuming characteristics of the treatment and control groups are identical, a second approach relying on econometric analysis calculated energy savings in a manner that accounted for socio-economic differences between the two groups (including family income, housing type, and housing size).

To estimate cost effectiveness, weatherization costs supplied by OCS were compared to direct monetary benefits from energy saved, as well as indirect societal benefits over the project lifespan of 20 years. An environmental benefit was calculated

[1] In many states households earning less than 150% of the federally set poverty level are considered low-income and eligible for the program, in Delaware the corresponding figure is 200%.

[2] NH provides weatherization services in New Castle County, FSCAA serves Kent and Sussex Counties, and ESG conducts statewide advanced diagnostic services on behalf of the program.

by converting energy savings into avoided CO_2 emissions based on carbon emission factors of different types of fuel.

The results of this study indicate that the Delaware WAP initiative has saved significant amounts of energy, has accomplished this in a cost effective manner, and has contributed to measurable reductions in pollution. Key findings are:

- For low-income homes heating with electricity, each weatherized household typically saved 2,539 kWh (18.3%) annually according to PRISM analysis and 2,268 kWh (16.3%) according to econometric analysis.
- For low-income homes heating with natural gas, each weatherized household typically saved 152 CCF (16.8%) annually according to PRISM analysis and 148 CCF (16.4%) according to econometric analysis.
- The WAP program and societal benefit-cost ratios were 1.71 and 3.39 respectively, for electrically heated homes.
- The WAP program and societal benefit-cost ratios were 1.69 and 3.40 respectively, for homes heated with natural gas.
- The Cost of Conserved Energy (CCE) for the Delaware WAP initiative is estimated to be $ 0.05/kWh - $ 0.06/kWh, considerably lower than the $ 0.10/kWh retail price of electricity that low-income households pay to heat with electricity.
- The Cost of Conserved Energy (CCE) for natural gas-heated homes is estimated to be $ 0.77/CCF - $ 0.90/CCF, again considerably lower than the $ 1.50/CCF retail price of natural gas paid by residential customers in Delaware.
- Each weatherized household saved about 2,000 pounds of CO_2 emissions per year, equivalent to a 5% reduction in emissions.
- Households weatherized during the study period saved a total of 900,000 pounds of CO_2 emissions per year, or a cumulative total of 18 million pounds of CO_2 over the lifetime of the project. This is equivalent to a 0.5% reduction in the State's current yearly residential sector emissions.

In sum, the Delaware WAP initiative provides significant energy, economic and environmental benefits that will accrue over years to come. These results once again establish that weatherization assistance for low-income households is far more beneficial than simple financial assistance to pay energy bills. Weatherization brings about numerous indirect benefits such as improved housing, increased employment, financial and resource savings from reduced consumption, and avoided pollution. The results of this research underscore the value of the WAP in energy policy as a demand-side management tool as well as an effective social policy for aiding low-income households.

Section I

Introduction

The Weatherization Assistance Program (WAP) was introduced by the Department of Energy (DOE) under Title IV of the Energy Conservation and Production Act of 1976.[3] Low-income families[4] are more adversely affected by high energy costs because these households spend on an average 14% of their annual income on energy needs while the all other households spend only about 3.5% (DOE, 2003). Energy costs for low-income families are especially high during peak heating and cooling seasons and therefore the WAP can help reduce these costs by increasing the energy efficiency of dwellings. It thereby frees financial resources for other uses and provides a long-term solution to higher energy bills (DOE, 2003; DOE, 2002).

The WAP addresses weatherization of single-family, multi-family and mobile homes. It uses federal and leveraged funds from state, charitable and private sector sources to deliver services by means of a network of partnerships between the DOE and more than 970 local weatherization agencies (DOE, 2003). Low-income families in all fifty states, the District of Columbia and among the Native American Tribes are eligible to apply for this program. Priority is given to elderly residents, residents with disabilities and families with children. Poverty income guidelines are provided to the states by the DOE (DOE, 2003; DOE, 2002).

The client selection criteria may differ from agency to agency with some selecting clients on a first come first serve basis and others aiming at clients with greater-than-average potential for cost-effective energy savings. Other criteria have also been developed that allow for larger investments for dwellings that offer greater energy saving possibilities rather than uniform expenditures per household (Brown et al, 1993). Sixteen percent of eligible households have been served so far although more than 27 million

[3] It has been subsequently amended by the 1978 Energy Conservation Policy Act, by the 1980 Energy Security Act, and the 1984 Human Services Reauthorization Act.

[4] The U.S. Department of Health and Human Services (HHS) annually sets federal poverty income guidelines for states to determine household eligibility for the WAP program. In many states households earning less than 150% of the federally set poverty level (minimum incomes are higher for Hawaii and Alaska) are considered low-income and eligible for the program (see: DOE, http://www.eere.energy.gov/weatherization/prog_guide.html). In the case of some states eligibility for the WAP is based on a household's income being less than 60% of the median income in the state (see: DOE, http://www.eere.energy.gov/weatherization/apply.html). Both homeowners and renters who meet income eligibility criteria can apply to the program but renters must get written permission from landlords in order for weatherization services to be performed (http://www.eere.energy.gov/weatherization/apply.html). For Delaware, households earning less than 200% of the federally set poverty level are eligible for the WAP (see: DHSS: http://www.dhss.delaware.gov/dhss/dssc/weatheriz.html).

households are currently eligible for assistance (DOE, http://www.eere.energy.gov/weatherization/reducing.html).

The WAP program functions through a decentralized system of agencies (Brown and Berry, 1994). For every $1 that the DOE invests, an additional $3.39 is leveraged from federal, state, charitable and private sources (DOE, 2002). The total funds allocated for the year 2004 are $227 million (DOE, http://www.eere.energy.gov/weatherization/prog_goals.html). The six regional offices of the DOE are responsible for the award of grants to the states, which then contract with local agencies to provide weatherization services (DOE, 2003).

Of the total amount of funds allocated to the program, 10% is used for training and technical assistance (T&TA) activities at the national and state level. The remaining funds are distributed to the states as program allocations. For each state the program allocation fund has two parts – a base allocation which is fixed for each state but differs from state to state[5] and a second formula-based allocation that accounts for the number of low income households in a state, climatic conditions and residential energy expenditures by low income households in each state. The sum of base allocations for all states is $171.3 million while the formula allocation is applicable to funds in excess of this base amount (DOE, http://www.eere.energy.gov/weatherization/ prog_goals.html).

Initially weatherization included simpler measures such as caulking, weather stripping of doors and windows, and covering of windows with plastic sheets. Gradually, with greater experience and knowledge of the cost-effectiveness of various actions, a greater variety of measures was introduced. By the 1980s, weatherization programs included the installation of storm windows and doors and insulation of attics. In 1984, weatherization funding from the DOE began to provide for energy efficiency improvements to existing space and water heating systems and in 1985 the replacement of faulty furnaces and boilers was permitted under this program.

In the 1990s, advanced home energy audits were included. This enabled weatherization service providers to analyze every dwelling comprehensively and determine the most appropriate and cost effective measures. In 1994 changes were made in the DOE regulations to allow for the inclusion of cooling efficiency measures such as air conditioner replacement, ventilation equipment and screening and shading devices. Such measures were particularly relevant to warmer climates where cooling costs are higher than those for heating. Recently, the DOE program has permitted work on heating systems and mechanical equipment (DOE, http://www.eere.energy.gov/weatherization/history.html).

By the year 2000 advanced energy audits were in use for WAPs nationwide and by the 2001 five million homes in the US had been weatherized under this program. Permission to use a greater variety of measures improved training of service providers,

[5] This depends upon several factors i.e. size of a state's WAP program, grant amount requested with the DOE, discretion of the DOE, etc (for further information, see DOE, 2000). Available at: http://www.waptac.org/sp.asp?id=1812.

the use of advanced audit tools and better management practices have helped to improve the performance of the program. As a result despite reductions in funding, the program produced 80% higher energy savings per dwelling in 1996 than that achieved in 1989 (DOE, http://www.eere.energy. gov/weatherization/history.html).

Weatherization service providers also educate clients in the proper use and maintenance of the installed measures and on energy efficiency (DOE, 2002). Typically, traditional energy education programs do not reach these households but an individualized approach by WAP service providers has proved to be effective (DOE, http://www.eere.energy.gov/weatherization/reducing.html).

Weatherization of dwellings produces many additional benefits. It reduces the environmental consequences of energy use by reducing carbon dioxide emissions by an average of one ton per weatherized home. It reduces national energy consumption by about 15 million barrels of oil per year directly contributing to energy security. It has been determined that weatherization creates more than $2 in energy related benefits for every $1 invested towards such measures and reduces annual energy consumption by an average of 31.2 MBtu per home. It saves energy costs to weatherized households by about 15% or about $237 per year.[6] Weatherization increases the market value of housing units by making them more affordable (DOE, http://www.eere.energy.gov/weatherization/improving.html). It also increases consumer awareness in energy efficiency practices (DOE, 2002, 2003).

Weatherization programs also stimulate the development of the local home energy industry (DOE, http://www.eere.energy.gov/weatherization/improving.html). The programs aid in the creation of jobs and present DOE funding supports about 8000 jobs nationwide. On average, 52 direct jobs are created for every million dollars invested in the program (which also upgrades local industry's capabilities by providing technical training to crews and contractors). Many of these jobs are in low-income areas and therefore help serve the need for local redevelopment. The creation of local jobs also helps to keep money circulating in the local economy, thereby additionally encouraging local development through a re-investment of energy savings (DOE, 2003).

A study by the Oak Ridge National Laboratory categorized the non-energy benefits of weatherization programs into three categories – ratepayer, household and societal benefits. The sum of all three categories of non-energy benefits for a weatherized household was estimated to be $3,346 in 2001 dollars (see Schweitzer and Tonn, 2002).

Rate payer benefits include payment related benefits (i.e., avoided rate subsidies; lower bad debt write-offs; reduced carrying costs on arrearage; fewer notices and customer calls; fewer shut-offs and reconnections; and reduced collection costs and

---

[6] The cost savings depend upon fuel prices (DOE, http://www.eere.energy.gov/weatherization/improving.html), and are equivalent to more than $1 million for all weatherized homes in the winter of 2000 (DOE, 2003).

service provision benefits like fewer emergency gas service calls; reduced transmission and distribution losses; and reduced insurance costs) (Schweitzer and Tonn, 2002).

Household benefits include affordability of housing benefits like water and sewer savings; enhanced property value; avoided shut-offs and reconnections; reduced transaction costs; and safety, health and comfort related benefits like fewer occurrence of fires, fewer illnesses and greater overall comfort.

Societal benefits can be environmental, social and economic. Environmental benefits include reduced air pollution, reduced water use and reduced sewage. Social benefits include the creation of jobs by the program. Economic benefits include creation of new jobs and therefore a boost to local economies; an improved ability of renters to pay their bills; and increased energy security (see Schweitzer and Tonn, 2002).

Despite significant benefits, there still exist areas of concern. Most of the current WAPs do not collect enough data to determine cost-effectiveness and therefore it cannot be determined if they can pass cost-effectiveness tests. In many states, utility regulators require a demonstration of the cost-effectiveness of DSM programs.[7]

[7] Although many utilities are involved in the program, most are still reluctant to combine the WAP with their demand response programs. In order for the WAP to be a successful state-utility partnership, it is important that the program's economic performance be proven to be cost-effective.

Section II

A Survey of National and State Research on Energy and Economic Savings from Low-Income WAPs

Past evaluations of low-income WAPs are reviewed in this section in order to provide benchmarks for the estimation of energy and economic savings resulting from such programs. All reviewed studies report savings in these areas although differences in fuel type and regional temperature, as well as evaluation methods, affect the magnitude of measured savings.

II–1 Energy Savings

In 1990, DOE conducted a comprehensive national assessment of the WAP, with the main goals of identifying energy savings and determining the cost effectiveness of its program (Brown and Berry, 1994; Brown et al, 1993). This evaluation gathered data from 4,796 dwellings weatherized in 1989 and a control group 3,776 residences (which consisted of applicants for weatherization services).[8] Complete data were obtained from 543 utilities that provided gas and/or electricity to weatherized and control dwellings. The dwellings were located in territories of 368 local agencies (Brown et al, 1993).

Energy savings in this case were calculated for DOE by a team at Oak Ridge National Laboratory (ORNL) using PRISM (PRInceton Scorekeeping Method), an advanced and extensively utilized software developed at Princeton University. The software normalizes for energy use over time by adjusting for temperature differences, and calculates gross energy savings as the difference between energy use before and after weatherization. Results for the control group are used to adjust for changes in energy use that would have happened without weatherization. Net energy savings are calculated by subtracting the average gross savings for control homes from the average gross savings for weatherized homes.

According to the performed study, the average energy savings for all weatherized dwellings was 18.2% in the energy used for space heating and 13.5% of total energy use (Brown et al, 1993). In another publication about this assessment, Brown et al (1993) note that electrically heated dwellings represented 10% of the residences weatherized by WAP during 1989. The weighted (for fuel mix) net savings for the Program nationwide was estimated to be 1,830 kWh/year. According to the study, this corresponded to a 12.2% reduction in total electricity, a 29.7% reduction in electricity used for space heating and air conditioning, and a 35.9% reduction in electricity used for space heating (see Brown et al, 1993).

---

[8] The control group can be drawn from applicants for the Low Income Home Energy Assistance Program (LIHEAP), but the metaevaluations in the ORNL studies have been mostly limited to WAP applicants.

The most recent assessments of the WAP are four meta-evaluations conducted by the Oak Ridge National Laboratory (ORNL): Berry 1997; Schweitzer and Berry 1999; Berry and Schweizer 2003; and Schweizer 2005. A meta-evaluation is a study that uses as its data points the findings from a number of individual studies on the topic of interest. All reports focused on energy and dollar savings for buildings heated with natural gas, with little discussion on electricity, because very few states have addressed electricity and therefore there was a lack of adequate data to allow for reliable analytical results (see Berry 1997; Schweitzer and Berry 1999; Berry and Schweizer 2003; and Schweizer 2005).

The results of the most recent meta-evaluation in 2005 are compared to findings from the earlier three meta-evaluations as well as the findings from the national evaluation of the 1989 weatherization program conducted by Brown et al (1993) (Table 1). The average savings for gas heated households as a percent of pre-weatherization consumption for all end uses is 22.9% in 2005, compared to 21.9% in the 2002 meta-evaluation, 19.6% in the 1999 meta-evaluation, 23.4% in the 1996 meta-evaluation, and 13.0% in the 1989 national evaluation (see Schweitzer 2005).

Table 1
Average Savings in Gas-heated Dwellings in the National WAPs

Study	Average natural gas savings per household (million BTUs)	Average savings per household as percentage of pre-weatherization consumption of all natural gas end uses (%)	Average savings per household as percentage of pre-weatherization consumption of natural gas for space heating (%)
2005 ORNL metaevaluation	30.5 (26.0-35.0)	22.9% (19.5-26.3)	32.3% (27.5-37.1)
2002 ORNL metaevaluation	29.1 (26.6-31.6)	21.9% (19.9-23.9)	30.8% (28.1-33.5)
1999 ORNL metaevaluation	26.1 (19.4-32.8)	19.6% (14.6-24.6)	27.6% (20.5-34.7)
1996 ORNL metaevaluation	31.2 (22.9-38.6)	23.4% (17.2-29.0)	33.5% (24.6-41.4)
1989 ORNL national evaluation	17.3 (15.1-19.5)	13.0% (11.3-14.7)	18.3% (16.0-20.6)

Source: Schweitzer 2005. The percentage figures in parentheses are based on a 90% confidence interval.

The evaluation of the Year 2000 Washington State WAP by Schweitzer and Berry (2001) reports mean normalized annual savings for electrically heated houses equal to 2,991 kWh, which amounts to 12.0% of pre-weatherizaton whole-house electricity use and 18.6% of the pre-weatherization electricity used for space heat. For the gas heated houses in the study, mean normalized annual savings were found to be 230.1 CCF, which represented 25.4% of pre-weatherization whole-house gas use and 30.8% of the pre-weatherization gas used for space heat.

With respect to the durability of weatherization measures, a 1989 Alliance to Save Energy (ASE) study addressed this question. It measured field performance of WAP measures installed in low-income homes over a five-year period. The major findings were: 1) the retrofits initially improved steady-state efficiency by 20 percent; 2) about one third of the initial gain was lost, on average, over five years; and 3) lack of customer education and of proper maintenance of the measures installed is probably the major reason for performance reductions (Kuennen et al. 1993). However, another study (1992) by the Wisconsin Energy Conservation Corporation (WECC), on the savings of the WAPs of two utilities, the Wisconsin Gas Company program (10% energy savings) and the Madison Gas & Electric Company program (13% energy savings) found that the savings did not erode over time but net energy savings actually demonstrated an increase over the course of the study.[9]

II–2 Cost-Effectiveness

The 1990 DOE assessment of the WAP, conducted by Brown et al (1993), examined the cost-effectiveness of WAP from three perspectives - installation, program and societal perspectives. From the installation perspective, the only benefit valued is energy savings, and the only costs included are installation expenditures. From a program perspective, the only benefit valued is energy savings, while costs include installation, management and overhead costs. From a societal perspective, benefits included both energy and non-energy benefits, and costs included installation, management and overhead costs.

This study found the WAP to be cost-effective from all perspectives (Brown et al 1993; Brown and Berry 1994).[10] In particular, it was concluded that the WAP saved energy, lowered fuel bills, improved health and safety and was cost-effective (see Brown and Berry, 1994). Cost-effectiveness was found to be more favorable in electrically heated homes compared to homes heated with other fuels due to the higher price of electricity. The cost of conserved energy for electrically heated homes was determined to be $0.04 per kWh, which compared favorably with the average national electricity price

[9] In a study of the rebound effect (a possible increase in energy use resulting from the installation of energy efficiency measures and using the available surplus on other consumable goods or investments that in turn consume energy), it is noted that this effect is most likely limited to less than 20% of the savings generated from the implementation of energy efficiency measures (Moezzi, 1998 in Wilhite and Norgard, 2004).

[10] The benefit/cost ratio was 1.09 from the program perspective; 1.72 from the societal perspective; and 1.61 from the installation perspective. If other program benefits (such as creation of jobs and the reduction of utility arrearages) were included, the benefit/cost ratio would likely show a substantial increase.

of $0.07 per kWh (1989 dollars) (Brown et al, 1993). The net current value of energy saved was determined to be $1,690 per dwelling (1989 dollars).

According to the 2002 meta-evaluation study, (Berry and Schweitzer, 2003), the benefit/cost ratio from the program perspective was approximately 1.3. When viewed from the social perspective, which includes the value of both energy and non-energy benefits, the calculated benefit/cost ratio increased to 2.7. This means that for every $1 spent an estimated $ 2.7 in benefits would be received (Berry and Schweitzer, 2003)[11]

The evaluation of the Vermont State WAP found the benefit-cost ratio after the inclusion of non-energy benefits to be 4.12. Non-energy benefits included the reduction of pollutants released to the environment, increased property value, tax benefits, employment benefits, improvement of health, etc. (Dalhoff, 2001). The State of Wisconsin has also reported that WAP measures are highly cost-effective (Lee et al, 2004).

[11] The result of cost-benefit analysis can vary depending on the discount rate used and the assumed lifetime of measures, etc. Berry et al used an average measure lifetime of 20 years, and a discount rate of 3.2%.

Section III

Review of Performance Evaluation Methods for WAPs

The evaluation of the impact of low-income weatherization programs on energy consumption requires extensive energy consumption data for heating and cooling with normalization for weather changes. The most commonly used methods of evaluating WAPs by taking into account weather related changes are the PRInceton Scorekeeping Method (PRISM) and regression models, typically employing econometric formulation of energy demand. Both are reviewed below.

III-1. The PRISM Model

The PRISM method is a statistical procedure that uses utility billing data from periods before and after installation of building retrofit measures, and average daily temperature data from the local weather station to determine weather adjusted energy savings resulting from weatherization programs. This method uses regression analysis to produce pre-weatherization and post-weatherization normalized annual consumption values (NAC_{pre} and NAC_{post} respectively) for each building analyzed, and the difference between these values provides the normalized annual energy savings (NAS) for the particular residence.

The sum of the NAS for all weatherized dwellings under evaluation provides an estimate of gross energy savings for a program. In the analysis of the WAP for a given set of buildings, the inclusion of a control group helps to determine the net energy savings incurred as a result of the retrofit measures in the weatherized buildings by calculating the difference between the NAS values for the control group and the weatherized group. Reliability statistics for the NAC values are the R^2 and CV(NAC) and help to determine the confidence that can be placed on PRISM outputs.[12]

PRISM software incorporates several models: the Heating-Only (HO) model for the evaluation of heating fuels; the Cooling-Only model for the evaluation of electricity used for cooling purposes only; and the Heating and Cooling (HC) model to be used when a single fuel is used for both heating and cooling purposes.

The PRISM program also has an Automated Model Selection (AMS) option, which, when selected, automatically determines the appropriate model to use for a particular building based on its consumption data. The PRISM program differs from other methods used for WAP evaluations in that the reference temperature it uses for the

[12] According to Fels et al (1995), in the context of PRISM, R^2 refers to the "R^2 of the least-squares regression of consumption data vs. degree days computed to the best reference temperature values" (p. II-37). The CV(NAC) is the "coefficient of variation or the relative standard error of the NAC." It is "computed as the standard error of the estimate divided by the estimate" (Fels et al, 1995: p. II-37).

weather-normalization of consumption data is a variable, rather then a constant such as 65°F (Fels et al, 1995; Fels, 1986). The regression model used by PRISM to determine the NAC for a building is as follows:

$$NAC = \underset{\text{(base level)}}{365\alpha} + \underset{\text{(heating season)}}{\delta_h \beta_h H_o(\tau_h)} + \underset{\text{(cooling season)}}{\delta_c \beta_c C_o(\tau_c)}$$

Where:

α	Base-level consumption (kWh/day)
β_h	Heating slope (kWh/°F-day)
β_c	Cooling slope (kWh/°F-day)
τ_h	Heating reference temperature (°F)
τ_c	Cooling reference temperature (°F)
δ_h	1 for HO and HC models, otherwise 0
δ_c	1 for CO and HC models, otherwise 0

$H_o(\tau_h)$ and $C_o(\tau_c)$ represent the long-term average heating and cooling degree-days per year respectively and are determined from ten or more years of daily temperature data to the heating and cooling reference temperatures (i.e., τ_h and τ_c respectively, which are determined by the PRISM program).

NAS is computed as the difference between NAC_{pre} and NAC_{post} (Fels et al, 1995 and Fels, 1986):

$$NAS = NAC_{pre} - NAC_{post}$$

$$NAS_{\%} = (1 - NAC_{post} / NAC_{pre}) * 100$$

For the weatherized group (W):

$$NAS_{raw}(W) = [NAC_{pre} - NAC_{post}]_W$$

$$NAS_{raw, \%}(W) = [(1 - NAC_{post} / NAC_{pre}) * 100]_W$$

Similarly for the control group (C):

$$NAS_{raw}(C) = [NAC_{pre} - NAC_{post}]_C$$

$$NAS_{raw, \%}(C) = [(1 - NAC_{post} / NAC_{pre}) * 100]_C$$

Control-adjusted savings are computed by the introduction of a control-adjustment factor:

$$C_{adj} = [NAC_{post} / NAC_{pre}]_C$$

Therefore control-adjusted savings of the weatherized group are:

$$NAS_{adj}\,(W) = [\ C_{adj} * NAC_{pre} - NAC_{post}]_W$$

$$NAS_{adj,\,\%}\,(W) = [\ C_{adj} - NAC_{pre} / NAC_{post}]_W$$

These formulae can be applied to the entire sample to obtain the net energy savings for the entire weatherized group, adjusted for the control group.

III-2. Econometric Models

The other major approach is econometric analysis. PRISM assumes that evaluators draw samples for both weatherized and non-weatherized group customers in which the differences in energy-consuming characteristics are not statistically significant. In reality this assumption is seldom met. The purpose of an econometric analysis is to adjust individual energy savings for cross-sectional differences between the two groups including household demographics, housing characteristics, etc. Since both time-series and cross-sectional data are combined in the analysis, the model is able to capture variations both within each home over time and across all homes in the sample.

The econometric model used in the analysis of Delaware's WAP conceptualized in three different ways: weather effects were accounted for by using NAC from PRISM as a dependent variable; weather-adjusted energy consumption based on a 30-year average as a dependent variable; and weather (heating and cooling degree days) as one of the independent variables.

In the first model, annual weather-adjusted energy use (NAC) from PRISM is treated as a function of WAP participation (weatherized household vs. non-weatherized household), weatherized period (pre- vs. post-weatherized period), and household and housing characteristics.[13]

[13] This model can then be expressed as follows:

$$NAC = \beta_0 + \beta_1 P + \beta_2 W + \beta_3 WP + \beta_4 S + \beta_5 WS + \varepsilon$$

Where, NAC: Normalized annual consumption from PRISM;
P: 0 for pre-weatherized period, 1 for post-weatherized period;
W: 0 for non-weatherized household, 1 for weatherized household;
WP: Interactive term between W and P (W * P);
S: Socio-economic characteristics of households (housing type, income, etc.);
WS: Interactive term between W and S (W * S); and
ε: Error term

In the second model, raw energy consumption from utility billings is adjusted by a weather-normalization factor computed as a ratio of average monthly temperature to the 30-year average monthly temperature. This weather-adjusted energy consumption then becomes the dependent variable and the usual participation and socioeconomic independent variables are used for the regression.[14]

In the third model, raw energy consumption is used as the dependent variable while a weather variable composed of heating or cooling degree-days (HDD or CDD) for each month is added to the usual participation and socioeconomic independent variables. This regression model can be expressed as follows:

$$RC = \beta_0 + \beta_1 HDD + \beta_2 P + \beta_3 W + \beta_4 WP + \beta_5 S + \beta_6 WS + \varepsilon$$

Where, RC: Actual raw (non-weather-adjusted) energy consumption;
HDD: Heating degree days (or cooling degree days for summer months);
P: 0 for pre-weatherized period, 1 for post-weatherized period;
W: 0 for non-weatherized household, 1 for weatherized household;
WP: Interactive term between W and P (W * P);
S: Socio-economic characteristics of households (housing type, income, etc.)
WS: Interactive term between W and S (W * S); and
ε: Error term

Detailed analysis showed that the third model (using RC and HDD) provided the most statistically significant results. This model was selected for the final econometric analysis of the Delaware program. According to this model, energy savings are calculated as follows:

Pre-weatherized consumption of control group:	$\beta_0 + \beta_1 + \beta_5$
Post-weatherized consumption of control group:	$\beta_0 + \beta_1 + \beta_2 + \beta_5$
Pre-weatherized consumption of weatherized group:	$\beta_0 + \beta_1 + \beta_3 + \beta_5 + \beta_6$
Post-weatherized consumption of weatherized group:	$\beta_0 + \beta_1 + \beta_2 + \beta_3 + \beta_4 + \beta_5 + \beta_6$
Energy savings of control group:	β_2
Energy savings of weatherized group:	$\beta_2 + \beta_4$
Net energy savings from WAP:	β_4

[14] This model can be expressed as follows:

$$WAC = \beta_0 + \beta_1 P + \beta_2 W + \beta_3 WP + \beta_4 S + \beta_5 WS + \varepsilon$$

Where, WAC: Weather adjusted energy consumption;
P: 0 for pre-weatherized period, 1 for post-weatherized period;
W: 0 for non-weatherized household, 1 for weatherized household;
WP: Interactive term between W and P (W * P);
S: Socio-economic characteristics of households (housing type, income);
WS: Interactive term between W and S (W * S); and
ε: Error term

Section IV

Delaware WAP Performance: Empirical Results

The evaluation of the low-income Weatherization Assistance Program of the state of Delaware was performed to determine energy savings, economic effectiveness and contribution towards environmental protection. For these purposes two evaluation methods were used – one is the standard PRISM model and the second is an econometric model that also helps to account for socio-economic factors. Both models adjust for weather impacts (although in different ways).

The effectiveness of the WAP program can be determined by means of pre-post and weatherized-control comparisons. Both PRISM and an econometric model can perform this kind of analysis to provide a gross and net energy savings values, respectively.

Electricity is used for both heating (in winter) and cooling (in summer) by many Delaware households throughout the state. Electricity consumption data were easily obtained from the respective utilities, Delmarva Power (formerly Conectiv) for New Castle County and Delaware Electric Co-operative for Kent and Sussex Counties. Altogether, adequate data were obtained for 49 households (25 weatherized group, 24 control group) in New Castle County and 50 households (25 weatherized group, 25 control group) in Kent and Sussex Counties.

Natural gas is used for winter heating mainly by residents in the northern part of Delaware. As such natural gas consumption data was only obtained for New Castle County from Delmarva Power. Altogether, adequate data were obtained for 54 households (27 weatherized group, 27 control group) in New Castle County. Since the other two counties evaluated in this study (i.e., Kent and Sussex) typically do not use natural gas for heating purposes, no natural gas data were collected in their cases.

Utility energy consumption data for a duration of two years (2003-2004) was obtained for individual buildings in the samples for each county. In the case of the weatherized group, the two years of data spanned 12 months of energy consumption data prior to the weatherization date (pre-weatherization period) and 12 months of energy consumption data after weatherization date (post-weatherization period) in order to ensure uniformity in pre and post periods and also to ensure complete coverage of summer and winter consumption months.[15]

Daily average temperatures for the period between January 1990 and December 2004 were obtained from a local weather station in each county. This provided a fourteen-year average of annual heating degree days (HDD) and cooling degree days

[15] Weatherization completion dates were provided by the Office of Community Services (OCS), State of Delaware.

(CDD) to be used in the PRISM and econometric analysis. In the case of New Castle County natural gas customers, this fourteen-year average temperature data spanned the duration July 1990 to June 2005 in order to account for some buildings in the sample for which the utility energy consumption data included some months of the year 2005.

IV-1 Energy Savings from PRISM Analysis

PRISM software was needed to evaluate the Delaware WAP effects on energy use. The Automated Model Selection option in the PRISM analysis was selected, which allows the program itself to determine the best suitable model (HO, CO or HC) for a given building based on the energy consumption data. The PRISM output data for each building analyzed provides values of NAC_{pre} and NAC_{post}; and the values of the NAC reliability criteria R^2 and CV. The PRISM savings summary output provides the median and mean energy savings for both the weatherized and control groups; standard errors of the savings estimates; and values of the reliability criteria for the median NAC for the weatherized and control groups, respectively.

IV-1.1 Electricity Savings

As noted above, adequate data were obtained for 49 households (25 weatherized group, 24 control group) in New Castle County and 50 households (25 weatherized group, 25 control group) in Kent and Sussex Counties that use electricity to heat their dwellings. The results are presented below.

IV–1.1.1. Automated Model Selection in PRISM

IV–1.1.1.1 New Castle County

The PRISM program was applied to this sample using the criteria of Automated Model Selection. Outliers were identified by using the robust version of recommended PRISM model (the robust version of PRISM downweights outliers in order to reduce their impact and provide reliable estimates of savings).

In the case of the New Castle County sample, the median savings and mean savings for the weatherized group were 649 kWh and 1,190 kWh respectively while the control group increased their median and mean energy consumption by 1,363 kWh and 2,054 kWh, respectively. As a result, adjusted median and mean savings for the weatherized group were 2,012 and 3,245 kWh, respectively. The table below provides the energy savings estimates for the New Castle County electric heating sample (for detailed results see Appendix A).[16]

[16] These savings are annualized and include cooling, as well as heating, season savings.

Table 2
Electricity Savings Estimates for New Castle County (AMS)

Sample	Number of Households	Median Savings (kWh)	Mean Savings (kWh)
Weatherized	25	649 (5.6%)	1,190 (7.1%)
Control	24	-1,363 (-9.5%)	-2,054 (-14.0%)
Adjusted Savings	49	2,012 (15.1%)	3,245 (21.1%)

IV–1.1.1.2 Kent and Sussex Counties

The PRISM program was applied to this sample using the criteria of Automated Model Selection with outliers down-weighted using the robust version of the recommended PRISM model. In this case the median savings and mean savings for the weatherized group were 414 kWh and 635 kWh, respectively, while the control group increased their median and mean energy consumption by 1,060 kWh and 1,216 kWh respectively. As a result adjusted median and mean savings for the weatherized group were 1,474 kWh and 1,851 kWh, respectively. The table below provides the energy savings estimates for the Sussex County sample (for detailed results see Appendix A).[17]

Table 3
Electricity Savings Estimates for Kent and Sussex Counties (AMS)

Sample	Number of Households	Median Savings (kWh)	Mean Savings (kWh)
Weatherized	25	414 (2.7%)	635 (3.6%)
Control	25	-1,060 (-6.8%)	-1,216 (-11.8%)
Adjusted Savings	50	1,474 (9.5%)	1,851 (15.5%)

IV–1.1.1.3 The State of Delaware

In order to estimate electricity savings for the State of Delaware, normalized electricity consumption data from New Castle, Kent and Sussex Counties were combined by concatenating the output file types, i.e. spread files and residual files, from the New Castle and Kent/Sussex PRISM runs. The combined sample size then comprises of 99 buildings (i.e., 50 weatherized and 49 control group buildings). It is observed that the

[17] These savings are annualized and include cooling, as well as heating, season savings. Because the heating season in the lower counties of Delaware is warmer, savings are expectably lower for Kent and Sussex County low and moderate-income residents.

median savings and mean savings for the weatherized group were 551 kWh and 912 kWh, respectively, while the control group increased their median and mean energy consumption by 1,254 kWh and 1,627 kWh, respectively. As a result, adjusted median and mean savings for the weatherized group (including improvements during the cooling and heating seasons) were 1,804 kWh and 2,539 kWh, respectively. The table below provides the total energy savings estimates for the Delaware electric sample (for detailed results see Appendix A).

Table 4
Electricity Savings Estimates for the State of Delaware (AMS)

Sample	Number of Households	Median savings (kWh)	Mean Savings (kWh)
Weatherized	50	551 (5.3%)	912 (5.3%)
Control	49	-1254 (-7.5%)	-1627 (-12.9%)
Adjusted Savings	99	1,804 (12.9%)	2,539 (18.3%)

IV – 1.1.2. Heating Only Model Selection in PRISM

The PRISM program was also applied to the New Castle County and Kent and Sussex County samples using the Heating Only Model option. Once again outliers were down-weighted by using the robust version of the recommended PRISM model. The normalized electricity consumption outputs from the Heating Only model runs (robust version) for New Castle County and Kent and Sussex Counties were combined together to estimate average savings for the State of Delaware. The combined sample size comprises 99 buildings (i.e., 50 weatherized and 49 control group buildings).

The median and mean savings for the weatherized group were 703 kWh and 1,158 kWh, respectively, while the control group increased their median and mean energy consumption by 1,060 kWh and 1,249 kWh, respectively. As a result, for heating improvements only, adjusted median and mean savings for the weatherized group were 1,763 kWh and 2,407 kWh, respectively. The table below provides the energy savings estimates for the Delaware electric sample (for detailed results see Appendix A).

Table 5
Electricity Savings Estimates for the State of Delaware (Heating Only)

Sample	Number of Households	Median Savings (kWh)	Mean Savings (kWh)
Weatherized	50	703 (6.1 %)	1,158 (7.7 %)
Control	49	-1,060 (-7.4 %)	-1,249 (-9.2 %)
Adjusted Savings	99	1,763 (13.5%)	2,407 (16.9%)

IV–1.2 Natural Gas Savings

The New Castle County gas sample is comprised of 27 dwellings in the weatherized and control groups (for a total of 54 dwellings). The PRISM program was applied to this sample using the criteria of Automated Model Selection and reducing the impact of outliers by using the robust version of the recommended PRISM model. In this case, it was not necessary to run the Heating Only model since gas is only used for heating purposes and not cooling (as against the case of electricity, which is used for both). The Automated Model recognized this from the data entered and correctly selected the heating only option within it to analyze household data (as a result the outputs of the Automated Model and Heating Only model, if run, would be identical).

In the case of natural gas-heated houses, the median and mean savings for the weatherized group were 109 CCF and 103 CCF, respectively, while the control group increased their median and mean energy consumption by 8 CCF and 48 CCF, respectively. As a result, adjusted median and mean savings for the weatherized group were 117 and 152 CCF, respectively. The table below provides the energy savings estimates for the New Castle County natural gas sample (for detailed results see Appendix A).

Table 6
Natural Gas Savings Estimates for New Castle County

Sample	Number of Households	Median Savings (CCF)	Mean Savings (CCF)
Weatherized	27	109 (10.5%)	103 (10.3%)
Control	27	-8 (-1.1%)	-48 (-6.5%)
Adjusted Savings	54	117 (11.6%)	152 (16.8%)

IV-2. Energy Savings from CEEP's Econometric Model

A major assumption of the PRISM model is that both weatherized and control groups are randomly selected from the same population. However, when comparing household profiles, significant cross-sectional differences were found to exist that affect energy consumption. The most significant socioeconomic factor observed in this study was housing type (H), where single-family homes and row houses generally had different energy consumption characteristics compared to mobile homes.[18] As a means of controlling for this factor, the CEEP econometric model was specified as follows:

$$RC = \beta_0 + \beta_1 HCDD + \beta_2 P + \beta_3 W + \beta_4 WP + \beta_5 H + \beta_6 WH + \varepsilon$$

Where, RC: Actual raw (non-weather-adjusted) energy consumption;
HCDD: Heating degree days (or Cooling degree days for summer months);
P: 0 for pre-weatherized period, 1 for post-weatherized period;
W: 0 for non-weatherized household, 1 for weatherized household;
WP: Interactive term between W and P (W * P);
H: 1 for single-family homes, 0 for mobile homes and row-houses;
WH: Interactive term between W and H (W * H); and
ε: Error term

The net savings for each participant is represented by the coefficient on the participation variable (WP), β_4.

IV–2.1 Electricity Savings: Heating and Cooling

Altogether, statistically adequate data was obtained for 49 households (25 in the weatherized group and 24 in the control group) in New Castle County and 50 households (25 in the weatherized group and 25 in the control group) in Kent and Sussex Counties.

IV–2.1.1.1 New Castle County

Since electricity is used for both heating and cooling, yearly savings (12 months) were first calculated for total electricity saved. The results are presented below:

$$\underset{(t=10.7)}{RC = 833} + \underset{(t=11.7)}{0.9\,HCDD} + \underset{(t=1.0)}{76\,P} - \underset{(t=-3.2)}{292\,W} - \underset{(t=-1.9)}{195\,WP} + \underset{(t=5.9)}{447\,H} - \underset{(t=-3.5)}{366\,WH} + \varepsilon$$

$R^2 = 0.21$ N = 49 F = 50.89

[18] Both housing type and family income were considered in the model, but family income was not statistically significant. This can be explained by the fact that the sampling was limited to households with incomes qualifying them for the Delaware WAP. This results in a narrow range of incomes in the sample and, therefore, little predictive power for this variable.

The F-value of 50.89 is far greater than the critical value of 2.965, indicating that the model is statistically significant at the 0.05 level. The R^2 is 0.21, indicating modest predictive ability.[19] All estimated coefficients except for P (t=1.0) are statistically significant as shown by the t-statistics reported above. As expected, weather is the most significant factor affecting electricity consumption in heating (having the highest beta value among the independent variables). The coefficient for WP, which represents energy savings from WAP, is significant. According to this model, the net electricity savings for a weatherized dwelling in New Castle County was 195 kWh per month or 2,340 kWh per year (195 kWh * 12). This represents a 15.2% saving rate (see Table 7).

IV–2.1.1.2. Kent and Sussex Counties

The same model specification used for New Castle County was applied to Kent and Sussex Counties as below:

$$\underset{(t=12.0)}{RC = 729} + \underset{(t=19.0)}{1.6\,HCDD} + \underset{(t=2.3)}{142\,P} + \underset{(t=1.6)}{109\,W} - \underset{(t=-2.0)}{182\,WP} - \underset{(t=-6.1)}{986\,H} + \underset{(t=4.4)}{773\,WH} + \varepsilon$$

$R^2 = 0.26$ N = 50 F = 68.67

The estimated coefficient of WP is statistically significant (t=-2.0). The most significant difference from New Castle County is the sign of H. Most weatherized low-income households in Kent and Sussex Counties live in mobile homes, and their electricity consumption is relatively higher than single homes, consequently showing a negative sign. According to this model, the net electricity savings for a weatherized dwelling in Kent and Sussex counties was 182 kWh per month or 2,184 kWh per year (182 kWh * 12), an 18.3% saving rate (Table 7).

IV–2.1.1.3 The State of Delaware

When 49 households from Kent and Sussex Counties and 50 from New Castle County are combined to estimate electricity savings from WAP for the State of Delaware, the following is found.

$$\underset{(t=18.3)}{RC = 900} + \underset{(t=18.7)}{1.1\,HCDD} + \underset{(t=2.0)}{104\,P} - \underset{(t=-1.9)}{108\,W} - \underset{(t=-2.6)}{189\,WP} + \underset{(t=3.1)}{177\,H} - \underset{(t=-4.2)}{323\,WH} + \varepsilon$$

$R^2 = 0.16$ N = 99 F = 75.88

The estimated coefficient of WP is statistically significant. According to this model, the net electricity savings for a typical low-income weatherized dwelling in Delaware was 189 kWh per month or 2,268 kWh per year (189 kWh * 12), equaling a 16.3% saving rate (Table 7).

---

[19] This is partly due to the use of as a dummy regression model whose predictive ability is not readily assessed by the R^2 statistic.

IV–2.1.2 Heating Only Model for the State of Delaware

Heating energy saved for winter months only was calculated using electricity data for 7 months (October to April) for all 99 households in the sample. The results are presented below:

$$RC = 982 + 1.2\,HDD + 129\,P - 350\,W - 192\,WP + 158\,H - 284\,WH + \varepsilon$$

(t=11.4) (t=12.1) (t=1.6) (t=-4.0) (t=-1.7) (t=1.8) (t=-2.3)

$R^2 = 0.16$ N = 99 F = 43.31

The estimated coefficient of WP is statistically significant at the 0.05 level in a one way test. According to this model, the net electricity savings for heating in winter for a weatherized dwelling in Delaware was 192 kWh per month or 1,344 kWh per year (192 kWh * 7). This corresponds to a saving rate of 9.4% for the typical low-income weatherized dwelling in the State (Table 7).

Table 7
Summary of Electricity Savings for Delaware Using the CEEP Econometric Model

Area	**Number of Households**			**Electricity Savings/Household**	
	Weatherized	Control	Total	kWh/yr	Percent
Heating and Cooling					
New Castle county	25	24	49	2,340	15.2%
Kent/Sussex county	25	25	50	2,184	18.3%
Delaware	50	49	99	2,268	16.3%
Heating only					
Delaware	50	49	99	1,344*	9.4%

Note: *Heating energy savings from the econometric model are for 7 months (October – April).

IV–2.2 Natural Gas Savings

Altogether, adequate data was obtained for 54 households (27 weatherized group, 27 control group) in New Castle County. The results are presented below:

$$RC = 17.2 + 0.2\,HDD + 4.1\,P + 7.9\,W - 12.3\,WP - 6.1\,H + 10.0\,WH + \varepsilon$$

(t=4.4) (t=42.2) (t=1.0) (t=1.6) (t=-2.2) (t=-1.5) (t=1.8)

$R^2 = 0.58$ N = 54 F = 302.10

The estimated coefficient of WP is statistically significant. According to this model, the net natural gas savings for a weatherized dwelling in Delaware was 12.3 CCF per month or 148 CCF per year, equivalent to an annual savings of 16.4%.

Table 8
Natural Gas Savings for Delaware Using the CEEP Econometric Model

Area	**Number of Households**			**Natural Gas Savings/Household**	
	Weatherized	Control	Total	CCF/yr	Percent
New Castle County	27	27	54	148	16.4%

IV-3. Comparison of Energy Savings from the PRISM and CEEP Econometric Models

Estimated energy savings from the Delaware WAP by the two different methods – PRISM and CEEP econometric analysis – show remarkably similar results. Since the data sets used for these two different analyses were exactly same, confidence in the accuracy and reliability of the results are strengthened.[20] In general, the econometric results anticipate slightly lower energy savings than the PRISM results.[21] A comparison of the estimated energy savings from Delaware's WAP by the two different models is presented in the following table.

Table 9
Comparison of Energy Savings for Delaware by the Two Models

ELECTRICITY				
Area	**PRISM Model Savings/Household**		**CEEP Econometric Model Savings/Household**	
	kWh/yr	Percent	kWh/yr	Percent
Heating and Cooling				
New Castle County	3,245	21.1%	2,340	15.2%
Kent/Sussex County	1,851	15.5%	2,184	18.3%
Delaware	2,539	18.3%	2,268	16.3%
Heating Only				
Delaware	2,407	16.9%	1,344*	9.4%
NATURAL GAS				
Area	**PRISM Model Savings/Household**		**CEEP Econometric Model Savings/Household**	
	CCF/yr	Percent	CCF/yr	Percent
New Castle County	152	16.8%	148	16.4%

Note: *Heating energy savings from the econometric model are for seven months, while the PRISM results (2,407 kWh) are annualized savings.

[20] In the case of heating, the econometric model used only 7 heating months (April-October) out of 12 months, but PRISM used the normalized annual consumption (NAC) for all 12 months.

[21] The difference is probably due to the different weather adjustment methods of the two models and the inclusion of socio-economic variables in the econometric model.

Section V

Cost-effectiveness of Delaware's WAP

Cost information was obtained from the Delaware Office of Community Services (OCS) to evaluate the economic performance of the WAP in Delaware. Weatherization costs include those for materials, installation labor and administration. OCS cost figures were provided at the county level and a calculated statewide average was developed, using relative sample size as the weighting factor. Average weatherization costs per household are presented in the following table:

Table 10
Average Weatherization Costs per Household for Delaware's WAP

County	Material Cost	Labor Cost	Total Installation Cost	Admin. Cost	Total Program Cost
	M	L	I = M + L	A	P = I + A
New Castle county	$673	$1,010	$1,683	$278	$1,961
Kent county	$591	$886	$1,477	$278	$1,755
Sussex county	$791	$1,186	$1,977	$278	$2,255
Delaware (average)	**$682**	**$1,023**	**$1,706**	**$278**	**$1,984**

Source: Office of Community Services, State of Delaware. 2005.

The cost-effectiveness of the Delaware WAP was examined from three different perspectives. From the installation perspective, only energy savings benefits are compared to on-site installation costs, which include expenditures for material and labor. From the program perspective, only energy savings benefits are compared to total costs, which include on-site installation and administration costs. Finally, the societal perspective compares both energy and selected non-energy benefits to total costs.

Analyses from the three perspectives used the same baseline assumptions – a real discount rate of 3.2% and a 20-year service lifetime (Schweiter and Tonn, 2002). Since impending energy price escalation[22] was not considered in our analysis, our estimates may be considered fairly conservative. Both installation and program perspectives consider benefit-cost ratios and the cost of conserved energy (CCE) as key measures of cost-effectiveness. Only benefit-cost ratios were determined for the societal perspective because CCE does not reflect non-energy benefits. As noted earlier, estimated energy savings were lower from the econometric analysis than the PRISM results. The lower

[22] *The News Journal*, a major newspaper reporting on Delaware, reported in a series of articles in February, 2005 that Delmarva Power is seeking a 59% rate hike when the state-imposed rate cap expires in 2006. The State is experiencing a 20-30% increase in natural prices above those that pertained for the years of billing data analyzed for this report.

econometric estimates were used for the cost-effectiveness analysis so that our results may be considered additionally conservative.

Much of the research evaluating low-income weatherization programs has not addressed non-energy impacts. The non-energy benefits from a societal perspective include the preservation of affordable housing; the enhancement of comfort, health and safety; increased employment and economic benefits; and reduced environmental externalities. A comprehensive nationwide study conducted by the Oak Ridge National Laboratory in 2002 found a net present value of $3,346 of non-energy benefits (Schweiter and Tonn, 2002) under different categories as presented in Table 11 below.[23] The total non-energy benefit value found in this study was used for our societal benefit-cost analysis.

Table 11
Net Present Value of Non-Energy Benefits of WAPs

Type of Non-Energy Impact	**NPV of the Impact per Dwelling (2001 $)**
Lower subsidies and insurance, reduced arrearages, collection costs and service calls	$331
Preservation of affordable housing, enhanced property value and extended life of dwelling	$783
Improved health, safety and comfort	$123
Reduced environmental externalities	$869
Avoided unemployment benefits	$117
Increased income and revenue from direct and indirect employment	$802
National security benefits	$321
Total NPV of non-energy benefits	**$3,346**

Source: Schweiter and Tonn, 2002. *Non-energy Benefits from the Weatherization Assistance Program: A Summary of Findings from the Recent Literature.* ORNL/CON-484.

V-1 Electricity

For electricity, the estimated energy savings (from the econometric model) is 2,268 kWh per household per year. The average retail price of electricity is taken to be $ 0.10/kWh in Delaware. The results of our economic analysis are presented table 12.

[23] Although the authors acknowledge that there is no consensus on quantifying the monetary value of many non-energy benefits, they believe that their figure is most likely a under-estimate (Schweiter and Tonn, 2002).

Table 12
Cost-effectiveness of Delaware's WAP for Electricity

Perspective	Energy Benefit[24]	Non-energy Benefit	Material Cost	Labor Cost	Admin. Cost	B/C Ratio
Installation	$3,389		$682	$1,023		1.99
Program	$3,389		$682	$1,023	$278	1.71
Societal	$3,389	$3,346	$682	$1,023	$278	3.39

The results show that Delaware's WAP is cost-effective for its weatherization of low-income homes heating with electricity. The benefit-cost ratios from all three perspectives were higher than 1.0, indicating that the benefits accruing from WAP are greater than the costs being incurred. As expected, the benefit-cost ratio derived from a societal perspective is the highest because it includes non-energy benefits of $ 3,346.

The cost of conserved energy (CCE) also shows that Delaware's WAP activities for electrically-heated houses is cost-effective. From the installation and program perspectives, the values of CCE were $ 0.05/kWh and $ 0.06/kWh (for detailed calculations see Appendix B), respectively, both being considerably lower than the $ 0.10/kWh retail price of electricity that Delaware households paid during the evaluation period.

V–2 Natural Gas

For natural gas, the estimated energy saving from the econometric model is 148 CCF per household per year. The average retail price of natural gas is $ 1.50/CCF in Delaware. For weatherization costs, the New Castle County average figures were used (see Table 9) since all the natural gas data were obtained from that jurisdiction. The results of our economic analysis are presented in the following table:

Table 13
Cost-effectiveness of Delaware's WAP for Natural Gas

Perspective	Energy Benefit[25]	Non-energy Benefit	Material Cost	Labor Cost	Admin. Cost	B/C Ratio
Installation	$3,317		$673	$1,010		1.97
Program	$3,317		$673	$1,010	$278	1.69
Societal	$3,317	$3,346	$673	$1,010	$278	3.40

The results again show that Delaware's WAP is cost-effective, in this case for homes heated with natural gas. The benefit-cost ratios from all three perspectives were

[24] For detailed calculations see Appendix B.
[25] For detailed calculations see Appendix B.

higher than 1.0, indicating that benefits are greater than the costs being incurred. As expected, the benefit-cost ratio derived from the societal perspective was the highest because it included non-energy benefits of $ 3,346.

The cost of conserved energy (CCE) also shows that Delaware's WAP for natural gas0heated homes is cost-effective. From the installation and program perspectives, the values of CCE were $0.77/CCF and $0.90/CCF (for detailed calculations see Appendix B), respectively, both being considerably lower than the $1.50/CCF retail residential price for natural gas.

Section VI

Environmental Benefits from Delaware's WAP

A successful weatherization program provides significant environmental benefits because weatherization leads to reduced energy consumption that translates to reduced emissions of pollutants and greenhouse gases. Environmental benefits were calculated for Delaware's WAP by converting the energy savings into pollution savings with respect to CO_2.

For electricity, the savings per household (2,268 kWh) were multiplied by a factor of 2.9 to reflect the actual primary energy saved at generation. This figure was then broken down to coal, natural gas and oil equivalents based on the proportion of electricity generation from each fossil fuel in the PJM area. From these coal, natural gas and oil equivalents, CO_2 emission savings were calculated. Finally, the emission savings for each household were summed (For detailed calculations see Appendix C).

For natural gas, the savings per household (148 CCF) was multiplied by a factor of 1.1 to reflect the actual primary energy saved at generation. From this figure, the CO_2 emission savings were calculated based on carbon content of natural gas (For detailed calculations see Appendix C). The results are presented in the following table:

Table 14
CO_2 Savings per Household from Delaware's WAP

Household Heating-type	End Use Energy Savings per Household per Year	Primary Energy Savings per Household per Year	CO_2 Savings per Household per Year (lbs)[26]
Electricity	2,268 kWh	6,577 kWh	2,099
Natural Gas	148 CCF	163 CCF	1,954

The results indicate that substantial pollution reduction takes place over the lifetime of the project, particularly when cumulative pollution savings are considered throughout the lifetime of the installed measures as depicted in Table 14.

[26] Our calculation of CO_2 savings matches very closely with the average of 1 ton per household per year cited in the literature (DOE, 2003), when the following conversion factor is used: 1 ton (non-metric) = 2,000 lbs.

Table 15
Total Cumulative CO_2 Savings from Delaware's WAP

CO_2 Savings per Household per Year (lbs) [conservative approximation, see Table 13]	**Total number of Households Weatherized during study period**[27]	**Total CO_2 Savings from Delaware WAP per Year (lbs)**	**Cumulative CO_2 Savings from Delaware WAP over 20 years (lbs)**
2,000	450	900,000	18,000,000

[27] Total number of households weatherized during the study period was obtained from the Delaware Office of Community Services (OCS).

Section VII

Policy Implications

Weatherization assistance programs for low-income customers provide an effective method of providing energy assistance to low-income families by reducing their home energy bills. The WAPs are considered to be a better option than simply providing financial assistance for energy services in that they also have several non-energy benefits for low-income families in terms of affordability of housing, increased safety of buildings, better health and greater comfort. Non-energy benefits also extend to the utilities in terms of reduced resource costs and reduced losses; to society in terms of avoided unemployment; and to the environment in terms of avoided pollution impacts and reduced consumption (Schweitzer and Tonn, 2002). As a result, energy and cost savings resulting from WAP programs have several policy implications:

- Their societal benefits point towards their importance in the formulation of social policy;
- They contribute to reductions in environmental impacts of energy generation and consumption by lowering emissions of greenhouse gases and other pollutants;
- By reducing energy consumption, they increase energy security; and
- WAPs serve as an effective demand-side management tool for utilities and residents by cost-effectively lowering the unit cost of home energy services.

This analysis of the low-income WAP of the State of Delaware provides empirical evidence of the above-mentioned benefits of this program and thus underscores its value in state level policy-making.

- For electricity heating households, each weatherized dwelling saved 2,539 kWh heating and cooling combined), or an 18.3% saving compared to non-weatherized homes, according to PRISM analysis and 2,268 kWh (16.3%) according to our econometric model.
- For electricity heating only, each weatherized household saved 2,407 kWh (a 16.9% saving) according to PRISM analysis and 1,344 kWh (9.4%) according to econometric analysis.[28]
- For natural gas heated homes, each weatherized household saved 152 CCF (a 16.8% of saving) according to the PRISM analysis and 148 CCF (16.4%) according to our econometric model.
- For electricity heated homes, the program and societal benefit-cost ratios were 1.71 and 3.39, respectively.

[28] If annualized as with PRISM, it turns out to be 2,304 kWh, which is equivalent to a savings of 16.2%.

- For natural gas heated homes, the program and societal benefit-cost ratios were 1.69 and 3.40, respectively.
- Each weatherized household avoids about 2,000 pounds of CO_2 emissions per year.
- The number of households weatherized during our study period save a total of 450 tons of CO_2 emissions per year, and a cumulative total of 9,000 tons of CO_2 over the lifetime of the installed measures.

The energy savings accruing from this program address two energy policy issues. By reducing annual energy demand during heating and cooling months they could help to serve as an effective DSM tool. Therefore utilities could benefit by including WAP programs in their customer service portfolio. A second energy policy contribution is that the reduced energy demand also directly contributes towards addressing policy issues pertaining to national energy security.

In terms of implications for social policy, the reduced energy consumption and a benefit-cost ratio greater than 1.0 (when both energy- and non-energy benefits are considered together) directly affect quality of life in terms financial savings for low-income families – money that could pay for other necessities. In addition, as Schweitzer and Tonn (2002) have pointed out, the program also increases the property value of retrofitted homes; provides health benefits and increases comfort level for low-income families; and creates employment opportunities and economic development in society.

The reduced emissions of greenhouse gases can contribute to a program of responses to climate change, as well as reducing air pollution since avoided emissions of CO_2 are associated with reductions in other gases (especially, SO_x). Reduced pollution due to reduced energy demand improves environmental quality for everyone, often benefiting low-income communities the most.

A final point is that WAP benefits can be long lived because measures can produce benefits for up to 20 years. But this is only possible if there is proper maintenance of weatherized homes. Thus it becomes important that customer education and training are included as important components of state WAPs. Although this current study did not evaluate the impact of customer education in Delaware's WAP, current literature strongly implies that education and continued monitoring can significantly improve the long-term performance of weatherization assistance programs.

References

Alliance to Save Energy. 1989. Longevity of Energy Savings: An Inspection and Analysis of Oil Heating Systems Five Years After Retrofit. Washington, DC: Alliance to Save Energy.

Berry, L., 1997. State-level evaluations of the Weatherization Assistance Program in 1990-1996: A metaevaluation that estimates national savings, ORNL/CON-435, Oak Ridge National Laboratory.

Berry, L. and Schweitzer.M., 2003. Metaevaluation of national weatherization assistance program based on state studies, 1993-2002. ORNL/CON-488, Oak Ridge National Laboratory.

Brown, M. A., Berry, L. G., Blazer, R. A. and Faby, E. 1993. *National Impacts of the Weaherization Assistance Program in Single-Family and Small Multifamily Dwellings.* ORNL/CON-326, Oak Ridge National Laboratory.

Dalhoff, G. 2001. An Evaluation of the Impacts of Vermont's Weatherization Assistance Program.

Delaware Health and Social Services (DHSS), Division of State Service Centers, Weatherization Assistance Program. Available at: http://www.dhss.delaware.gov/dhss/dssc/weatheriz.html

Energy Information Administration. 2005. Fuel and Energy Source Codes and Emission Coefficients. U.S. Department of Energy. Available at: http://www.eia.doe.gov/oiaf/1605/coefficients.html

Fels, Margaret F. 1986. PRISM: An Introduction, In Energy and Buildings, Vol. 9, No. 1, p. 5-18

Fels, M., Kissok, K., Marean, M. M. and Reynolds, K. 1995. PRISM (Advanced Version 1.0): Users Guide, Center for Energy and Environmental Studies, Princeton University, NJ.

Fenichel, A. 1992. Low-Income Weatherization: DSM Resource, Customer Service, or Social Equity Program? *DSM Quarterly* Fall: 16-25.

Kuennen, C. R., Miller, A. and Wang, C. 1993. *Weatherization: Trends, Issues and New Technologies.* Center for Energy and Environmental Policy, University of Delaware.

Lee, L., Rathburn, P., and Schauer, L. 2004. Low-income Public Benefits Evaluation, State of Wisconsin, Department of Administration, Division of Energy. Executive summary available at: http://www.doa.state.wi.us/docs_view2.asp?docid=3989.

Moezzi, M. 1998. The Predicament of Efficiency. In *Proceedings of the 1998 ACEEE Summer Study: Energy Efficiency in Buildings,* 4. Pacific Grove, CA, USA.

Schweitzer.M. and Berry, L., 1999. Metaevaluation of national weatherization assistance program based on state studies, 1996-1998. ORNL/CON-467, Oak Ridge National Laboratory.

Schweitzer.M. and Berry, L., 2001. Evaluation of the Washington State weatherization assistance program. ORNL/CON-478, Oak Ridge National Laboratory.

Schweitzer, M. and Tonn, B. 2002. Nonenergy Benefits from the Weatherization Assistance Program: A Summary of Findings from the Recent Literature. Prepared by Oak Ridge National Laboratory for the U.S. Department of Energy, ORNL/CON-484. Available at: http://weatherization.ornl.gov/download_files/Con-484-april02.pdf.

Schweitzer, M, 2005. Estimating the National Effects of the U.S. Department of Energy's Weatherization Assistance Program with State-Level Data, 1993-2005. ORNL/CON-493, Oak Ridge National Laboratory.

U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. History of the Weatherization Assistance Program. Available at: http://www.eere.energy.gov/weatherization/history.html.

U.S. Department of Energy. 2003 Office of Energy Efficiency and Renewable Energy, Weatherization Assistance Program: Weatherization Works. Available at: http://www.eere.energy.gov/office_eere/pdfs/wap_fs.pdf.

U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. Weatherization Assistance Program: Goals and Metrics. Available at: http://www.eere.energy.gov/weatherization/prog_goals.html.

U.S. Department of Energy, Weatherization Assistance Program Guidelines and Procedures. Available at: http://www.eere.energy.gov/weatherization/prog_guide.html

U.S. Department of Energy. 2002. Weatherization Assistance Program: Home page. Available at: http://www.eere.energy.gov/weatherization/

U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. Weatherization Assistance Program: How Do I Apply for Weatherization. Available at: http://www.eere.energy.gov/weatherization/apply.html

U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. Reducing the Energy Burden on Needy Families. Available at: http://www.eere.energy.gov/weatherization/reducings.html.

U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. Improving the Economies of Low-Income Communities. Available at: http://www.eere.energy.gov/weatherization/improving.html.

U.S. Department of Energy: Weatherization Assistance Program for Low-Income Persons - Title 10, Part 440, Final Rule - Revised as of December 8, 2000. Available at: http://www.waptac.org/sp.asp?id=1812

Wilhite, H. and Norgaard, J. S. 2004. Equating Efficiency with Reduction: A Self-Deception in Energy Policy. In *Energy and Environment, Vol. 15, No. 6.*

Appendix A

PRISM Analysis Results

Electricity Savings Estimates for New Castle County (AMS)

PRISM (Advanced Version 1.0)
Savings Summary

** NUMBER OF SAVINGS SITES **

	On Meter File	Used in Savings
PART	25	25
NPART	24	24
TOTAL	49	49

** SAVINGS KWH/Yr [Savings = Pre - Post] **

	Median (±SE)		Mean (±SE)	
PART	649	(±713)	1,190	(±536)
NPART	-1,363	(±628)	-2,054	(±831)
ADJUSTED	2,012	(±950)	3,245	(±989)

** PERCENT SAVINGS % [%Savings = (Pre - Post) / Pre * 100] **

	Median (±SE)		Mean (±SE)	
PART	5.6	(±4.8)	7.1	(±3.7)
NPART	-9.5	(±4.2)	-14.0	(±6.7)
ADJUSTED:	15.1	(±6.4)	21.1	(±7.7)

** MODEL TYPES **
Model Choice: Automated MS, with Outlier Detection

	Cases	HO	(Robust) (Subset)	CO	(Robust) (Subset)	HC
PART-PRE	25	9	(1)	16	(2)	0
PART-POST	25	10	(1)	15	(4)	0
NPART-PRE	24	20	(4)	4	(0)	0
NPART-POST	24	21	(2)	3	(1)	0
Total	98	60	(8)	38	(7)	0

** MEDIAN R² AND CV(NAC) VALUES **

	NPART	PART
R²-PRE (±SE)	0.925(±0.026)	0.905(±0.067)
R²-POST (±SE)	0.903(±0.032)	0.855(±0.067)
CV(NAC)%-PRE (±SE)	3.7 (±0.5)	5.8 (±0.8)
CV(NAC)%-POST (±SE)	4.2 (±0.5)	4.9 (±0.7)

Electricity Savings Estimates for Kent and Sussex Counties (AMS)

PRISM (Advanced Version 1.0)
Savings Summary

** NUMBER OF SAVINGS SITES **

	On Meter File	Used in Savings
PART	25	25
NPART	25	25
TOTAL	50	50

** SAVINGS KWH/Yr [Savings = Pre - Post] **

	Median (±SE)		Mean (±SE)	
PART	414	(±471)	635	(±309)
NPART	-1,060	(±449)	-1,216	(±643)
ADJUSTED	1,474	(±651)	1,851	(±713)

** PERCENT SAVINGS % [%Savings = (Pre - Post) / Pre * 100] **

	Median (±SE)		Mean (±SE)	
PART	2.7	(±2.8)	3.6	(±1.8)
NPART	-6.8	(±2.9)	-11.8	(±5.0)
ADJUSTED:	9.5	(±4.1)	15.5	(±5.3)

** MODEL TYPES **
Model Choice: Automated MS, with Outlier Detection

	Cases	HO	(Robust) (Subset)	CO	(Robust) (Subset)	HC
PART-PRE	25	15	(1)	10	(3)	0
PART-POST	25	13	(1)	12	(3)	0
NPART-PRE	25	22	(1)	3	(0)	0
NPART-POST	25	24	(1)	1	(0)	0
Total	100	74	(4)	26	(6)	0

** MEDIAN R^2 AND CV(NAC) VALUES **

	NPART		PART	
R^2-PRE (±SE)	0.942	(±0.021)	0.840	(±0.090)
R^2-POST (±SE)	0.955	(±0.025)	0.915	(±0.029)
CV(NAC)%-PRE (±SE)	3.9	(±0.5)	4.6	(±0.6)
CV(NAC)%-POST (±SE)	3.7	(±0.9)	4.1	(±0.6)

Electricity Savings Estimates for the State of Delaware (AMS)

PRISM (Advanced Version 1.0)
Savings Summary

** NUMBER OF SAVINGS SITES **

	On Meter File	Used in Savings
PART	50	50
NPART	49	49
TOTAL	99	99

** SAVINGS KWH/Yr [Savings = Pre - Post] **

	Median (±SE)		Mean (±SE)	
PART	551	(±389)	912	(±309)
NPART	-1,254	(±361)	-1,627	(±521)
ADJUSTED	1,804	(±531)	2,539	(±606)

** PERCENT SAVINGS % [%Savings = (Pre - Post) / Pre * 100] **

	Median (±SE)		Mean (±SE)	
PART	5.3	(±2.5)	5.3	(±2.0)
NPART	-7.5	(±2.2)	-12.9	(±4.1)
ADJUSTED:	12.9	(±3.3)	18.3	(±4.6)

** MODEL TYPES **

Model Choice: Automated MS, with Outlier Detection

	Cases	HO	(Robust) (Subset)	CO	(Robust) (Subset)	HC
PART-PRE	50	24	(2)	26	(5)	0
PART-POST	50	23	(2)	27	(7)	0
NPART-PRE	49	42	(5)	7	(0)	0
NPART-POST	49	45	(3)	4	(1)	0
Total	198	134	(12)	64	(13)	0

** MEDIAN R^2 AND CV(NAC) VALUES **

	NPART	PART
R^2-PRE (±SE)	0.935(±0.016)	0.866(±0.060)
R^2-POST (±SE)	0.925(±0.019)	0.893(±0.040)
CV(NAC)%-PRE (±SE)	3.8 (±0.3)	5.0 (±0.5)
CV(NAC)%-POST (±SE)	3.9 (±0.5)	4.8 (±0.5)

Electricity Savings Estimates for the State of Delaware (Heating only)

```
PRISM (Advanced Version 1.0)
Savings Summary


** NUMBER OF SAVINGS SITES **
             On Meter File    Used in Savings
            ===============  =================
PART            50                 50
NPART           49                 49
TOTAL           99                 99

** SAVINGS KWH/Yr  [Savings = Pre - Post] **
               Median (±SE)        Mean (±SE)
              ================    ==============
PART            703    (±355)    1,158    (±322)
NPART        -1,060    (±347)   -1,249    (±385)
ADJUSTED      1,763    (±496)    2,407    (±502)

** PERCENT SAVINGS %  [%Savings = (Pre - Post) / Pre * 100] **
               Median (±SE)        Mean (±SE)
              ================    ==============
PART             6.1    (±2.4)       7.7    (±1.9)
NPART           -7.4    (±2.2)      -9.2    (±2.7)
ADJUSTED:       13.5    (±3.3)      16.9    (±3.4)

** MODEL TYPES **
Model Choice: HO (Heating-Only), with Outlier Detection
                                            (Robust)
                         Cases      HO(Subset)
                        ====== ======= =======
PART-PRE                    50      50     (5)
PART-POST                   50      50    (10)

NPART-PRE                   49      49     (8)
NPART-POST                  49      49     (4)
                        ====== ======= =======
Total                      198     198    (27)

** MEDIAN R² AND CV(NAC) VALUES **
                                 NPART                PART
                            ================    ================
R²-PRE (±SE)                   0.928(±0.023)       0.633(±0.076)
R²-POST (±SE)                  0.925(±0.020)       0.593(±0.062)

CV(NAC)%-PRE (±SE)               3.9  (±0.4)         6.1  (±0.6)
CV(NAC)%-POST (±SE)              4.2  (±0.4)         5.7  (±0.6)
```

Natural Gas Savings Estimates for New Castle County

PRISM (Advanced Version 1.0)
Savings Summary

** NUMBER OF SAVINGS SITES **

	On Meter File	Used in Savings
PART	27	27
NPART	27	27
TOTAL	54	54

** SAVINGS CCF/Yr [Savings = Pre - Post] **

	Median	(±SE)	Mean	(±SE)
PART	109	(±26)	103	(±24)
NPART	-8	(±38)	-48	(±30)
ADJUSTED	117	(±46)	152	(±38)

** PERCENT SAVINGS % [%Savings = (Pre - Post) / Pre * 100] **

	Median	(±SE)	Mean	(±SE)
PART	10.5	(±2.8)	10.3	(±2.5)
NPART	-1.1	(±4.7)	-6.5	(±3.4)
ADJUSTED:	11.6	(±5.4)	16.8	(±4.2)

** MODEL TYPES **
Model Choice: Automated MS, with Outlier Detection

	Cases	HO	(Robust) (Subset)	CO	(Robust) (Subset)	HC
PART-PRE	27	27	(2)	0	(0)	0
PART-POST	27	27	(3)	0	(0)	0
NPART-PRE	27	27	(1)	0	(0)	0
NPART-POST	27	27	(3)	0	(0)	0
Total	108	108	(9)	0	(0)	0

** MEDIAN R^2 AND CV(NAC) VALUES **

	NPART	PART
R^2-PRE (±SE)	0.974(±0.014)	0.950(±0.018)
R^2-POST (±SE)	0.962(±0.014)	0.981(±0.020)
CV(NAC)%-PRE (±SE)	5.1 (±1.8)	6.5 (±1.2)
CV(NAC)%-POST (±SE)	6.0 (±1.5)	3.9 (±1.4)

Appendix B

Cost-effectiveness Calculations

Economic Savings Calculations for Delaware's WAP

Electricity

Annual electricity savings per household = 2,268 kWh
Average retail price of electricity in Delaware = 0.10 $/kWh
Annual economic savings per household = 2,268 * 0.10 = $ 226.80

Cumulative savings = $\sum$ (Economic savings for year $_t$ * 0.968) $_{t = 1 - 20}$

= $3,389

(assuming a 3.2% discount rate and a 20 year project lifetime)

Natural Gas

Annual natural gas savings per household = 148 CCF
Average retail price of natural gas in Delaware = 1.5 $/CCF
Annual economic savings per household = 148 * 1.5 = $ 222.00

Cumulative savings = $\sum$ (Economic savings for year $_t$ * 0.968) $_{t = 1 - 20}$

= $3,317

(assuming a 3.2% discount rate and a 20 year project lifetime)

Cost of Conserved Energy (CCE) Calculations for Delaware's WAP

CCE = initial cost of weatherization measures * CRF / energy saved per year

Where, CRF is the capital recovery factor which accounts for the time value of money invested initially. Its numerical value depends on the lifetime of weatherization measures, t, and the discount rate, r:

CRF (r,t) = r / { 1 – $(1 + r)^{-t}$}

For t = 20 and r = 3.2, CRF = 0.068

Electricity

CCE from program perspective = 1,984 * 0.068 / 2,268 = 0.06 $/kWh

CCE from installation perspective = 1,706 * 0.068 / 2,268 = 0.05 $/kWh

Natural Gas

CCE from program perspective = 1,961 * 0.068 / 148 = 0.90 $/CCF

CCE from installation perspective = 1,683 * 0.068 / 148 = 0.77 $/CCF

Note: Cost figures are taken from Table 9, page 22 (OCS, 2005)

Appendix C

CO_2 Emissions Savings Calculations

CO_2 Emissions Savings Calculations for Delaware's WAP

Electricity

End user energy saved per household = 2,268 kWh
Primary energy equivalent saved per household = 2,268 * 2.9 = 6,577 kWh

PJM proportion of electricity generation from different fuels:
Coal: 52.5%; Natural Gas: 6.9%; Oil: 1.1%

Proportion of 6,577 kWh generated from coal = 6,577 * 52.5/100 = 3,453 kWh
Proportion of 6,577 kWh generated from natural gas = 6,577 * 6.9/100 = 454 kWh
Proportion of 6,577 kWh generated from oil = 6,577 * 1.1/100 = 72 kWh

3,453 kWh generated from coal = 3,453 * 0.000142 = 0.49 short tons of coal
454 kWh generated from n. gas = 454 * 0.0034 = 1.54 thousand cubic feet of n. gas
72 kWh generated from oil = 72 * 0.00059 = 0.04 barrels of oil

0.49 short tons of coal produces = 0.49 * 3,822 = 1,874 pounds of CO_2
1.54 thousand cubic feet of natural gas produces = 1.54 * 120 = 185 pounds of CO_2
0.04 barrels of oil produces = 0.04 * 940 = 40 pounds of CO_2

Total CO_2 emissions saved per household per year = 1,874 + 185 + 40 = 2,099 pounds

Natural Gas

End user energy saved per household = 148 CCF
Primary energy equivalent saved per household = 148 * 1.1 = 162.8 CCF

162.8 CCF = 16.28 thousand cubic feet

16.28 thousand cubic feet of natural gas produces = 16.28 * 120 = 1,954 pounds of CO_2

Total CO_2 emissions saved per household per year = 1,954 pounds

Note: All conversion factors obtained from:
Energy Information Administration. 2005. Fuel and Energy Source Codes and Emission Coefficients. U.S. Department of Energy. Available at: http://www.eia.doe.gov/oiaf/1605/coefficients.html