EVALUATION

EVALUATION OF THE 2003/2005 OREGON WEATHERIZATION ASSISTANCE PROGRAM

FINAL REVIEW DRAFT

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I. INTRODUCTION TO THE EVALUATION

The Oregon Low-Income Weatherization Assistance Program (Oregon WAP) provides energy conservation services, necessary health & safety repairs, heating system repairs and replacements, baseload energy efficiency improvements, and energy education to Oregon households that are at or below sixty percent (60%) of Oregon's median income. The program is managed by the Oregon Office o Housing and Community Services (OHCS) and is implemented through its subgrantees, which include Community Based Organizations, Community Action Agencies, Senior Centers, Housing Authorities, and Tribes. This is the first evaluation of the program.

This evaluation of Oregon WAP covers two program years, 2005 and 2006. During these years, WAP expanded rapidly and substantially. Also, OHCS initiated efforts during these years to develop systematic program reporting and control tools, including the effort which has developed the current systematic training system. These program reporting, control, and training components came into full operation later than the two years covered in the evaluation, and are continuing to develop.

WAP combines and coordinates funding from several sources including federal funds (Department of Energy – Weatherization Assistance Program, Department of Health & Human Services – Low Income Home Energy Assistance Program (LIHEAP) and separate LIHEAP leveraging money, Petroleum Violation Escrow funds, and the Bonneville Power Administration), state investor-owned electric utility public purpose funds (ECHO) and regulated natural gas utility funds (OLIEE), and other sources.

The topics covered in this report are identical to those planned for a future national evaluation (as they apply to Northern tier states). This evaluation provides information that can be used for the development of future evaluations, which will focus on improvements.

The major topics are:

- Network & Population Characteristics
- Program Characteristics
- Energy & Cost Savings (Whole House Savings Analysis)
- Non-Energy Benefits
- Cost Effectiveness
- Specific Measures Performance (Measure Savings Analysis)
- Weatherization Network Issues
- Explanatory Factors
- Program Accomplishments

II. NETWORK & POPULATION CHARACTERISTICS

This section of the report describes the population of households eligible for the Oregon Weatherization Assistance Program (OR WAP), program operation, the network of subgrantees that implements the program, and program leveraging.

THE POPULATION ELIGIBLE FOR THE PROGRAM

Oregon households eligible for the weatherization program are households at or below the current criteria for the statewide Low Income Energy Assistance Program (Oregon LIEAP).[1] Each year, the US Office of Management and Budget adjusts the income guidelines to update eligibility.[2] The Oregon income criterion is sixty percent (60%) of statewide median income.[3] Table 1 shows the annual and monthly income by household size that meets the program eligibility criterion for 2008.[4] Other requirements for participation include:[5]

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1 Persons who have applied for and have been found eligible for the Low Income Home Energy Assistance Program of Act of 1981 (LIHEAP or LIEAP) are also eligible for the weatherization program.

2 The annual OMB adjustment follows a proscribed procedure for yearly adjustment. However, the procedure is not sound and over several years results in setting a snowballing undercount for both determination of poverty and determination of program eligibility nationally. Program eligibility for Oregon is better determined than for many other states because Oregon has selected the 60% of statewide median income option rather than a percentage of poverty option.

3 The median value of a statistical distribution is the value that divides the cases in the distribution into two equal halves. In this application, one-half of Oregon households are above the median of the income distribution and one-half are below the median of the income distribution.

4 Income eligibility for the 2008 program year, rather than the 2005 and 2006 program years is shown to use the most current information

5 The LIHEAP statute (Section 2605(b)(2)(b) of Public Law 97- 35) established one-hundred and fifty percent (150%) of the poverty guidelines as a maximum income level allowed in determining LIHEAP eligibility, except where sixty percent (60%) of a state's median income is higher. In Oregon, 60% of state median income is higher than 150% of poverty. A few other special provisions may apply, including acceptance of households where income is from social security and a provision for homes set to be renovated under a public program.

- Written permission of the building owner or the owner's agent [10 CFR section 440.22(b)(1)].

- If the dwelling to be weatherized is rented, [that] a formal agreement between landlord and tenant has been reached addressing issues of eviction from and sale of property receiving weatherization materials [10 CFR section 40.22(c)].

Priority is given to senior and disabled persons who are qualified applicants and to qualified households with children under the age of six.[6]

Eligible Households for Program Year 2008
(Sixty Percent of Oregon Median Income)

Col. 1	Col. 2	Col. 3
Household Size	**Annual Income**	**Monthly Income**
1	$19,327	$1,611
2	$25,274	$2,106
3	$31,220	$2,602
4	$37,167	$3,097
5	$43,114	$3,593
6	$49,060	$4,088
7	$50,175	$4,181
8	$51,290	$4,274
9	$52,405	$4,367
10	$53,520	$4,460
11	$54,635	$4,553
12	$55,751	$4,646
Each additional member over age six	$1,412	$118

Table 1: Income Eligibility for Program Year 2008.

[6] For this program, "senior" is defined as sixty years of age or over.

The percentage of Oregon households of different household sizes is shown in Table 2, based on the 2000 Census.[7] This provides a rough approximation, assuming that incomes are distributed evenly between zero income and the median income for each household size, for the percentages by family size of households to sixty percent of median income.

Estimate of Qualifying Households				
Col. 1	**Col. 2**	**Col. 3**	**Col. 4**	**Col. 5**
Household Size	**Total Households**	**Cases to Median**	**Sixty Percent of Cases to Median**	**Percentage by Household Size**
1	347,718	173,859	104,315	26.07%
2	479,777	239,889	143,933	35.97%
3	205,850	102,925	61,755	15.43%
4	173,939	86,970	52,182	13.04%
5	78,101	39,051	23,430	5.86%
6	29,437	14,719	8,831	2.21%
7 & up	18,901	9,451	5,670	1.42%
Total	1,333,723	666,862	400,117	100.00%

Table 2: Percentage of Qualifying Homes by Household Size.

As shown in Table 2, the estimate of households qualifying for Oregon WAP is about 400,000. Similarly, and using the same assumption for even distribution of income, given the total number of Oregon

[7] Though Census 2000 is now some years in the past and absolute numbers would now be different than in 1999-2000, the evaluation team expects the percentages to be more stable. Table 2 is based on calculations using data from Census 2000, SF-3, using American Factfinder on the Bureau of the Census website. Due to the assumption of an even distribution of incomes, the result is only a "ballpark" approximation.

households in the 2007 American Community Survey (1,449,662 +/- 7,388), the approximate number of qualifying Oregon homes is estimated at 434,899, which can be rounded to 435,000.[8]

According to the State Plan for 2008, the target number of homes to be weatherized using federal Department of Energy funding from April 1, 2008 through March 31, 2009 is eight-hundred and sixty (860). The target necessarily varies from year to year since federal funding is variable. Production for 2005 and 2006 is shown in Table 3.

Number of Completions Per Year for Program Years 2005 & 2006		
Col. 1	**Col. 2**	**Col. 3**
Funding Source	**2005 Jobs Completed**	**2006 Jobs Completed**
United States Department of Health & Human Services (LIHEAP)	1,734	1,695
United States Department of Energy (DOE)	1,391	1,391
Petroleum Violation Escrow Funds (PVE)	0	60
Bonneville Power Administration (BPA)	492	632
Investor-Owned Electric Utility Public Purpose Funds (ECHO)	2,228	1,800
Total	5,845	5,478
Note: Program years are defined as April 1st through March 31st.		

Table 3: Approximate Number of Jobs Completed per Year.

8 The number of Oregon households in 2007 is taken from the American Community Survey on the Bureau of the Census website using American Factfinder.

With this production rate, and the possibility to revisit sites every five years if needed,[9] at least 405,000 potential jobs are not reached in any given five year period.[10] This means that Oregon WAP could productively employ substantial additional funding to reach more homes.[11]

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[9] Due to a quirk in the authorization, sites using US Department of Health and Human Services and US Department of Energy funds may not be revisited. Under Oregon guidelines, sites using utility funding may be revisited, if necessary, after five years. For the following footnote (note 10), we assume the federal legislative quirk is eliminated since it has no relevance to material reality or the physics of the current low-income housing stock. The federal rule used to be expressed as "once in ten years," and it flows down from federal authorizing legislation. Actually, the legislation specifies a date in the early 1990s. Any home weatherized after that date either by the Weatherization Assistance Program or through local funding is to be excluded from service. This is, of course, unrealistic in terms of meeting actual needs of families, especially considering that housing conditions in an existing home can change in major ways over a few years. From a citizen perspective, the rule is arbitrary and results in unwise and unequal treatment, particularly with the pattern of frequent household moves in the West. If a home needs weatherization or weatherization-related repairs, as is typical of the low-income housing stock, the real problem is a matter of the physics of the home. The wait time, if any, should not be more than five years.

[10] Estimated as follows: (1) Production is about 6,000 homes (of all types) per year; at the end of any five year period, there are 30,000 jobs completed. At the beginning of year six, the year one homes could come back into the pool for service, if necessary (however see note 9). At any point in time, of the approximately 435,000 homes in the service population, there will be about 405,000 to go. This is an overestimate, since most homes treated in the previous five years will not require additional weatherization. However, given that the program services health and safety problems related to weatherization as well as heating system repair and replacement, it is quite possible for a home that receives weatherization in year one to need a furnace repair or new furnace in year six. A more conservative estimate of need would be approximately 350,000 unreached homes in any year. The point here is simply to illustrate the "ballpark" sense that production over five years is in the neighborhood of 30,000 homes, while need is always over 350,000 and below 405,000. These numbers for need, however, creep upwards year by year as workers' real incomes continue to decline and additional homes enter the pool, and take into account only the official definition of need rather than the much larger actual need for the program when income insufficient households above sixty percent of state median income are included.

[11] The subgrantee agencies typically have long waiting lists which can be on the order of eight months to five years. [See: Hill, Gail Kinsey, "Wait Long for Help in Home Insulation," *The Oregonian*, October 14, 2005.] In a few cases it may appear there is no waiting list, but this is an artifact of how cases are sometimes counted (the artifact stems from some agencies beginning counts when homes are scheduled for treatment, rather than when they first make contact with the agency to apply); the actual waiting lists are on the order of eight months to five years. Higher funding levels would allow the agencies to reduce or eliminate the wait. Increased funding would also diminish the financial "balancing act" these agencies must go through as they try to fully use funds that different types of restrictive requirements, before using other available funds. The agencies do attempt to fully leverage the funds they receive to make the best use of all resources. Agencies also face difficulties when the funding level is unpredictable and uncertain. Agencies with weatherization

PROGRAM OPERATION

The Community Action Program is designed to increase energy efficiency in income-eligible[12] residential dwellings. It provides for the installation of certain energy efficiency measures in qualifying residential dwellings following completion of a home energy evaluation performed by a community action agency (CAA). The agencies are sub-grantees to the State of Oregon Department of Housing and Community Services (OHCS) and are eligible to administer funding under the Federal Low Income Home Energy Assistance Program (LIHEAP). The CAAs coordinate federal, state, utility, and community program funds to optimize service to households and the energy efficiency of low income homes, consistent with state and federal health and safety requirements and other protocols.

The agencies have sole responsibility to screen and approve applicants for eligibility. The agencies are required to follow established protocols for the qualification of and disbursement to eligible participants in accordance with the guidelines promulgated by OHCS and the Low-Income Energy Assistance Act of 1981.[13]

Each Community Action Agency (CAA) runs its program as it sees fit, consistent with federal and state regulations and guidelines. Some agencies contract for crews while others have weatherization staff. The agencies also partner with other organizations to provide better service. CAAs accept applications from potential participants, screen the applications, prioritize the applications, and add them to their waiting list, which in most cases spans multiple years. Selected homes are typically visited repeatedly to assess what work needs to be completed, to install the recommended weatherization and related measures,

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staff face difficult staffing decisions when funding levels fluctuate wildly. As non-profits without a substantial capital reserve, they do not have a funding pool outside project allocations that would allow them to staff up quickly for expansions or to rotate staff to other work for a year or two when there are funding contractions. Agencies that contract out the work sometimes face having to establish contracts without any certainty about the number of homes the contract covers. The contracting firms must be qualified and have the appropriate staff available to complete the work. The agencies not only face unpredictable funding but also uncertain funding. They mention that they often have a limited lead time on the status of their funding. They may not know that a funding source will exist more than a few months in advance.

[12] Income eligibility is set at sixty percent (60%) of state median income by number of persons in the household (Table 1). The income figures are updated each year.

[13] As amended, and as outlined in the OHCA Omnibus Contract.

address any health and safety issues, and for inspection. Health and safety violation remediation is an important component of the program. CAAs deliver the program, and handle paperwork, billing, and reporting.

THE NETWORK OF SUBGRANTEES: OECA

Oregon Energy Coordinators Association (OECA) is a non-profit professional organization that helps develop better energy solutions for Oregon's low income households. The network is made up of nineteen (19) subgrantees, each with its own geographic service area. Membership includes individuals from community action agencies, state agencies, tribal organizations, and both public and private utilities as well as other non-profit organizations including area agencies on aging, senior centers, and a development corporation. These groups collaborate to provide weatherization services, energy assistance payments, and energy conservation education for income eligible households in Oregon. OECA provides energy auditor and installer training to its member organizations so that low income families can receive high quality services that help them reduce their heating and cooling costs in order to maintain a safe, affordable and comfortable home.[14] Also, OECA serves as a standing committee on energy issues for the Community Action Partnership of Oregon (CAPO), and has helped implement Oregon's energy deregulation public purposes legislation to benefit low-income households.

OECA manages itself with a ten person non-profit Board of Directors. Board members are elected from association members. OECA works with the state administrator and responds to the state administrator through the OECA Executive Director on an as needed basis. The State Administrator is invited to attend all OECA meetings. In addition, OECA staff contact the state administrator with questions and request guidance.[15]

[14] OECA is the training contractor for Oregon Housing and Community Services.

[15] While the State Administrator's response is typically not immediate, the evaluation team was told that OECA leadership feels it does eventually receive the guidance it needs. Also, the evaluation team was told that OECA staff is working on improving the relationship with the state administrator.

WEATHERIZATION PROGRAM LEVERAGING

Oregon Housing and Community Services (OHCS) administers Low Income Home Energy Assistance Program (LIHEAP) funds available for weatherization under a state option, funds provided by the Bonneville Power Administration (BPA) low-income weatherization program, the legislated Energy Conservation Helping Oregonians (ECHO) program which provides funding from the state's investor-owned utilities, Petroleum Violation Escrow (PVE) funds, and funds which are designated for low-income weatherization from time to time due to legal settlements. The subgrantees also have access to State Home Oil Weatherization Program (SHOW) funds and some direct utility funding and rebates from natural gas companies. SHOW funds and utility rebates are not administered through OHCS.

The Community Action Agencies (CAAs) leverage their funds as an inherent part of program management.[16] In leveraging, the CAAs use funds from multiple sources to complete each weatherization job. Leveraging is necessary because different types of funding have different rules; some funds can only be used for specific activities or with certain limitations. For example, utility funding from natural gas companies can only be used on homes with natural gas service while funding from electric utilities can be used on homes with electric service. Some funds must be used by a certain date; or the funds can only be used for certain measures. Sometimes the funding source requires that each individual measure in each individual home must be independently cost effective in its own right. The agencies have to "work smart" to take all these considerations onto account when managing the program for their service territories in order to (1) maximize the number of low income homes completed and (2) maximize the provision of required services for each home.

If leveraging were not used, some of the funding sources would be completely used up and other sources would be barely touched, resulting in far fewer completed homes. One of the key benefits of leveraging

[16] "Leveraging" has two meanings in the weatherization context. First, when the state is successful in attracting non-federal funding for the Weatherization Assistance Program (for example, ECHO and OLIEE funds), it counts in a competition with the other states for a small supplemental federal funding award. This additional federal award is referred to as "leveraging funds." Here, however, the focus is on melding of funding sources on jobs so as to comply with their individual requirements and restrictions while maximizing needed service for the homes.

is the ability to repair homes when needed.[17] These repairs, such as sealing holes, fixing furnaces and dealing with old wiring problems (especially in rural areas of the state), are done in conjunction with the energy efficiency measures installed. Most of the funding sources allow a small amount to be used for repairs, but often no single source would provide enough to complete the necessary repairs. With leveraging, more repairs can be completed because the repair portions of multiple funds are consolidated. Even with leveraging, however, if a home needs a furnace replacement, the furnace replacement may use all the funding available for that home.[18]

[17] Repairs may be required for weatherization to be effective. For example, failure to repair holes in a wall (to the outside air) would interfere with the effectiveness of installing door sweeps and replacing a window. Sometimes, repairs are required for health and safety reasons, such as when a gas appliance fails a combustion test or when old wiring is inadequate. Often, repairs are necessary for both reasons in order to make the home livable.

[18] Not all homes can be treated; sometimes the cost is simply too high for the program. These homes are classified as “walk away” homes.

III. PROGRAM CHARACTERISTICS

This section on program characteristics reviews program implementation and the process of weatherization, the houses and clients served, and priorities within individual homes.

PROGRAM IMPLEMENTATION AND WEATHERIZATION PROCESS

Oregon's WAP provides weatherization and energy conservation services *at no cost* to low-income households. WAP reduces household energy use and energy costs by improving the energy efficiency of a participant's home.[19] For each participant, the weatherization process is initiated through application to the subgrantee agencies where eligible households are placed on a waiting list. The waiting period varies with each local agency. Households with one or more members who are senior (60 years of age or older), disabled, or with children who are under six years of age are given priority. The agencies cover every county in the state.[20] Households eligible for participation must have household incomes that are 60% of the state median income or below (for program year 2008 qualifying income levels see Table 3).[21]

Applicants can call in or be referred, typically through economic assistance. The program is promoted via word of mouth, program flyers, Headstart and community agencies. Applicant households that meet program requirements are approved. If the applicant household is a rental household, the homeowner or landlord must also give their approval prior to provision of

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[19] US Department of Energy, Energy Efficiency and Renewable Energy, Energy Assistance Program, "Oregon Weatherization and Low-Income Energy Programs." See Oregon page at the USDOE website (http://www.eere.energy.gov/weatherization/cfm/index.cfm/state_abbr=or).

[20] The subgrantee agencies in Oregon are Community Action Programs (CAPs), Senior Centers, Housing Authorities, and Tribes.

[21] Page 11 in this report. For additional information on the program, see the Oregon Housing and Community Services website at http://www.ohcs.oregon.gov/OHCS/SOS_LowIncomeWeatherization.shtml. Agencies by area are shown at http://cado-oregon.org/members.htm, the Community Action Directors of Oregon (CADO) website.

services. If the landlord does not approve, the agency may still provide certain services (such as energy education, low flow shower heads, light bulbs, aerators, and wall outlet gaskets). However, for full weatherization landlord approval is required.

The normal pattern of applications over a year includes a large influx of applicants in the fall as the weather gets cooler. Once the home has been approved the applicant goes onto a waiting list which can be as long as five (5) years, unless the job is classified as a health and safety situation. The home will be audited, air sealed, insulated and inspected. Measures installed in the program vary according to the audit of each residence and cost-benefit criteria, but can include pre and post measure testing, ceiling insulation, wall insulation, floor insulation, duct insulation, duct sealing and repair, infiltration measures (air sealing), furnace repair or replacement, water heater repair or replacement, new energy efficient windows, new energy efficient doors, minor repairs (related to energy efficient measures), and correction of health and safety issues.[22]

The Oregon Community Action Agencies use REM/*Rate*™ to model the homes as required by the program.[23] The cost benefit cutoff for the programs is a benefit cost ratio of one. The agencies implement state weatherization guidelines that emphasize a "whole house" approach so that weatherization improvements that are very cost effective can carry other weatherization improvements that are less cost effective or that are not quite cost effective.[24]

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[22] Typically, apartments receive a set of easily installed minor measures. Major measures are installed in single family households according to program criteria. Sometimes major measures are not installed in single family households due to the need for more extensive repairs than the program can support.

[23] REM/*Rate*™ is a proprietary product of Architectural Energy Corporation. REM/*Rate*™ is approved by USDOE for this application.   The software calculates heating, cooling, hot water, lighting, and appliance energy loads, consumption and costs for new and existing single and multi-family homes. See the webpage: http://www.archenergy.com/products/rem/rem_rate/.

[24] With the "whole house" approach the overall package of weatherization improvements installed in the home is cost effective even though some of the individual improvements may not be. Federal, state, and state electric utility funds are applied using this rule. Gas utility funding has some additional restrictions.

The agencies complete the work in a variety of ways. Some agencies run their own crews by hiring on staff to complete the weatherization work. Other agencies contract out the work to weatherization and insulation contractors. Each method has its benefits and drawbacks. Running crews requires stable funding sources. Agencies rely on a combination of funds some of which are inherently unstable (e.g. federal funding), but when all the funding sources are combined there may be enough stability to enable the agency to run crews. Using weatherization contractors ameliorates the funding instability issue, but has its own plusses and minuses. This method also faces manpower issues, because there are limited qualified contractors.[25]

HOUSES AND CLIENTS SERVED

As noted above, Weatherization Assistance follows prioritization of services. Typically households with senior citizens, young children, or the disabled receive a higher priority. As a result there is a greater concentration of households with senior citizens, young children and disabled residents among the households served. Additional prioritizations include those who have been on the waiting list for more than a year or those households whose income is farm worker based. Other priorities are households with elderly, disabled, and/or young children.

Unaffordable heating costs have significant consequences for low-income households and funding is very limited. Given the relatively small amount of funding (from all sources combined) in relation to need, two special characteristics of the Weatherization Assistance Program are (1) its focus on vulnerable members of society and (2) its focus on health and safety issues. These provide a reasonable approach for rationing services.

The low income weatherization program provides services to all housing types, however there is a high percentage of mobile and manufactured homes, and also a high percentage of older housing. In some

[25] Weatherization work is normally a less profitable market than the new construction market, and skills are transferable. This creates a situation in which there is usually a very limited number of local contractors willing and able to take on assignments of weatherization work.

years many multifamily homes are weatherized through the program. The number of homes completed each year is variable because funding is variable.

PRIORITIES: SPENDING PATTERNS WITHIN PARTICIPATING HOMES

The agencies view the home as a complete entity and the REM/*Rate*™ model is based on the whole house. The agencies pool funds from a variety of sources to complete the work on a given home. They balance the cash flow over the course of the year using time sensitive funds first, and use restricted funds where they can. Agencies can use some of the funds for repairs on a home and this varies depending on the source of the funding. They may also use more cost-effective measures to carry less cost-effective measures, such that the energy improvements installed in a home are cost-effective as a package even though some individual measures may not be.

The agencies follow two goals, which are in tension with each other. They focus the use of funds on completing jobs, *as many as possible* and *to the fullest extent possible*. One agency said that for every one-hundred dollars received, five dollars is used for monitoring, five dollars for state administration, ten dollars for repairs, and eighty dollars is used for measures in the house. These numbers will, of course, vary by agency and from year to year.

IV. WHOLE HOUSE SAVINGS ANALYSIS

What size of energy savings was produced due to the program for weatherization work conducted in 2003-2005? Energy savings varies by heating fuel and housing type. The purpose of this section of the evaluation is to estimate the average annual energy savings per home by fuel and housing type for program homes. We begin with an overview of the methodology used to estimate savings.

METHODOLOGICAL OVERVIEW

Our discussion of methodology begins with a definition of the periods used in this study. The treatment period (2003-2005) was provided in the terms of the evaluation. Here, we are interested in homes treated through the WAP program between July 2003 and June 2005. Likewise, the need for twelve months of pre and post treatment utility billing data defines the pre period and the post period.

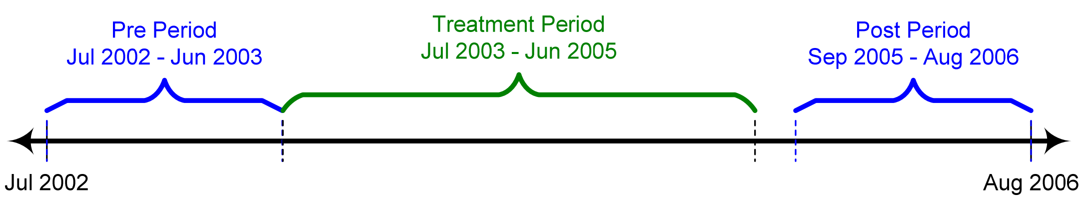

Figure 1: Study Period Definitions.

As shown in the chart, the start of the twelve month post period was lagged two months. This allows for the completion of jobs in progress before the first meter read. The lag also helps to minimize the potential of treatment period usage showing up in cycle billing data. While the possible biasing influence of these factors is likely minimal, specifying the periods as above controls for this potential source o.

A PRISM® analysis[26] was originally planned for this evaluation to be consistent with the approach specified in the now indefinitely postponed national evaluation of the Weatherization Assistance

[26] For a description of the PRISM® software, see http://www.princeton.edu/~marean/,

Program. Instead, a pooled time-series cross-sectional model was adopted because of the ability to specify functional forms of the model that allow the simultaneous specification of multiple effects beyond weather. These effects, described more fully below, would require groupings of several sets of homes to estimate their impact in a PRISM approach. For some effects, the small number of homes in the resulting groups could make it difficult to obtain statistically reliable estimates of program impacts. The pooled time-series cross-sectional model approach also has the advantage of providing an estimate of gross program impacts directly from the specified model.

The general form of the model used to assess whole house program impacts is shown below:

Equation 1: General Form – Whole House Impacts Model.

$$EPD_{j,t} = f(TrtDum_{j,t}, HDD_{j,t}, TrtHDD_{j,t}, CDD_{j,t}, TrtCDD_{j,t}, Other_{j,t})$$

where each of the terms in the model are specified as follows:

Term	Description
$EPD_{j,t}$	Energy use per day for home j in period t. Units will be kWh or therms depending on the fuel being modeled.
$TrtDum_{j,t}$	Dummy variable taking the value of zero in all pre-treatment periods for home j and one in all post treatment periods. This variable provides a measure of the non-weather (base load) related impacts associated with treatment.
$HDD_{j,t}$	Heating degree days (base 65) for home j during billing period t. This term measures the average daily energy usage associated with changes in heating degree days.
$TrtHDD_{j,t}$	Product of treatment indicator (TrtDum) and HDD, results in zero for all pre treatment periods and HDD in all post treatment periods. This term provides a measure of the HDD correlated impacts associated with treatment.
$CDD_{j,t}$	Cooling degree days (base 70) for home j during billing period t. This term measures the average daily energy usage associated with changes in cooling degree days.
$TrtCDD_{j,t}$	Product of treatment indicator (TrtDum) and CDD, results in zero for all pre treatment periods and HDD in all post treatment periods. This term provides a measure of the CDD correlated impacts associated with treatment.
$Other_{j,t}$	Other variables that may be specified to account for changes in energy usage.

The main effects of the program can be directly tested and quantified through the treatment period dummy (TrtDum), the product of the treatment period dummy times the heating degree days (TrtHDD), and the product of the treatment period dummy times the cooling degree days (TrtCDD) variables. By specifying other variables as interactions with these main effects variables it is possible to test for the impacts of a variety of conditions on estimated savings, including occupant tenancy (owner/renter) and the inclusion of health and safety measures in the treatment package.

While this type of specification allows for the inclusion of control homes, we did not have access to a valid control group of individually selected homes for our analysis. Instead, we adjusted gross savings using the percentage change in weather normalized usage for the residential class as a whole between the pre and post periods.

SAMPLE DESIGN

After an extensive review of program data, described in sections two and three of this report, it was decided that in order to provide adequate representation by the two primary heating fuels and three housing types a stratified random sample was needed. The study sampling plan showing strata and sample sizes is shown in Table 4.

	Fuel Type		
Housing Type	**Electric**	**Natural Gas**	**Totals**
Single Family	200	200	400
Multi Family	200	0	200
Manufactured	200	200	400
Totals	600	400	1000

Table 4: Sample Size by Stratum.

The goal was to achieve an ultimate sample size of 100 homes in each stratum for the whole house savings analysis. Sample attrition from the sampling plan (Table 4) was expected from several sources including the ability of the agencies to locate the records of the sample homes, the ability to identify utility account numbers, the ability of the utilities to match account numbers to billing records and the completeness of the billing records. The sample size was doubled to 200 homes per strata to allow for these losses.

DATA COLLECTION

Once the sample of homes was selected for analysis, a data collection form was sent to each agency listing the job number and selected job attributes of all sampled homes by agency. The form provided for the collection of identifying information including the address and utility account numbers. Sample collection forms were returned by fourteen of the eighteen agencies representing eighty percent (80%) percent of the sampled homes.

Next, we grouped the sample homes by serving gas and electric utility and requested monthly billing records over all study periods. A total of 25 electric utilities and two gas utilities were contacted with most cooperating with our request. Since some of the homes were returned by the agencies with an address but no utility account number, we address standardized all sample homes before sending them to the utilities in the hope that addresses could be matched in the event the account number was either missing or bad. The number of sample homes we ultimately received with usable billing data is discussed in each of the results sections below.

ESTIMATED IMPACT - NATURAL GAS SPACE HEAT HOMES

In order to be included in the impact model described earlier, a home was required to have at least 10 meter reads in both the pre and post periods. The number of homes meeting this criterion is listed in Table 5.

Housing Type	Number
Manufactured	91
Single Family	132
Total	223

* Excludes baseload only homes

Table 5: Gas Homes with Sufficient Billing Data.

The final sample count is near the target of 100 homes in each segment, although manufactured homes are less represented than single family homes. Still, the number of homes is sufficient for reliable analysis. Natural gas usage in the sample homes was modeled using the specification shown below.

Equation 2: Natural Gas Model.

$$EPD_{j,t} = b_1 + (b_2 \times TrtDum_{j,t}) + (b_3 \times HDD_{j,t}) + (b_4 \times TrtHDD_{j,t}) + (b_p \times Other_{j,t}) + \varepsilon_{j,t}$$

In this case, energy use per day (EPD) is defined as therms per day and b_p represents the parameters on other variables tested for influence. After a few comments regarding results common across housing types, the model results and estimated program savings per home are discussed by type of housing. Model R-Square, the percentage of total variation in energy per day (EPD) explained by the model, was found to be reasonable for a model using pooled time-series and cross-section data. Cross-sectional (between home) variation is typically large and more challenging to explain than time-series (month-to-month) variation. Models with only time series data typically result in much higher R-Square values.

The baseload impact term in the model above (the treatment period dummy, TrtDum) was found to be not statistically significant and, consequently, has been omitted from both natural gas models. There was also slight evidence of multicollinearity with the space heating impact term (TrtHDD).

MANUFACTURED HOMES

Regression model results for natural gas heated manufactured homes are shown in Table 6.

Regression Model Results - Gas Manufactured Homes				
Observations	2143			
R-Square	45%			
Variable	Coefficient Estimate	Std Error	t-Value	Pr > |t|
Intercept	0.58593	0.02583	22.7	< .0001
HDD (base 60)	0.00368	0.00009785	37.6	< .0001
Treatment * HDD	-0.00088472	0.00010323	-8.6	< .0001

Table 6: Results - Gas Heated Manufactured Homes.

Overall the model is sound with forty-five percent (45%) of the total variation explained and strongly significant explanatory variables. Using the coefficients from the estimated equation, the annual usage estimates are calculated and shown below (Table 7).

Weather Normalized Annual Therms per Home - Manufactured Homes				
			Gross Savings	
	Pre	Post	Therms	Percent
Base Load	214	214	0	0%
Heating Load	354	269	85	24%
Total Load	568	483	85	15%
Net Savings Calculations:				
Weather normailzed percent change in residential class				-3.0%
Implied change in participant usage				-16.8
Net savings				68
Percent net savings				12.0%

Table 7: Weather normalized Therms per Gas Heat Manufactured Home.

Annual gross savings per house is estimated to be eighty-five therms, or fifteen percent (15%). All of the savings are estimated to be savings in space heat, a twenty-four percent (24%) reduction in space heat usage. As explained earlier, average monthly usage from the entire residential class was used to measure the non-program induced change in weather normalized usage between the pre and post periods. After making this adjustment to gross savings, net savings are estimated at 68 therms per home, or twelve percent (12%).

Regression model results for natural gas heated single family homes are shown in Table 8.

Regression Model Results - Gas Single Family Homes				
Observations	3385			
R-Square	39%			
Variable	Coefficient Estimate	Std Error	t-Value	Pr > |t|
Intercept	0.52766	0.02843	18.6	< .0001
HDD (base 60)	0.00482	0.00011529	41.8	< .0001
Treatment * HDD	-0.00157	0.00011814	-13.3	< .0001

Table 8: Regression Results for Gas Heated Single Family Homes.

Overall the model is sound with 39 percent of the total variation explained and strongly significant explanatory variables. Estimates are calculated using the coefficients shown below (Table 9).

Weather Normalized Annual Therms per Home - Single Family				
			Gross Savings	
	Pre	**Post**	**Therms**	**Percent**
Base Load	193	193	0	0%
Heating Load	463	312	151	33%
Total Load	656	505	151	23%
Net Savings Calculations:				
Weather normailzed percent change in residential class				-3.0%
Implied change in participant usage				-19.5
Net savings				131
Percent net savings				20.0%

Table 9: Weather Normalized Therms per Gas Heated Single Family Home.

Annual gross savings per house is estimated to be 151 therms (23%). All of the savings are estimated to be space heat, a thirty-three percent (33%) reduction in space heat usage. As explained earlier, average monthly usage from the entire residential class was used to measure the non-program induced change in weather normalized usage between the pre and post periods. After making this adjustment to gross savings, net savings are estimated at 131 therms per home (20%).

ESTIMATED IMPACT - ELECTRIC SPACE HEAT HOMES USAGE

In order to be included in the impact model described earlier, a home was required to have at least ten meter reads in both the pre and post periods. The number of homes meeting this criterion is listed in Table 10.

Housing Type	Number
Manufactured	76
Multifamily	15
Single Family	75
Total	166
* Excludes baseload only homes	

Table 10: Electric Space heat Homes with Sufficient Billing Data.

The final sample count fell short of the target of 100 homes in each segment, although still sufficient for analysis of manufactured homes and single family homes. Unfortunately, there were far too few multifamily homes for reliable analysis. This may be due to the greater incidence of occupancy turnover in multifamily housing. With only a few exceptions, electric utilities only provided billing histories for homes with constant occupancy over the study period.

Electricity usage in electric space heat homes was modeled using the specification shown below.

Equation 3: Electricity Use in Electric Space Heat Homes.

$$EPD_{j,t} = b_1 + (b_2 \times TrtDum_{j,t}) + (b_3 \times HDD_{j,t}) + (b_4 \times TrtHDD_{j,t}) + (b_5 \times CDD_{j,t}) + (b_6 \times TrtCDD_{j,t}) + (b_p \times Other_{j,t}) + \varepsilon_{j,t}$$

In this case, energy per day (EPD) is defined as kWh per day and b_p represents the parameters on other variables tested for influence. After a few comments regarding results common across housing types, the model results and estimated program savings per home are discussed by type of housing. Model R-Square, the percentage of total variation in energy per day (EPD) explained by the model, was found to be reasonable for a model using pooled time-series and cross-section data. Cross-sectional (between home) variation is typically large and more challenging to explain than time-series (month-to-month) variation. Models with only time series data typically result in much higher R-Square values.

The two cooling degree day terms were found to be insignificant in various specifications of the models. In other words, space cooling was not found to be a significant end-use load for the sample homes. This seems like a realistic finding given the relatively low need for space cooling in the most heavily populated areas of Oregon and the likely income effects on penetration and use of space cooling equipment in program homes.

The baseload impact term in the model above, the treatment period dummy (TrtDum), was found to be insignificant and, consequently, was omitted from the electric models. As with natural gas homes, there was also slight evident of multicollinearity with the space heating impact term (TrtHDD). The own-rent status of occupants was also found to have an insignificant influence on the level of annual savings. The incidence of health and safety related measures was found to have a significant and positive impact on the level of savings. Health and safety related variables were excluded from the model so that the results represent the average participant, some of whom receive health and safety measures while some do not.

MANUFACTURED HOMES

Regression model results for electrically heated manufactured homes are shown in Table 11.

Regression Model Results - Electric Manufactured Homes				
Observations	1813			
R-Square	34%			
Variable	Coefficient Estimate	Std Error	t-Value	Pr > |t|
Intercept	27.96	0.6087	45.9	< .0001
HDD (base 60)	0.06161	0.00219	28.1	< .0001
Treatment * HDD	-0.01508	0.00234	-6.4	< .0001

Table 11: Results – Electric Heat Manufactured Homes.

Overall the model explains thirty-four percent (34%) of the total variation in average kWh usage per day. The independent variables are strongly significant. Using the coefficients from the estimated equation annual usage estimates are calculated and shown below.

Weather Normalized Annual kWh Per Home - Manufactured Homes				
			Gross Savings	
	Pre	Post	kWh	Percent
Base Load	10,205	10,205	0	0%
Heating Load	5,923	4,473	1450	24%
Total Load	16,129	14,679	1450	9%
Net Savings Calculations:				
Weather normailzed percent change in residential class				0.8%
Implied change in participant usage				133
Net savings				1,583
Percent net savings				9.8%

Table 12: Weather Normalized KWH per Electric Heat Manufactured Home.

Annual gross savings per house is estimated to be 1,450 (9%). All of the savings are estimated to be space heat savings, a twenty-four percent (24%) reduction in space heat usage. As explained earlier, average monthly usage from the entire residential class was used to measure the non-program induced change in weather normalized usage between the pre and post periods. After making this adjustment to gross savings, net savings are estimated at 1,583 kWh per home (9.8%).

SINGLE FAMILY HOMES

Regression model results for electric space heat single family homes are shown in Table 13.

Regression Model Results - Electric Single Family Homes				
Observations	1632			
R-Square	23%			
Variable	Coefficient Estimate	Std Error	t-Value	Pr > |t|
Intercept	32.857	0.6817	48.2	< .0001
HDD (base 60)	0.04547	0.00246	18.5	< .0001
Treatment * HDD	-0.00404	0.00262	-1.5	0.1231

Table 13: Results - Electric Heat Single Family Homes.

Overall the model explains twenty-three percent (23%) of the total variation in monthly kWh use per day. As expected, the heating degree days (HDD) term is highly significant. The treatment and HDD interaction term is only moderately significant. Annual usage estimates, using the coefficients from the estimated equation are shown in Table 14.

Weather Normalized Annual kWh Per Home - Single Family				
			Gross Savings	
	Pre	Post	kWh	Percent
Base Load	11,993	11,993	0	0%
Heating Load	4,372	3,983	388	9%
Total Load	16,364	15,976	388	2%
Net Savings Calculations:				
Weather normailzed percent change in residential class				0.8%
Implied change in participant usage				135
Net savings				524
Percent net savings				3.2%

Table 14: Weather Normalized Kwh per Home – Elec. Heat S.F.

Annual gross savings per house is estimated to be 388 kWh (2%). All of the savings are estimated to be space heat, a nine percent (9%) reduction in space heat usage. It is not clear why the average annual space heat impacts are not as large in electrically heated single family homes as was found in gas heated single family homes and gas and electrically heated manufactured homes. As explained earlier, average monthly usage from the entire residential class was used to measure the non-program induced change in weather normalized usage between the pre and post periods. After making this adjustment to gross savings, net savings are estimated at 524 kWh per home (3.2%). As a possible explanation, many of these homes may be also using another fuel.

In summary, the annual *net savings* for manufactured homes using gas heat is 68 therms (12%); for electric heat 1,593 kWh (9.8%). The annual *net savings* for non-manufactured single family homes using gas heat is 131 therms (20%), for electrically heated homes 524 kWh (3.2%).

V. CONSIDERATION OF NON-ENERGY BENEFITS

This section of the evaluation reviews current understandings of Non-Energy Benefits (NEBS) of low-income residential weatherization efforts. The key reality in accounting for Non-Energy Benefits is that home weatherization yields benefits beyond those of energy savings and demand reduction. In the middle 1980's, not much work had been done on Non-Energy Benefits of residential weatherization other than understanding that bill reduction is a benefit that accompanies lower energy use, and that there would be additional savings to utilities in the collections area if low-income households could be presented with smaller bills that they could more easily pay.[27] Also, it was generally understood that if a low-income household could eliminate drafts and bring heating and cooling equipment into an efficient and better maintained condition, and cure unsafe conditions in the home through weatherization assistance, there would be health and safety benefits to the household and to the community.

THE REALITY OF BENEFITS OTHER THAN ENERGY SAVINGS

Some of the first evidence of Non-Energy Benefits was developed from middle and high income households. In the middle 1980's, the Hood River Conservation Project was implemented in Hood River and Mosier Oregon by the Bonneville Power Administration, the Hood River Electric Cooperative, Pacific Power, the Natural Resources Defense Council and other energy-related organizations.[28] This demonstration project was designed, in part, to test maximum participation for electrically heated homes for which whole house weatherization was provided at no cost to households, including all income levels. During the project, it was learned that while most households of all income levels were interested in residential weatherization, some households with middle income or above were more interested in window replacement (one of the program improvements installed in the homes). For some participants, window replacement was a measure that greatly promoted project participation. A number of households

[27] The areas of bill savings to participants, lowering of cost to utilities of collection and bad debt, and resulting benefit to all utility customers were studied and later systematized by Roger Colton. Colton developed analytic approaches in these areas that are now standard in evaluation of low-income programs developed for advocates and for utility collections departments.

[28] Hirst, Eric (1987). Cooperation and Community Conservation, Final Report, Hood River Conservation Project, DOE/BP-11287-18.

for which energy conservation was not a primary motivation decided to participate because the new windows gave homes a clean, attractive, and more upscale appearance. Also, following weatherization, many households discovered comfort benefits – rooms were warmer in winter and cooler in summer, and people felt better about the physical condition of the home for themselves and their children, and now felt assured about their ability to maintain a livable indoor environment. This is an example of early learning about what are today called “Non-Energy Benefits” or “NEBS.” Similarly, in her recent review of Non-Energy Benefits, Jennifer Thorne Amann notes that:[29]

> “…many homeowners purchase whole-house retrofit services for the associated non-energy benefits (NEBS) including improved comfort, aesthetic enhancements, and better indoor air quality.”

Upper income households willing to pay the full cost of whole-house weatherization for these benefits, with energy savings being a secondary concern, are an indicator of the reality of substantial Non-Energy Benefits. Since the middle 1980’s there have been many studies of Non-Energy Benefits of whole-house weatherization programs; these studies have documented a wide variety of benefits to households, to the utility, and to the community.[30]

WHY ARE NEBS IMPORTANT?

First, NEBS are important for purposes of understanding. Just to have a holistic understanding of weatherization work and its values from different perspectives is valuable.[31] The Weatherization

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29 Amann, Jenifer Thorne, “Valuation of Non-Energy Benefits to Determine Cost-Effectiveness of Whole-House Retrofit Programs: A Literature Review,” Washington, DC: American Council for an Energy-Efficient Economy, May 2006, Report Number A061, Page iii. This report is downloadable form http://www.aceee.org/.

30 In particular, Lisa Skumatz at Skumatz Economic Research Associates has completed several studies that both identify areas of benefit and develop ways to quantify Non-Energy Benefits. See: http://www.serainc.com.

31 Conventional economics tells us that oil companies are fantastically profitable by excluding (externalizing) the cost to others of the carbon dioxide loading of the atmosphere and the oceans (global warming, loss of coastal areas, famine, drought, migration of species, loss of species, acidification of the oceans, resource wars, and the like). From a holistic perspective, these costs would have to be added back and, if so, it is likely these companies would be bankrupt. Similarly, conventionally economics typically neglects the non-energy benefits

Assistance Program administered by the US Department of Energy naturally tends to put weight on goals of energy savings and demand reduction. However, the authorizing legislation puts *equal emphasis* on health and safety.[32] Also, given institutional alignments, if the program were to be moved to the Department of Health and Human Services it might well shift primary its primary emphasis to public health, with energy savings as an almost co-equal but secondary goal. It is important to be aware that the impacts of weatherization work go to child health and many other outcomes as well as to energy savings.

At the same time, all whole-house weatherization work is guided by a concern for cost-effectiveness. For the federal/state Weatherization Assistance Program, cost-effectiveness is insured by regulations that establish health and safety as an important practical goal. The need for expenditures for health and safety in low-income housing is built into the program. This is in contrast, for example, with some private sector (for profit) weatherization efforts and some utility weatherization programs that focus only on kWh or therm savings.[33]

The US Department of Energy requires states to adopt a weatherization assessment protocol from a list. The listed protocols require a systematic pre-study for a state to develop savings estimates for measures based on actual housing stock and weather (example: REM/Design™ or REM/Rate™).[34] The result is a

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of energy conservation programs, even though, as discussed here and in the works cited, the non-energy benefits are often the primary motivators of upper-income householders in seeking the benefits of home weatherization or such typically upper-income programs as Home Performance with Energy Star.

[32] Title 10, §440.1, Purpose and Scope, reads as follows: "This part implements a weatherization assistance program to increase the energy efficiency of dwellings owned or occupied by low-income persons, reduce their total residential expenditures and improve health and safety, especially low-income persons who are particularly vulnerable such as the elderly, persons with disabilities, families with children, high residential users, and households with a high energy burden.

[33] Private sector programs are often caught "between a rock and a hard place" since payment to them is often on a per therm saved or per kWh saved basis, while the low-income housing stock requires holistic treatment to address deterioration and repairs, including repairs essential to ensure the health and safety of the persons in the household. The economic signal incorporated in the form of energy performance payment in such programs is to skip or go light on health and safety in order to quickly complete the highest and easiest energy savings measures per home and get on to the next one. It is, of course, possible to structure workable private sector programs, by removing incentives to maximize energy savings and by providing incentives to find and fix health and safety problems.

[34] For REM software, see: http://www.archenergy.com/products/rem/.

set of tables which indicate to subgrantee agencies those measures appropriate for homes with different characteristics.[35]

Where legislation or commission decisions require participation by state utility regulatory commissions, other tests, developed from the tradition of utility Demand-Side Management programs (DSM) and not specifically for low-income programs sometimes become involved. Non-Energy Benefits became important in this context to help regulatory commissions better understand and quantify the full set of benefits of low-income whole-house residential weatherization.

Commissions often look to the old 1980's California cost-benefit tests developed for DSM programs. These are the Participant Test, the Rate Impact Test, the Administrator's (or Utility) Test, the Total Resource Cost Test (TRC), and the Societal Test. The common problem with all of these tests is that they were designed at a certain conjuncture to contrast acquisition of saved kWh and therms (as well as demand reduction) to development of the next plant (in an economic perspective, referred to as the "marginal plant"). They were not designed for low-income programs.

In the last few years, while requiring calculation of the California Tests, state commissions have tended to focus on the Total Resource Cost (TRC) as the most important test. Low-income programs typically do not pass the TRC.[36] This occurs for two reasons. First, low-income households generally struggle to minimize their energy use prior to weatherization (although they can only minimize to the extent possible given the physical characteristics of drafty homes and older heating and cooling equipment) in order to lower bills. Also, the low-income portions of the state's housing stock are predominantly older homes that are in need of multiple repairs, some of which must be completed prior to weatherizing the homes. To implement a whole-house low-income residential weatherization effort, while the percentage of

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35 The perspective of the current study is that such software is very useful to indicate measures to install, but that projected savings for each home should be modified to "true-up" to the actual previous twelve-month energy use for the home.

36 If a low-income weatherization program passes the TRC, it suggests that homes in the low-income sectors are not being properly served; in particular that low effort/high return measures are being installed in place of comprehensive whole house treatment and that health and safety concerns may not be adequately addressed. Stuffing a home with CFLs and some low cost/no cost measures can produce this effect.

energy savings is often significant, the amount of energy savings may be lower than needed to pass the TRC.

A properly implemented low-income program will have a somewhat higher cost than a DSM program since it is required to address health and safety conditions in the home and because it is designed as a comprehensive whole house program. With the ratio of the value of (energy) benefits to project cost lower than in a DSM program, the low-income program should not be expected to the TRC.

The federal legislation authorizing the Weatherization Assistance Program explicitly authorizes health and safety provisions, as well as goals in serving population groups in need, including households with small children, households with seniors, and households with persons with disabilities. Similarly, nearly all state commissions recognize the need for weatherization of low-income households. Many encourage or require various forms of utility funding to coordinate with the state's federal Weatherization Assistance Program. At least four states (California, Kentucky, Wisconsin, and the District of Columbia) require a "Public Purpose Test" of program cost-effectiveness for the utility "add-on" funds. The California Program Administrator test allows consideration of utility benefits. The California Societal test includes social benefits like reduced pollution and social service improvements. The Public Purpose Test includes these benefits, plus the Non Energy Benefits (NEBS).

In states that do not use the Public Purpose Test, universal service funding may provide moderate or substantial leverage to the state's implementation of the federal Weatherization Assistance Program through a small assessment on utility bills. In such cases, cost-benefit is usually computed consistent with federal and state Weatherization Assistance Program regulations and guidelines or as consistent with legislative intent (which has taken a large number of factors into account). Generally, US jurisdictions exempt low-income weatherization programs from the strict application or interpretation of the TRC test through specific state legislation or other recognition of need.

Whether taken directly into account in a formal tests, NEBS are important to commissions and others to enable understanding of the value of residential low-income weatherization programs.

Beyond this, we need better tests than the old California tests, more like the newer California public purpose test that takes NEBS into account. A new, more relevant, test would be tailored to our current context of economic decline and climate. Cities, counties, and state governments are not seeing energy conservation only as resource acquisition, but much more as necessary steps in preparation for climate change and global warming. A test is needed that can take into account that the future is discontinuous with the past, not more of the same (as assumed by the mathematics of the California tests), but with global warming, failure of snowpack,[37] failed hydro systems (unless there is significant re-engineering), dramatically rising prices for electricity and gas,[38] and shortages and triage of natural gas.[39] This is only a small subset of the interlocking and mutually reinforcing problems just ahead. A realistic test for current

[37] Welch, Craig, "Global Warming Hitting Northwest Hard, Researchers Warn," *Seattle Times*, Saturday, February 14, 2004; Luers, Amy Lind, "A Tale of Two Futures, California Feels the Heat," Pp. 8-9 *Catalyst*, Fall 2004; Hayhoe, K., et al, "Emissions Pathways, Climate Change, and Impacts on California. *The Proceedings of the National Academy of Science*s, 101:34, 2004; Welch, Craig, "Global Warming Hitting Northwest Hard, Researchers Warn," *Seattle Times*, Saturday, February 14, 2004.

[38] The February 2008 issue of Public Utilities Fortnightly focuses on "Managing the Big Build" and provides a picture of the scope of the build-out necessary to meet anticipated energy demand. A similar picture of scope is presented in the Energy Foundation's Annual Report for 2006. The problem is the number of units required. A few nuclear plants or a few coal plants would not make much difference but the build-out envisions over one-hundred plants in the US alone, and the build-out is proceeding worldwide with competition for resources driving prices rapidly upwards, with costs sometimes doubling in a year for plants about to go into construction. The negative health impact of huge numbers of new coal plants over the planet is dramatic, and the effect on global warming is unconscionable. Similarly, hundreds of new nuclear plants present an unacceptable risk. Both of these pathways will result in social tensions and struggles that will both prevent or delay construction and radically escalate prices. Natural gas supply within the US has past the tipping point and is declining, requiring increased energy input per unit of energy output. At the same time, biofuels, until recently seen as a partial substitute, have been demonstrated to have environmental impacts greater that those from burning fossil fuels. See: Jha, Alok, "Burning Biofuels May be Worse Than Coal or Oil, say Experts," The Guardian/UK, Friday, January 4, 2008. Also see Peach, Hugh, "Coal," Pp. 69-73 and "Fossil Fuels," Pp. 157-162 in Sal Restivo and Peter H. Denton, *Battleground Science and Technology*. Westport, CT & London: Greenwood Press, 2008.

[39] Following Katrina, natural gas was rationed in the Southeast, shutting down industry to permit residential use. The supply system is strained, and any similar problem can shut down sections of supply that cannot be recovered.

context would place much higher values on getting the residential population ready to survive an economically and climatologically difficult future.

A problem with the form of current tests is that the assumption of the tests is that they are not concretely focused on the coming climate change and current economic problems. Instead, they abstractly consider an abstract return on investment that discounts the value of results in future years. If the resulting benefit to cost ratio is less than one (<1) on a TRC test, the rule is that weatherization should not go forward regardless of physical need. Further, beyond twenty years in the future, savings are discounted to be essentially zero. This artifact of the tests is equivalent to assuming the world ends in twenty years, even though homes often last one hundred or one hundred and fifty years, or more. But, in reality, the situation is one of economics subject to material (physical) constraints, rather than the standard economic assumption of a constantly renewed and resource rich situation.[40] And, from a social perspective the discount rate makes no sense.

These differences conform both to the physics of the situation and to the need to be ready for a difficult future for our children.[41] Children today will wish when they become adults that we had made the necessary investments now. For them, our investments are sunk costs. The investments in weatherization we do not make today will be harder for them as the energy system encounters multiple discontinuities and the economics of everyday life becomes more difficult. Better tests would employ a material (physical) perspective, would be future oriented rather than discounted, and would not treat "today" as the privileged point in time.

KEY STUDIES

[40] The classic study of what happens when resource constraints and the laws of physics dominate an economic market is Georgesçu-Roegen, Nicholas, *The Entropy Law and the Economic Process*. Cambridge, Massachusetts: Harvard University Press, 1971. See also: Beard, T. Randolph & Gabiel A Lozada, Economics, Entropy and the Environment, The Extraordinary Economics of Georgesçu-Roegen. Cheltenham, UK & Northhampton, MA, USA: Edward Elgar Publishing, 1999; Odum, Howard T. & Elizabeth C. Odum, *A Prosperous Way Down, Principles & Policies*. Boulder, Colorado: University Press of Colorado, 2001; Galbraith, John Kenneth, *A Theory of Price Control.* Cambridge: Harvard University Press, 1952.

[41] Streeten, Paul, "What Do We Owe the Future," Resources Policy, March 1986, Pp. 4-16.

There have been many studies of NEBS for both DSM and low-income weatherization programs over several years. Recently work has been done in child health, for example:

- The "CSNAP" study shows that babies and toddlers in homes with energy insecurity are more likely to be in poor health, to have a history of hospitalization, to be at risk for developmental problems, and to be food insecure.[42]

- A National Bureau of Economic Research study demonstrates that when energy bills increase in winter, poor families tend to pay the energy bills but decrease food purchases by approximately the same amount, leading to a drop of 200 calories a day for both adults and children over the winter months.[43]

- The "Energy Costs and Child Health" report presents results of studies of impact of cost of energy on child health.[44]

However, while there is significant ongoing research in several areas, there are three key studies that summarize work to date for low-income residential weatherization:

- The California Low-Income Public Purpose Test, a the manual for conducting the California low-income program tests which includes all NEBS.[45]

- The ACEEE review study, a recent review of NEBS literature for both residential DSM and low-income residential programs.[46]

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42 Children's Sentinel Nutrition Assessment Program, "Fuel For Our Future, Impacts of Energy Insecurity on Children's Health, Nutrition, and Learning." Boston, Massachusetts: September 2007.

43 Bhattacharya, Thomas DeLeire, Steven Haider and Janet Currie, "Heat or Eat? Cold Weather Shocks and Nutrition in Poor American Families." Cambridge, Massachusetts: National Bureau of Economic Research, Working Paper No. 9004, June 2002.

44 Child Health Impact Working Group, "Unhealthy Consequences, A Child Health Impact Assessment of Energy Costs and the Low Income Home Energy Assistance Program." Boston, Massachusetts: November 2006.

45 RRM Working Group Cost Effectiveness Committee, *The Low Income Public Purpose Test (LIPPT) Updated for Version 2.0*. Oregon, Wisconsin: TecMarket Works, May 2001.

46 Amann, Jennifer Thorne, "Valuation of Non-Energy Benefits to Determine Cost-Effectiveness of Whole-House Retrofit Programs: A Literature Review." Washington, DC: American Council for an Energy-Efficient Economy, May 2006, Report Number A061.

- The Schweitzer & Tonn Oak Ridge study, the most relevant study, providing values for NEBS for the federal/state Weatherization Assistance Program.[47]

The California manual is a useful tool for dialoging with state public utility commissions and others who are using the old California tests and are not aware that there is a new California test specifically for low-income programs[48] that takes all NEBS into account. Amann's ACEEE review study provides the NEBs categories, calculations and cost tests used in different states.

The Schweitzer & Tonn Oak Ridge Study presents NEBS for several categories of benefits, most aggregated across subcategories. The major categories include:

- Ratepayer Benefits (Payment Related)
- Ratepayer Benefits (Provision of Services)
- Household Benefits (Affordable Housing)
- Household Benefits (Health, Safety, and Comfort)
- Societal Benefits (Environmental)
- Societal Benefits (Social)
- Societal Benefits (Economic)

The result of the Schweitzer & Tonn study is a net present value of the NEBS, assuming a twenty-year measure life and a 3.2% discount rate is $3,346 in 2003 dollars. Adjusting using the Consumer Price Index calculator on the Bureau of Labor Statistics website,[49] this is $3,988 in 2008 dollars.

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[47] Schweitzer, Martin & Bruce Tonn, *NonEnergy Benefits from the Weatherization Assistance Program: A Summary of Findings from the Recent Literature*. Oak Ridge, Tennessee: Oak Ridge National Laboratory, April 2002, ORNL/CON-484.

[48] Also, it is often not realized that the California Standard Practice Manual, which specifies the mechanics of the set of California tests (except the Public Purpose Test) is accompanied by a public input process and policy considerations that set some of the inputs for the tests based on public interest and commission policy. In California, where the tests were developed, the tests are engaged in an active, participatory manner..

[49] http://www.bls.gov/home.htm.

VI. OVERALL COST-EFFECTIVENESS RESULTS

The purpose of this section is to estimate the cost-effectiveness of the Oregon Weatherization Assistance Program. In many ways this section represents a synopsis of the results from prior sections on program costs and savings expressed in terms of standard metrics used in economic analysis. These metrics include the present value (PV) of the stream of benefits and costs generated by the program and the ratio of benefits to costs. Non-energy benefits (NEBS) are also included.

PROGRAM COSTS

The total cost of delivering the Oregon WAP is comprised of treatment cost and administration expenses. Both of these types of costs are shown in Table 15. All costs are expressed in 2008 dollars. Treatment costs are further broken down by type of measure.

	Electric		Natural Gas	
Type of Measure	Single Family	Manuf. Homes	Single Family	Manuf. Homes
Weatherization	$ 3,032	$ 4,182	$ 3,121	$ 3,481
Baseload	$ 133	$ 147	$ 118	$ 115
Health and Safety	$ 25	$ 92	$ 123	$ 101
Energy Education	$ 8	$ 16	$ 11	$ 7
Home Repair	$ 32	$ 156	$ 95	$ 118
Furnace Repair	$ 11	$ 37	$ 52	$ 45
Furnace Replacement	$ -	$ 85	$ 281	$ 419
Total Cost of Treatment	$ 3,241	$ 4,716	$ 3,801	$ 4,287
Administration (10%)	$ 324	$ 472	$ 380	$ 429
Total Cost Per Home (2008 $)	$ 3,565	$ 5,188	$ 4,181	$ 4,715

Table 15: Treatment costs per home, by cohort.

Weatherization costs are the largest expense of the program accounting for over three fourths of the total cost per home. Administration expenses are ten percent (10%) of total treatment costs.[50]

PROGRAM BENEFITS

The treatment of homes through the program generates a series of annual benefits. These benefits can be classified in two primary groups; energy and non-energy benefits. Energy benefits are the savings in energy bills accruing to the households of treated homes and the reduction in utility system expense associated with the reduction in energy supply requirements. The reduction in annual energy bills is reported in Section 3 and shown graphically in Figure 2.

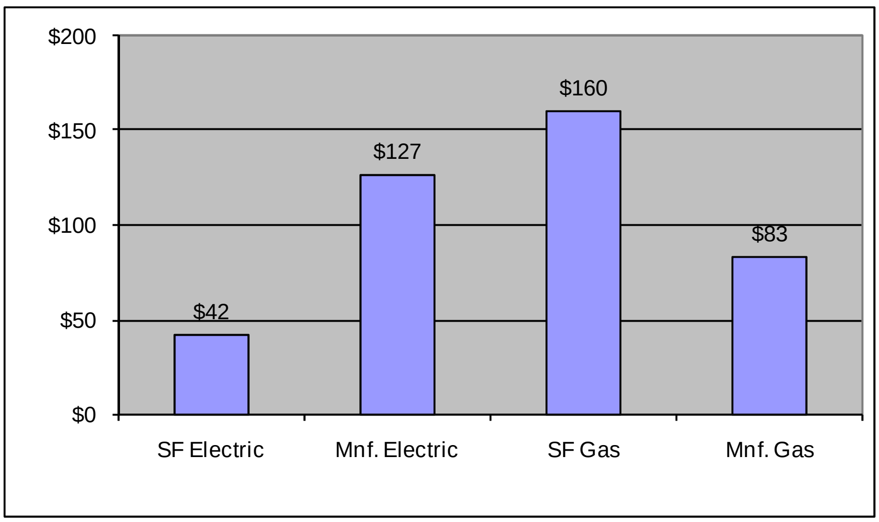

Figure 2: Annual energy bill savings per household.

The average annual household energy bill savings ranges from $42 to $160, depending on the type of building and on the type of heating fuel. Bill savings are, of course, driven by the annual kWh and therms saved. See Section 4 for a more complete discussion of the whole house energy savings by study cohort. Non-energy benefits include a range of benefits that accrue to client households, utilities, local

[50] See earlier sections of this report for additional information on program costs and funding.

economies, national security and the environment. These benefits are discussed and reported in Section 5 as a net present value benefit of $3,988.

COST-EFFECTIVENESS RESULTS

Economic analysis of program cost-effectiveness is traditionally reported from five perspectives or tests. A perspective looks only at the costs and benefits accruing to a particular group. These traditionally include participants, the utility, rate payers, the energy system (total resource), and the society. Since participants pay no cost and the utility and impacts on rate payers are utility specific and beyond the scope of this analysis, we report on the last two perspectives: the total resource cost (TRC) and the societal test.

Both the TRC and societal test include the avoided cost of energy supply as a benefit. In the case of the TRC, avoided energy supply costs are the primary benefit. The societal test includes non-energy benefits in addition to the avoided cost of energy. The benefit-cost analysis was conducted using a tool provided by the Energy Trust of Oregon (ETO).[51] The primary advantage of the ETO tool is that the avoided cost of energy supply from multiple Oregon utilities has been analyzed and embedded in the benefit-cost analysis tool. A summary of benefit-cost inputs and results are shown in Table 16. Program costs, savings and life of the program benefits are used in the calculation of the cost effectiveness results.

[51] Energy Trust of Oregon Savings Calculation – Residential Sector, February 14, 2008.

Summary of Cost Effectiveness Inputs and Results Oregon Weatherization Assistance Program Evaluation				
	Electric		Natural Gas	
	Single Family	Manuf. Homes	Single Family	Manuf. Homes
Total Cost Per Home (2008 $)	$3,529	$5,147	$4,165	$4,884
Average Annual Savings Per Home				
Electricity (kWh)	524	1583		
Natural Gas (therms)			131	68
Bill savings ($)	$51	$132	$159	$93
Average Measure Life (years)	36	32	37	32
Non-Energy Benefits (PV 2008 $)	$3,988	$3,988	$3,988	$3,988
Cost Effectiveness Results:				
PV of Utility System (TRC) Benefits	$943	$2,715	$1,698	$836
PV of Societal Benefits	$4,931	$6,703	$5,686	$4,824
B/C Ratio - Utility System (TRC)	0.27	0.53	0.41	0.17
B/C Ratio - Societal	1.40	1.30	1.37	0.99

Table 16: Summary of Cost-Effectiveness Inputs and Results.

Cost effectiveness results are shown from a total utility (energy) system perspective (TRC) and from the societal perspective. The present value (PV) of benefits for the TRC perspective represent the avoided cost of energy supply that the utility system no longer bears. The PV of benefits for the societal perspective is the sum of the TRC PV and the non-energy benefits. Benefit-cost (b-c) ratios are calculated by dividing the PV of benefits by the total cost per home. The b-c ratios are shown graphically in Figure 3. As shown, the Oregon WAP program is not cost- effective from a purely energy perspective (TRC).

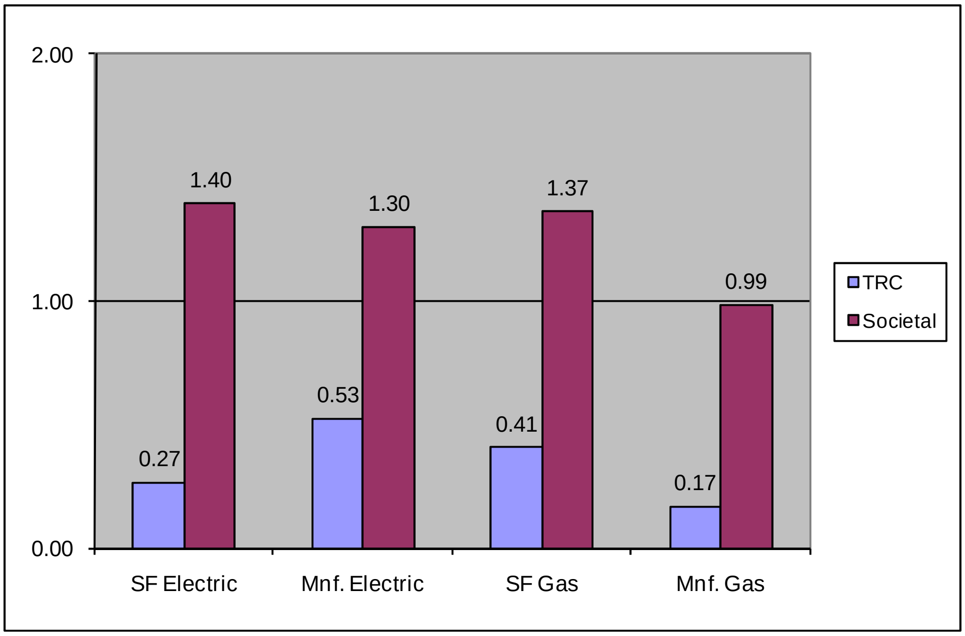

Figure 3: TRC and Societal Benefit-Cost Ratios by Study Cohort.

The TRC Benefit-Cost Ratios are less than one for each of the cohorts in this study. From a societal perspective, however, the Oregon WAP is cost-effective for three of the four cohorts in the study, although just below the margin for manufactured homes heated with natural gas. This result demonstrates the importance of non-energy benefits in the economic results. As discussed in other sections of this report, primarily Section 5, non-energy benefits such as health and safety improvements to client households are an important objective of the Oregon WAP. The cost-effectiveness results support the importance of these non-energy objectives.

VII. MEASURES ANALYSIS

The purpose of this section is to estimate the annual energy savings from specific measures installed. The results are reported by fuel and housing type. We begin with the method to estimate savings.

The analysis of measure specific savings was based on the same methodology and definitions of study periods as the whole house analysis reported in Section 3. Measure specific impacts were assessed using the modified form of the general model used to assess whole house program impacts, as shown below:

Equation 4: Model for Assessment of Measure Specific Impacts.

$$EPD_{j,t} = f(TrtDum_{j,t,mbase}, HDD_{j,t}, TrtHDD_{j,t,mheat})$$

where each of the terms in the model are specified as follows:

Term	Description
Subscript *mbase*	Indicates base load measure *mbase*.
Subscript *mheat*	Indicates space heating measure *mheat*.
$EPD_{j,t}$	Energy use per day for home j in period t. Units will be kWh or therms depending on the fuel being modeled.
$TrtDum_{j,,t,mbase}$	One dummy variable for baseload related measure (*mbase*), taking the value of zero in all pre-treatment periods for home j and one in all post treatment periods if home j included installation of measure *mbase*. This variable provides a measure of the non-weather (base load) related impacts associated with treatment from measure *mbase*.
$HDD_{j,t}$	Heating degree days (base 65) for home j during billing period t. This term measures the average daily energy usage associated with changes in heating degree days.
$TrtHDD_{j,t,mheat}$	Product of treatment indicator for space heat measure *mheat* and HDD, results in zero for all pre treatment periods and HDD in all post treatment periods when *mheat* is installed in the home. This term provides a measure of the HDD correlated impacts associated with treatment with measure *mheat*.

Note that one modification from the whole house model is that the treatment related variables in the model, TrtDum and TrtHDD, have been specified to include a subscript indicating the specific measure. Other modifications include the elimination of CDD and Other terms, based on the results from the whole house analysis.

The measure impacts can be directly tested and quantified through the TrtDum and TrtHDD variables.

For whole house savings (Section 4) we adjusted gross savings using the percentage change in weather normalized usage for the residential class as a whole between the pre and post periods. Given the inherent difficultly with separating measure specific savings from whole house billing analysis it seems a meaningless exercise to try to partition the control impact between measures. Since we are also comparing the measure savings to program planning assumptions, it is not appropriate to adjust savings for the extraneous influences measured with a control group. Accordingly, this analysis deals with the gross level impacts of measures without adjustments for changes in control home consumption.

An important difference between the whole house analysis reported in Section 4 and the measure specific analysis is the relationship between the objective and the unit of measurement. In Section 4, our modeling objective was to estimate whole house savings using consumption measured at the whole house level. Our objective corresponded well with our unit of measurement. For this section, we have an interest in measuring the savings associated with individual measures. However, our level of measurement of consumption is still at the whole house level since we do not have end-use metered data. Intuitively, one can see that the challenges are greater due to the mismatch between our objective, measure specific, and our unit of measurement, whole house. Statistically, the challenge becomes one of association between the measures, which often times leads to the obfuscation of the impacts of specific measures. Our attempt to deal with these confounding relationships is reported in the results section.

SAMPLE DESIGN AND DATA COLLECTION

The analysis in this section used the sample of homes with adequate billing records from the whole house analysis as the starting point for the data collection for the measure analysis. Measure level detail was requested from each agency for homes in the sample with sufficient billing records for analysis. Waiting until we were confident a home had the required billing data before asking for measure detail had the advantage of minimizing the data collection efforts requested of the agencies. We requested measure detail for 292 jobs, of which 236 homes were returned. These homes are the basis for the measure specific analysis reported in this section.

In collecting the data it was apparent from the comments we received from agency staff as well as our own analysis and review that a clear distinction between the listed measures does not always exist. For example, there are three types of duct treatments listed: wrapping, sealing and leak reduction. For program tracking and monitoring purposes, these are probably best collapsed into a single category. Some agencies reported that these types of logical aggregations were already taking place in the program records.

DESCRIPTIVE ANALYSIS

There are a total of 19 individual measures that may be included in the weatherization and treatment of program homes. Each of these measures is shown in the table below along with installation percentage savings and cost for electrically heated homes. This information is listed separately for single family and manufactured homes. There were insufficient records for analysis of multifamily records.

Attic insulation, sub-floor insulation and lighting have the highest installation rate, each at or above sixty percent (60%) in single family homes. For manufactured homes, attic insulation and mobile home roof systems combine for a just over sixty percent (60%) installation rate, about the same as single family attic insulation. Sub-floor insulation and lighting are also installed at around sixty percent (60%). Replacement windows are more commonly included in the treatment of manufactured homes than single family.

Measures were expected to deliver annual savings of 4,800 kWh in single family homes and 5,500 kWh in manufactured homes. The average cost per home for installation of the listed measures was $2,400 in single family and $3,600 for manufactured homes. The higher savings and cost in manufactured homes is due primarily to the higher installation of windows in these homes.

Measure	Single Family Homes Number Installing	Percent Installing	Avg Savings (kWh)	Avg Cost (Dollars)	Manufactured (Mobile) Homes Number Installing	Percent Installing	Avg Savings (kWh)	Avg Cost (Dollars)
Attic Insulation	31	62.0%	1,599	$904	14	29.2%	2,689	$1,752
Kneewall Insulation	3	6.0%	574	$286	0	0.0%	.	.
Sidewall Insulation	8	16.0%	3,881	$1,036	0	0.0%	.	.
Subfloor Insulation	30	60.0%	2,600	$1,442	26	54.2%	2,287	$1,350
Replacement Windows	9	18.0%	2,109	$2,865	26	54.2%	2,689	$1,935
Insulated Exterior Door	2	4.0%	416	$352	12	25.0%	625	$412
Duct Wrapping	3	6.0%	1,632	$478	1	2.1%	372	$85
Duct and HVAC Sealing	4	8.0%	2,376	$597	12	25.0%	1,549	$251
Duct Leakage Reduction	2	4.0%	1,441	$1,300	6	12.5%	1,260	$790
Water Pipe Wrap	0	0.0%	.		0	0.0%	.	.
Air Infiltration	10	20.0%	1,000	$291	16	33.3%	395	$199
MH Roof Systems	0	0.0%	.	.	14	29.2%	1,907	$2,384
Furnace Repair	0	0.0%	.	.	6	12.5%	703	$273
Furnace Replacement	9	18.0%	-	$23	13	27.1%	40	$488
Water Heater Replacement	0	0.0%	.	.	2	4.2%	967	$429
Refrigerator Replacement	8	16.0%	1,314	$427	11	22.9%	1,082	$416
Lighting Change Out with CFLs	32	64.0%	649	$34	28	58.3%	372	$36
Energy Education	5	10.0%	477	$40	7	14.6%	226	$99
Other	0	0.0%	.	$640	1	2.1%	229	$178
All Homes	50		4,822	$2,423	48		5,518	$3,637

Table 17: Measures Installed in Electric Heat Homes.

Measure	Single Family Homes Number Installing	Percent Installing	Avg Savings (Therms)	Avg Cost (Dollars)	Manufactured (mobile) Homes Number Installing	Percent Installing	Savings (Therms)	Avg Cost (Dollars)
Attic Insulation	49	60.5%	88	$931	12	21.1%	112	$1,636
Kneewall Insulation	7	8.6%	33	$299	0	0.0%	.	.
Sidewall Insulation	35	43.2%	184	$1,059	3	5.3%	104	$401
Subfloor Insulation	33	40.7%	129	$1,477	28	49.1%	116	$856
Replacement Windows	8	9.9%	144	$1,613	26	45.6%	133	$1,949
Insulated Exterior Door	3	3.7%	29	$462	16	28.1%	29	$508
Duct Wrapping	27	33.3%	78	$745	1	1.8%	3	$76
Duct and HVAC Sealing	5	6.2%	66	$410	7	12.3%	42	$222
Duct Leakage Reduction	19	23.5%	59	$716	13	22.8%	70	$665
Water Pipe Wrap	0	0.0%	.	$300	0	0.0%	.	$200
Air Infiltration	23	28.4%	98	$371	27	47.4%	69	$267
MH Roof Systems	1	1.2%	208	$1,479	18	31.6%	93	$2,219
Furnace Repair	4	4.9%	73	$562	6	10.5%	63	$235
Furnace Replacement	26	32.1%	27	$455	19	33.3%	35	$299
Water Heater Replacement	1	1.2%	20	$310	1	1.8%	41	$825
Refrigerator Replacement	16	19.8%	-	$425	9	15.8%	-	$415
Lighting Change Out with CFLs	55	67.9%	-	$51	33	57.9%	-	$40
Energy Education	2	2.5%	25	$101	6	10.5%	8	$107
Other	2	2.5%	12	$19	0	0.0%	.	.
All Homes	81		291	$2,689	57		258	$3,064

Table 18: Measures Installed In Gas Heated Homes.

As in electrically heated homes, attic/roof insulation, sub-floor insulation and lighting are the most popular treatments. Interestingly, sidewall insulation and duct treatments are installed at a much higher rate in single family gas homes than manufactured gas homes or electrically heated homes. This may partially explain the findings from the whole house savings reported in Section 4 where gas heated single family homes were found to have the highest percentage savings in space heating energy.

The number of measures installed per home is shown in the table below (column percentage may not add to 100% due to rounding error).

Measures Installed	Electrically Heated Homes		Gas Heated Homes	
	Single Family	Manufactued Homes	Single Family	Manufactued Homes
1	8%	8%	4%	5%
2	26%	4%	17%	11%
3	32%	25%	25%	32%
4	16%	17%	22%	25%
5	16%	31%	25%	16%
6	2%	10%	6%	5%
7	0%	4%	1%	7%

Table 19: Measures Installed per Home.

Despite the large number of measures, over ninety percent (90%) of homes are treated with five or fewer measures. Two thirds of electrically heated single family homes are treated with three or fewer measures. Electrically heated manufactured homes tend to have the most measures installed, with forty-five percent (45%) receiving four or more measures.

WHOLE HOUSE SAVINGS REALIZATION RATE

With the weighted average savings rate calculated from the program records (reported in the measure tables above) and the whole house savings results reported in Section 4, we can compute savings realization rates at the whole house level.

	Expected	Measured	Realization Rate
Electric (annual kWh)			
Single Family	4,822	524	11%
Manufactured	5,518	1,583	29%
Gas (annual therms)			
Single Family	291	131	45%
Manufactured	258	68	26%

Table 20: Savings Realization Rate by Heating fuel and Building Type.

Overall, measured savings are only about a third of the expected savings from the program. Although impact evaluation results are often lower than planned savings the magnitude of the discrepancy is large. Realization rates at these levels are most often found as result of program planning estimates that are based on pure engineering calculation without regard to the actual energy consumption for the buildings in the pre-treatment period. The planning estimates for the OR WAP program operate in this fashion. It may be possible to increase the realization rate found in future evaluation if actual home usage is brought to bear on the original estimates of savings.

Recommendation: Use twelve months of energy usage data to true-up expected savings estimates, prior to reporting expected annual energy savings.

ANALYSIS OF MEASURES SAVINGS

The model used to estimate measure specific savings has already been discussed earlier in this section. Our empirical work with modeling measure specific savings was hampered by the high degree of correlation between treatments and the fact that the timing of the treatment is the same for all measures in a given house. For statistically meaningful estimates of measure impacts we would need data with substantial variation in the mix of measures going into homes and the timing of installation. It became apparent early in the modeling efforts that measures would need to be grouped in order to reduce between measure correlation and test for impacts. Unlike the whole house analysis which eliminated all meter reads during the two year treatment period, we decided to keep all treatment period consumption records except for a two month period around the installation date. This allowed for greater variability in the timing of measures by essentially allowing each home to have a unique pre and post period based on the treatment date of the home. The disadvantage of this approach, and the reason it was not used for the whole house analysis, is that it makes it more difficult to apply control group changes given the lack of consistently defined pre and post periods. As we have already discussed, it does not make sense to adjust measure savings for control group changes so this issue is not of concern in the measure analysis.

Measures were primarily grouped based on judgment and then tested statistically in model estimation. Groupings of measures ultimately used for the analysis are shown below:

Measure Group	Sum of Individual Measures
Shell Improvements	Attic Insulation, Kneewall Insulation, Sidewall Insulation, Sub-floor Insulation, Insulated Exterior Doors, Air Infiltration, MH Roof Systems
Duct Tightening	Duct Wrapping, Duct and HVAC Sealing, Duct Leakage Reduction

Table 21: Measure Groups.

Measures not grouped were considered individually with the grouped measures. Due to the inherent difficulty with statistically separating the influence of one measure from another the results in this section should be considered suspect. The regression equation results are highly sensitive to choices made by the modeler. For example, two equations may yield similar overall results but be based on different sets of measures specified in the equation. This can happen when two variables tend to be describing the same impact due to the correlation between the two. Accordingly, the real value in the analysis lies more in the qualitative observations of the analyst who sees how variable impacts shift with model specification, rather than the interpretation of the quantitative results. For that reason we first present our observations on the relationship between measure treatment energy usage followed by regression model results.

General observations on measure savings are listed below.

1. It was difficult to bring in more than two or three measures at a time without insignificant or incorrectly signed measure variables.

2. Shell improvements were the most consistently significant of the measures.

3. Duct treatments tended to have less correlation with energy usage in electric homes than gas heated homes

4. Shell and duct improvements tended to be difficult to separate individually. In some models they were grouped together to allow measurement of the combined effect.

5. Furnace replacements may have lead to increased consumption, especially in electrically heated homes. This may indicate abnormally low pre period usage due to the operational condition of the space heating equipment.

6. Lighting measures were associated with higher baseload usage in many of the electric models. This may be due to the spurious correlation of increased baseload usage over time.

MODEL RESULTS

The parameters and associated t-stats are shown for measure impact variables from each of the models. Separate models were run by heating fuel and housing type.

	Electrically Heated Homes				Gas Heated Homes			
	Single Family		Manufactured Homes		Single Family		Manufactured Homes	
	Beta	t-Stat	Beta	t-Stat	Beta	t-Stat	Beta	t-Stat
Shell Insulation					-0.000746	-6.3	NA	
Duct Tightening					-0.000803	-6.3	NA	
Shell-Duct Combined	-0.01319	-5.4	-0.01393	-6.1	NA		-0.000427	-3.5
Replacement Windows							-0.000460	-3.5
Furnace Replacement					-0.001360	-4.6		
Refrigerator Replacement	-7.02	-5.4						
Education			-0.01421	-2.9				

Table 22: Measure Impact Parameters from Model results.

All but one of the equations results in only two measure variables being included in the analysis. Due to the high degree of correlation between the measure variables, even after grouping the measures as described above, it was difficult to bring more than two or three variables into the model at any one time. While testing varies combinations of variables in the equation, priority was given to measures that had a high installation rate when it came down to a choice between competing explanatory variables. One thing that is clear from developing these types of models is that the results are highly dependent on the choices and tradeoffs made by the modeler. This is necessary, given the limits of regression analysis to separate the influence of highly correlated variables. Still, it speaks to the need to use caution when attempting to interpret the results in a quantitative sense.

MEASURE REALIZATION RATES

Average expected savings are compared to the measured results in the table below. We recommend that these results be viewed as relational rather than absolute given the limits of the analysis discussed above.

	Electrically Heated Homes						Gas Heated Homes					
	Single Family			Manufactured Homes			Single Family			Manufactured Homes		
	Expected	Measured	Realization Rate	Expected	Measured	Realization Rate	Expected	Measured	Realization Rate	Expected	Measured	Realization Rate
Shell Insulation	2,038			1,678			118	72	61%	86		
Duct Tightening	1,920			1,396			70	77	111%	57		
Shell-Duct Combined	3,958	1,304	33%	3,074	1,377	45%				143	41	29%
Replacement Windows										133	44	33%
Furnace Replacement							27	131	484%			
Refrigerator Replacement	1,314	2,562	195%									
Education				226	1,405	622%						

Table 23: Measure Specific Impacts and Realization Rates.

The wide variation in measure realization rates is further indication of the pitfalls of using these results for quantitative purposes. Shell and duct insulation had the highest realization rates in single family gas heated homes. This is consistent with the whole house realization rates results reported earlier in this section. We also found evidence that refrigerator replacement and education was positively correlated with savings in electrically heated single family and manufactured homes, respectively. Furnace replacements in gas heated homes were found to add positively to savings at a higher than expected rate.

VIII. WEATHERIZATION NETWORK ISSUES

This section of the study looks at client education, training, staff training, program monitoring and recommendations for ongoing data collection and standardization. We contacted the Oregon Energy Coordinators Association (OECA), the Community Action Partnership of Oregon (CAPO), Neighbor Impact, Oregon Housing and Community Services (OHCS), and the Washington County Community Action Agency (WCCAA) and asked them to address the different approaches to client education, to describe how weatherization staff training is conducted, to discuss program monitoring, and to provide recommendations for data collection and standardization. We also developed recommendations for data collection and evaluation from the evaluation team's experience with the 2003-2005 Evaluation data collection and analysis. These areas are addressed below.

CLIENT EDUCATION

Client education is an integral part of the Oregon WAP. According to WCCAA, clients (homeowners or tenants) should hear any message multiple times. They have developed their program so that information is presented multiple times and in different ways.

In the living space evaluation, the WCCAA staff presents both efficiency and safety information. In the baseload audit, the auditor provides overlapping and additional information to the occupant. In a third visit the home is audited and more information is provided to the homeowner or tenant. The WCCAA leverages each program visit to provide additional and repeated information. Throughout the course of the visits the household receives information on energy usage, problems of mold, lead problems, water heater thermostat settings, heating system operation, and energy efficiency tips. They typically also receive CFLs, low flow showerheads, faucet aerators, refrigerator brushes, refrigerator thermometer cards, carbon monoxide detectors for gas homes, and information on what they can expect from the program and what is expected of them in the program. During the visits, information about heating system problems and servicing is gathered as is information about the refrigerator. In each of the visits the energy efficiency and safety messages are reinforced for the occupant with the aim of developing a well-informed occupant.

The educational component of the weatherization program has not been evaluated. However, evaluations of the program have been completed and show that the program generates lighting and refrigeration savings. New state requirements will likely generate an evaluation of the education component of the weatherization program. WCCAA believes that increased client contact and multiple versions of informational material will increase the education level on energy efficiency and safety for tenants and home owners.

WEATHERIZATION STAFF TRAINING

The Oregon Energy Coordinator's Association (OECA) is tasked with providing weatherization training for the agencies. The agencies receive training and technical assistance funds from the state which they can use at their discretion; these training and technical assistance funds can be rolled over into program dollars if there are no training needs. OECA developed the Residential Energy Analyst Program (REAP) which is composed of three primary courses: *Energy Analyst*, *Shell Technician* and *Diagnostic Technician*. Each is a one week course which includes both a written test and a practical test component. The majority of the courses are comprised of hands on work.

These courses are available to anyone the Community Action Agencies send to the course, with typical attendance of fourteen persons in each class. The list of offerings is available online, and agencies sign up for them. Each of the three core courses provides the attendee with a certification for that subject area. Once all three courses have been completed an additional certification is given to the individual. These certifications are required within thirty days of being hired and are the minimum curriculum required to allow an individual to audit, install, and inspect measures. Each agency must have at least one certified individual on staff and the additional certification allows the individual to teach the curriculum once they have had 2 years of experience. Training sessions take place at an agency that has a qualified trainer on staff. Additional course offerings are available, but these three courses constitute the core training.

There is real value in the training: trained installers are more efficient and can complete more jobs, and they are more effective as demonstrated by a reduced number of callbacks for a trained individual. Lessons learned include that a hands-on format is much better than a classroom format. As a result the program is now tailored to include maximum hands on time and more limited classroom time. In general, OECA has found over time that as the trainers become more experienced and have seen a greater diversity of homes, both the training content and the content of training examinations have become more refined. Now the training includes more visual aids to expose attendees to other options. The OECA training is well regarded and they are often asked to conduct the training in other states.

PROGRAM MONITORING

As a program requirement, every weatherized home is inspected. Program monitoring is a step beyond inspection and is the result of a two pronged effort. The weatherization program is monitored via (1) peer monitoring and (2) Oregon Housing and Community Services (OHCS) staff visits to the agency.

Peer monitoring entails agency staff exchanges. One agency's staff member is sent to a different agency, preferably one which does things differently, for a week to observe their program operations. The peer exchange program is viewed as a time to exchange ideas and methods to improve the program operations of all agencies.

OHCS staff also visits each agency for three to five days to review program operations. In these visits, OHCS staff reviews ten files of agency completed work, and completes several standard agency evaluation protocols. This includes file and fieldwork review. In the fieldwork review OHCS staff members visit a completed home and repeat all the efficiency testing (*e.g.,* blower door and duct blaster tests). OHCS spends two to three hours at the previously weatherized home rechecking all aspects of the work completed earlier. Based on the comprehensive review results, the agency is then rated as Exemplary, Stable, Vulnerable, or At Risk. In order to get an Exemplary rating the agency must participate in the peer exchange program; furthermore agencies who receive a Vulnerable or At Risk rating must also participate in the peer exchange program.

Agencies that have had their OHCS visit report that the process is exceedingly valuable. They say that they learned about their program and that the review provides a way for OHCS to provide extra training and technical assistance to agencies that need it. To date, of the three completed OHCS review evaluations, no agencies have been rated Vulnerable or At Risk. Participating agencies see the program monitoring process as working well.

DATA COLLECTION AND STANDARDIZATION

There are areas in which program monitoring, tracking and evaluation efforts could benefit from improved data collection. The evaluation team recommends that data collection activities be modified to take advantage of these benefits. As OHCS considers modifications to its data collection systems and processes, we suggest the following changes be strongly considered:

1. Location information

   - Systematically secure and record *the actual physical address* of each building. Having this information will allow the overlay of detailed demographics, if desired. It will also be of value for possible comparison group selection in future program evaluations.

2. Utility service information for acquiring billing information for future evaluations.

   - Systematically secure and record the *name of electric utility and utility supplying space heating*.

   - Systematically secure and record *full utility account numbers* for both utilities.

3. Home treatment details for tracking treatment levels. For each *measure* installed:

   - Systematically record the *installation cost*.

   - Systematically record expected savings in BTUs. Knowing the measure and space and water heating fuels will allow conversion of BTUs to fuel specific units (e.g. kWh, therms). Currently some agencies are recording BTUs, some therms or kWh, and some just dollar costs. This should be standardized across agencies.

These recommendations are incremental to the information already being collected and stored by OHCS. Adoption of these changes will need to be weighed against the cost of making the modifications but the evaluation team believes each of the modifications will yield improvements in program tracking, measurement and evaluation.

IX. EXPLANATORY FACTORS

This section discusses program characteristics and key factors that influence energy savings and costs effectiveness. There are two topics: percentage of pre-weatherization whole-house energy savings, and realization rates. The percentage of pre-weatherization whole-house energy savings is defined as the gross energy savings, adjusted for weather. The realization rate is the percentage of modeled energy savings achieved, and is usually considered on a measure level.

PERCENTAGE OF PRE-WEATHERIZATION WHOLE-HOUSE ENERGY SAVINGS

In Section 4, the whole house savings analysis found annual *gross energy savings* as follows:

- 92 therms (17%) for manufactured homes with gas space heat
- 1,511 kWh (9%) for manufactured homes with electric space heat
- 150 therms (23%) for single family homes with gas space heat
- 495 kWh (3%) for homes for single family homes with electric heat

These gross energy savings results are compared with similar results from a Washington State Weatherization Assistance Program Evaluation from 2001 in Table 24.[52]

In Table 24, we can determine that annual energy usage for non-manufactured single family homes in the Oregon sample is about two-thirds of energy use of the homes in the Washington sample (16,500 kWh vs. 24,925 kWh; 632 therms vs. 933). This makes sense because the Pacific Northwest climate zones show this kind of difference, depending on the location of homes.

Also (Table 24), the percentage savings for non-manufactured single family homes with natural gas space heating in Oregon is about the same as for Washington homes (23% vs. 25.4%). This indicates that Oregon and Washington results are in line for homes with gas heat.

[52] Net energy savings are not compared since the Washington evaluation did not develop a comparison group, so was unable to compute net energy savings. Schweitzer, Martin & Linda G. Berry, *Evaluation of the Washington State Weatherization Assistance Program*. Oak Ridge, Tennessee: Oak Ridge National Laboratory, March 2001, ORNL-CON-478.

Comparison with Washington State 2001 Evaluation (Gross Energy Savings)			
Oregon		**Washington**	
Energy Savings	**% of Pre-Weatherization Whole-House Use**	**Energy Savings**	**% of Pre-Weatherization Whole-House Use**
Single Family: Electric Heat		**Homes: Electric Heat**	
495 kWh	3%	2,991 kWh (n=114)	12%
Manufactured: Electric Heat			
1,511 kWh	9%		
Single Family: Gas Heat		**Homes: Gas Heat**	
150 therms	23%	237 therms (n=71)	25.4%
Manufactured: Gas Heat			
92 therms	17%		
Note: For the Washington Evaluation, homes with natural gas space heating energy savings was reported as 230.1 CCF; this was converted to 237 therms for this table. Note 2: Washington homes are not identified in the ORNL study as to manufactured and non-manufactured, but are single family homes.			

Table 24: Comparison with Washington Evaluation.

Beyond this, comparing the Oregon result for non-manufactured single family gas heated homes (23%) with the results for gas heated homes in the last four national metaevaluations conducted by the Oak Ridge National Laboratory (ORNL) provides a very close match. The periodic ORNL studies are based on reports from those states that provide state-level Weatherization Assistance Program evaluations to ORNL, a changing subset of states for each of the successive studies. Nearly all states reporting and included in the metaevaluations are states with cold climates. The ORNL results are: fourth metaevaluation (22.9%); third metaevaluation (21.9%), second metaevaluation (19.6%); first metaevaluation (23.4%).[53] For gas heated non-manufactured homes, Oregon results

[53] Results for electrically heated homes were either not reported or reported but determined to be unreliable due to small sample sizes. See Figure ES1, page xiii in Schweitzer, Martin, *Estimating the National Effects of the U.S. Department of Energy's Weatherization Assistance Program with State-Level Data: A Metaevaluation using Studies from 1993-2005.* Oak Ridge, Tennessee: Oak Ridge National Laboratory, September 2005, ORNL/CON-493.

essentially identical with national program results. For gas heated manufactured homes, the Oregon result (17%) is not too different from homes in the Washington study or from the national metaevaluation series of results for homes.[54]

Returning to Table 25, for non-manufactured homes with electric heat, the Oregon result of three percent (3%) electricity savings is low. The Oregon result for manufactured homes with electric heat (9%) is not too far from the Washington result for homes with electric heat (12%). The Oregon result for manufactured homes with electric heat (9%) matches the result (9%) for homes in the most recent national metaevaluation.[55] However, there were not sufficient data points for state level evaluation reports for homes with electric heat in the metaevaluation to consider results reliable.[56]

In Section 4, it was suggest that the Oregon results for homes with electric heat would be expected to be low if many of these homes also have wood heat or some other source of heating. Supplementary wood heat, or reversing roles and using installed electric heat as the supplementary heating source is not unusual across Oregon, and this would tend to lower the overall percentage savings results for the state. In addition, electricity percentage savings for electrically heated homes are expected to be uniformly lower than natural gas percentage savings for gas heated homes, since homes use electricity for so many purposes in addition to space heating, and these other uses of electricity are not affected by weatherizing the home.

Recommendation: We recommend that a small subset of weatherized electrically heated homes be a focus of subsequent evaluation work to develop the factors that are restraining the percentage gross energy savings, and to see if savings can be systematically raised. We suggest that this subset of homes be analyzed using EZ Sim, to determine their potential for energy savings.

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[54] Neither the Washington evaluation, nor the national metaevaluations break out manufactured homes for reporting.

[55] Schweitzer (2005), Appendix B, P. 30.

[56] Only six states reported study results, so the nine percent (9%) result for the metaevaluation is an expression of these six data points.

REALIZATION RATES

A realization rate is a ratio of the measured energy savings to the expected energy savings. In the analysis of whole-house realization rates in Section 7 (Pp. 43-44), it was found that, overall, measured energy savings are about one-third of expected savings from the program. For single family electric heat homes, the realization rate was thirteen percent (13%); for manufactured homes with electric heat, the realization rate was thirty percent (30%); for manufactured homes with gas heat, the realization rate was 29%; and for single family homes with gas heat, the realization rate was forty-five percent (45%).

In an early comprehensive study of realization rates, Nadel & Keating found residential realization rates in the range of twenty-two percent (22%) to one-hundred and seven percent (107%) across eleven residential programs of different types.[57] Results clustered in the range of 22%-45%, with two high outliers. The simple average was 48%. In the Pacific Northwest, in the early 1980's the Bonneville Power Administration (BPA) introduced a model called the Simulated Heat Loss Methodology (SHLM), a simple model that was developed prior to today's ubiquitous computers[58] and less sophisticated than today's analytical tools.[59] BPA developed SHLM for utility personnel conducting on-site energy audits of residential buildings. SHLM was designed to allow utility auditors to estimate space heat savings associated with a list of approved weatherization measures. Auditors also used SHLM to estimate the financial incentive that BPA would pay for installation of measures recommended through the audit.

During the early through middle 1980's this model was used to estimate energy use and potential energy savings in the region's residential energy conservation programs. Over the 1980's it was learned that SHLM was not accounting correctly for conditions in homes including use of wood heat. It tended to systematically over-predict energy savings, thus leading to low realization rates. This did not cause a problem for BPA because load analysts systematically discounted SHLM results before incorporating

57 Nadel, Steven M. & Kenneth M. Keating, "Engineering Estimates vs. Impact Evaluation Results: How do They Compare and Why?" Washington, D.C.: American Council for an Energy Efficient Economy, 1991.

58 PCs were just coming into business use in the early 1980s, and truly portable computers had not yet been developed.

59 Discussion of SHLM draws from a review by Mark Cherniack, included as an appendix.

them in the forecast. However, on an individual home basis, SHLM caused poor realization rates. Nevertheless, it remained a useful program tool for determining the measure package for each home.

These examples are noted to indicate that the problem of realization rates is one of long standing in the area of residential weatherization programs. Today, the Oregon Weatherization Assistance Program uses REM/Rate™ software to estimate space heat savings associated with a list of approved weatherization measures. Used alone, REM/Rate™ systematically over-predicts energy savings, the same problem experienced with SHLM, and (as indicated in the Nadel & Keating study) a problem built-in to all modeling efforts not “trued-up” to direct energy usage information for the prior year. To correct this problem, we recommend that a “true-up” with one year of energy use data be used to adjust the REM/Rate™ estimate (or other similar estimate) of energy savings to the actual use of the home. This type of adjustment was recommended by Nadel & Keating, and the evaluators recommend it here to eliminate the realization rate problem prior to the agencies reporting results.

Recommendation: Use twelve months of energy usage data to true-up expected savings estimates, prior to reporting expected annual energy savings.

X. PROGRAM ACCOMPLISHMENTS

As analyzed in Section 2, the Oregon Weatherization Assistance Program is meeting its legal obligations in the area of participation goals. However, given this accomplishment, needs are dramatically increasing while goals remain fixed by the federal enabling legislation for the program and the current expression of Oregon goals and objectives.

MEETING LEGAL OBLIGATIONS & INTENDED GOALS

The Weatherization Assistance Program is meeting is legal obligations and intended goals, as defined by program legislation, the specifications of the annual State of Oregon Weatherization Assistance Plan (Plan) submitted to the United States Department of Energy, and the specific goals established each year and included in the Plan.[60] In particular, the Oregon Weatherization Assistance Program has a holistic emphasis which includes a major focus on health and safety, and a realistic approach to repairs required in much of the low-income portions of the Oregon housing stock.

When properly valued, along with weatherization improvements, the program is unmatched as the best vehicle for addition of utility, fuel fund, or other funding.[61] At the same time the program is not an entitlement program, but runs each year subject to available funding. The substantial need for the program relative to the available funding from all sources has led to a five year waiting list for service for some of the subgrantee agencies.[62] Although the program is meeting its legal obligation and intended

[60] Title 10, §440.1, Purpose and Scope, reads as follows: "This part implements a weatherization assistance program to increase the energy efficiency of dwellings owned or occupied by low-income persons, reduce their total residential expenditures and improve health and safety, especially low-income persons who are particularly vulnerable such as the elderly, persons with disabilities, families with children, high residential users, and households with a high energy burden."

[61] A superficial analysis will sometime suggest that private weatherization services will obtain higher energy savings at lower cost. However, this type of analysis does not take into account the benefits of a coordinated program, and when higher savings are achieved it is primarily due to a "silo" focus on energy savings that does not adequately address health and safety or needed repairs, replacement furnaces, or the like. For the treatment of costs and benefits in coordinated programs, see Lawrence J. Hill & Marilyn A. Brown, "Estimating the Cost-Effectiveness of Coordinated DSM Programs," Pp. 181-196, *Evaluation Review*, 19:2, April 1995.

[62] If an agency seems to have a short waiting list, it is likely that this is an artifact of a special local definition of "waiting list." Some agencies redefine their waiting list to begin with approval of work. This is

goals, it should be significantly ramped up to better meet the actual needs for home weatherization in Oregon. The gap between need as recognized under definitions provided in the federal authorizing legislation and the material need of Oregon households is large.

ASSESSING NEED

In planning for need, a central tool in evaluation is a "needs analysis." In a needs analysis, we take a fresh look at the material need that actually exists for the program. This differs from the analysis in Section 2, since we look at need from a broader perspective than the current authorized eligibility criteria.[63]

We first review resource constraints and socioeconomic constraints to "go outside the box" and assess the general picture of increasing need in a holistic sense. Based on this information, material need for weatherization and related services reaches much higher into the distribution of income than current eligibility levels. Real income is continually being removed (in the forms of income, job-related benefits, and social transfers) from households in the bottom eighty percent of the income distribution. This creates an ongoing process of increasing need, with no factors on the horizon to turn the process around.

In the area of weatherization services, Oregon has freed itself from the corrupt metric of the federal poverty standard. Setting eligibility at sixty percent of state household median income is a significantly progressive step, and authorized within the federal legislation that provides the grounding for the Weatherization Assistance Program. However, family budget studies provide the best methodology for setting fair eligibility levels, in the sense that eligibility then actually matches need as experienced by households. To explore the gap, we review the findings for eligibility developed from family budget

understandable from a management perspective. However, a client understands the wait list as beginning from first contact with the agency.

[63] Both perspectives are useful. In Section 1 we ask the question of how well current production is proceeding in relation to the number of eligible clients and conclude that substantial additional funding could easily be employed by the program to serve existing eligible homes. In Section 10 we look additionally at other households that require weatherization services since the existing income eligibility criterion was set prior to the current situation of diminished real household incomes and substantially increasing energy costs.

studies. At the same time, we show how removal of the systematic biasing of the construction of the Consumer Price Index since the middle 1960s indicates the same result. With the gap established, we provide an estimate of the number of qualifying households if eligibility is raised to the level of actual need.

STATEMENT OF THE TIMES: PHYSICAL AND SOCIOECONOMIC LIMITS

Physical limits are treated in standard economic textbooks as a special case. We are now living this special case of economics in the area of energy supply, so conventional market models for energy production and distribution are not the correct models to use in understanding our current situation.

A second difference from the conventional economic market model is that real income continues to move from the bottom eighty percent of households to the upper five percent and especially the upper one percent and above.

These differences create two sets of critical forces, on the one side physical and on the other socioeconomic. Both sets of critical forces are driven by several factors that combine and reinforce our situation of ever increasing need.

PHYSICAL RESOURCE CONSTRAINTS

The energy sector is currently experiencing a problem of physical limits. In this situation, physical laws dominate economic production possibilities. The production of the necessary amount of energy (of different forms) at reasonable cost to meet essential demand of industry, business, and residences is increasingly problematic.[64]

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64 The situation in which physics (material reality) dominates economic realities and beliefs is a special area of economics, which requires central engineering planning of production and state direction of distribution because markets fail. The type of market failure is a distribution failure because costs rise to the point at which they cannot be met under the market system of income distribution. The continuing rise in cost is due to market failure on the production side as resource limits are approached and easy to secure stocks of energy sources such as coal, gas, and oil are used up without the possibility for replenishment. See Georgesçu-Roegen, Nicholas, *The Entropy Law and the Economic Process*. Cambridge, Massachusetts: Harvard University Press, 1971. Also see Beard, T. Randolph & Gabriel A. Lozada*, Economics, Entropy and the*

- The basic constraint is that currently energy in the forms most used in the residential sector (natural gas, electricity, and oil) is characterized by increasing marginal cost of production. Each year, it takes more energy per unit of energy extracted. [65] This is the classical problem of physical limits.

- Another constraint is related to the shift over the past thirty years towards using natural gas for generation of electricity, both for environmental and competitive reasons. This has caused the natural gas and electricity supply systems to become increasingly interdependent. Gas customers are put into competition with electric generation in competition for gas supply.

- Global warming is diminishing snow pack and so leading to the weakening of the hydro system.[66] Changes due to global warming are occurring rapidly, so that within the near future (fifty years) the hydro system will likely have to be substantially re-engineered to remain functional year around.

- The “build-out” of electric supply in the US (matched by a similar build-out around the planet) is causing rapid cost escalation for new plants, with plants that are currently long-planned and now nearing construction doubling in cost in a year. With a globalized economy, the competition for scarce construction resources and experienced knowledge of plant construction are adding significantly to cost pressures on planned US generation.

- For natural gas, the US supply is declining. The current plans for reliance on liquefied natural gas, shipped from remote areas often hostile to the US, raises real security concerns and resistance to the proposed locations of LNG plants in communities.

Environment, the Extraordinary Economics of Georgesçu-Roegen. Cheltenham, UK & Northampton, Massachusetts: Edward Elgar Publishing, 1999.

[65] See Odum, Howard T. & Elizabeth C. Odum, A *Prosperous Way Down, Principles and Policies*. Boulder, Colorado, The University Press of Colorado, 2001.

[66] Welch, Craig, “Global Warming Hitting Northwest Hard, Researchers Warn,” *Seattle Times*, Saturday, February 14, 2004; Luers, Amy Lind, “A Tale of Two Futures, California Feels the Heat,” Pp. 8-9, *Catalyst*, Fall 2004.

- The nuclear waste disposal problem has not been solved. Also, many nuclear plants have, for cooling purposes, been located in areas susceptible to global warming effects as sea levels rise.

- "Clean coal" isn't clean and the federal public/private clean coal demonstration has been shut down due to cost problems.[67]

- The carbon cost from the output of carbon dioxide and related gasses is not yet charged back to producers and remains externalized (to be covered the rest of society). Apparently, solar energy would be economic if the true costs of fossil fuels were charged to producers; however, when it happens, likely within the next decade, this will significantly increase energy costs to households and lead to major problems of ability to pay.[68]

SOCIOECONOMIC CONSTRAINTS

There are also a set of simultaneous socioeconomic constraints that further modify the energy supply problems:

- Population continues to grow, causing pressure on the technical capability of energy supply in a situation of inherent scarcity, driving up price.

- Corn crops are currently under competition between automotive uses and use for food. Market forces caused by the push towards biofuels are diverting production from grain and other crops, leading to lower supplies and rapid increases in food prices globally, so that about half of humanity is now food insecure. There have been recent food riots in several countries and in the US food banks are unable to sustain previous levels of donations as need increases for food due to sustained loss of income relative to food costs.

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[67] Revkin, Andrew C., "A 'Bold' Step to Capture an Elusive Gas Falters," *New York Times*, February 3, 2008. See also, Pasternak, Judy, "Global Warming Has a New Battleground: Coal Plants,", April 14, 2008.

[68] A major sector of the electric utility industry is campaigning to have the carbon cost introduced into the basic economics of energy industry, although they are looking for a carbon market to establish the carbon price rather than an engineering analysis.

- A growing interaction of natural gas and electricity use occurs for customers having difficulty paying gas utility bills, who tend to substitute electric heaters for a gas furnace when the gas is shut off. This pattern links underpayment and shut offs of gas service to eventual underpayment and shut offs of electric service.

- A consequence of resource constraint is long-term increase in energy prices. It becomes increasingly difficult and then impossible for increasing numbers of customers to be able to pay for the energy required to maintain an acceptable standard of living.

- Since approximately 1970, real income has been shifting in favor of the richest segments of the income distribution (the upper five percent of households by income, but especially the upper one percent of households by income and above the upper one percent).

- With the decline in the power of labor unions since approximately 1970, and especially as a function of the globalization of the economy, workers have been put to a severe disadvantage. Income has transferred away from households in the bottom eighty percent of the income distribution to the upper five percent, and especially to the upper one percent and above.

- In Oregon, the top 1.5% of households by income received about 5% of Oregon household income in 1990 and about 9% in 2000. Radically rising income inequality parallels inequality in ownership and wealth, weakening the labor/business social compact that developed after World War II and undermining democratic institutions. This process is continuing.

- As shown in Figure 4, the Oregon “Income Donut” for Census 2000 data reveals that households in the bottom twenty percent of Oregon household (by income) received about five percent (5%) of total Oregon household income. At same time, households in the top quintile received forty-five percent (45%). The income donut indicates why low and middle income families have trouble paying bills for energy, prescriptions, medical services and other essential needs. With the real value of household income declining for many, it is simply not possible to pay necessary bills with this distribution of income for households and families on the bottom and for an increasing number of households and families in the middle.

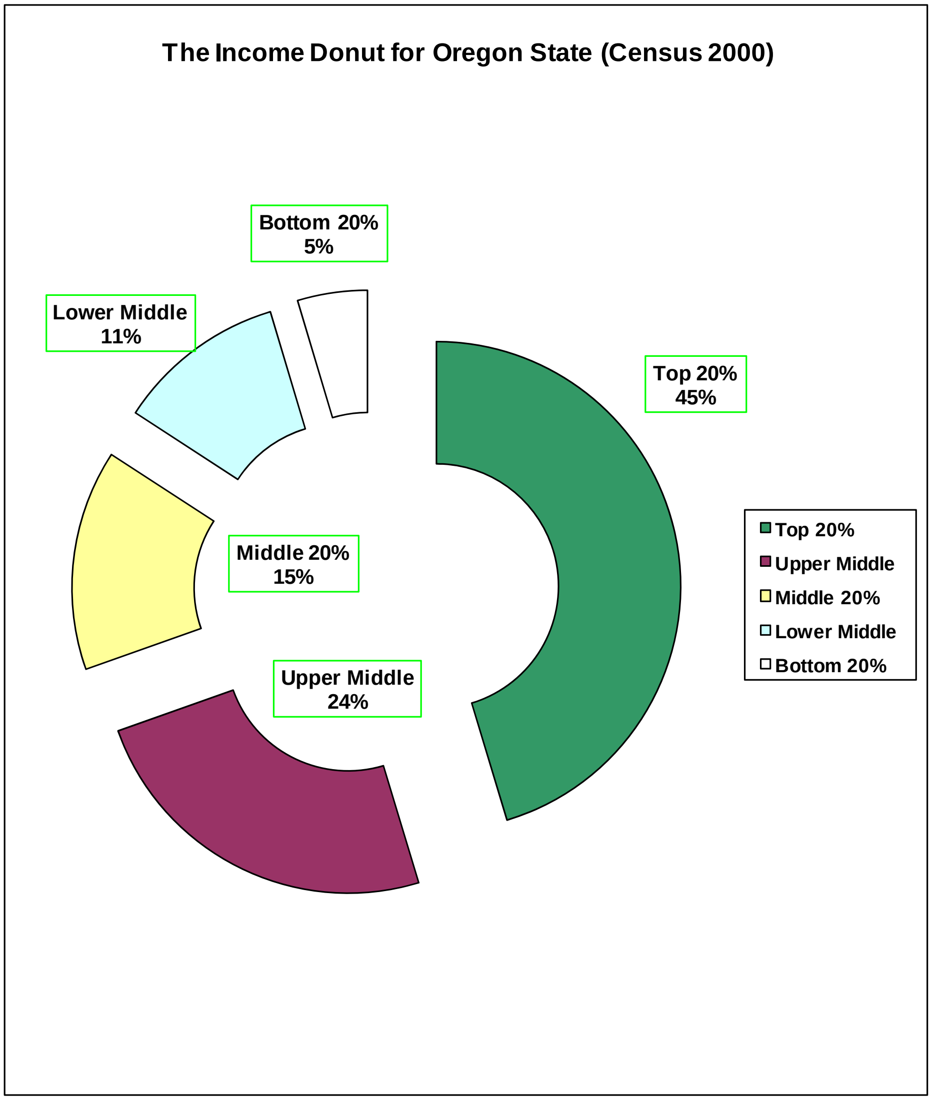

Figure 4: Oregon Income Donut.

- In particular, families with children (including middle-class families) have been losing real income from year to year (compare Figures 5 & 6).[69]

[69] Figures 2 & 3 are based on our analysis of data from the Center for Budget and Policy Priorities. See the series of "Pulling Apart" studies conducted by the Center for Budget and Policy Priorites (http://cbpp.org/).

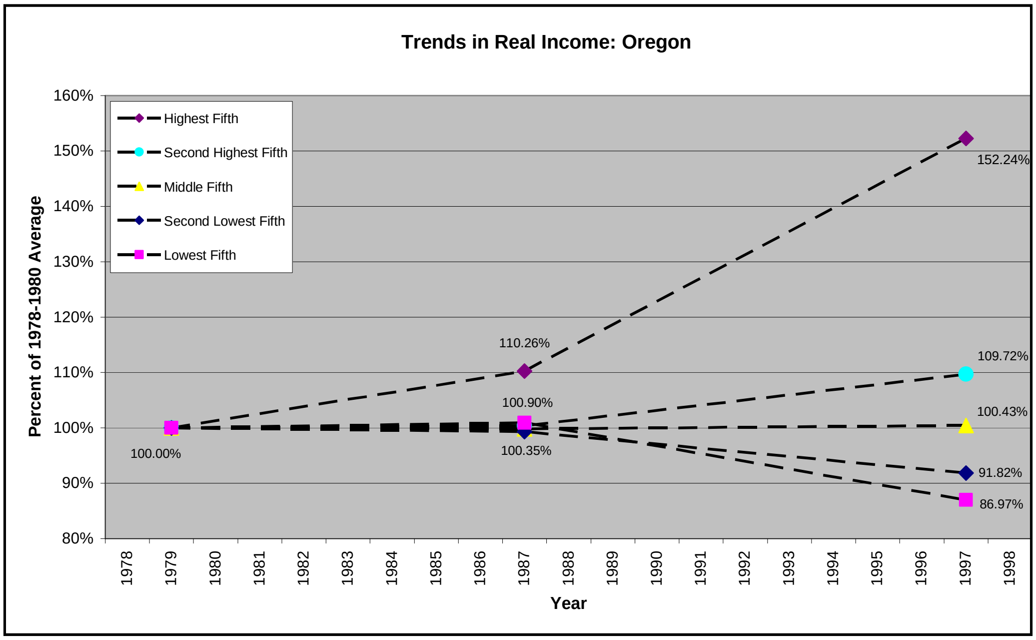

Figure 5: Income Trend - Oregon Families.

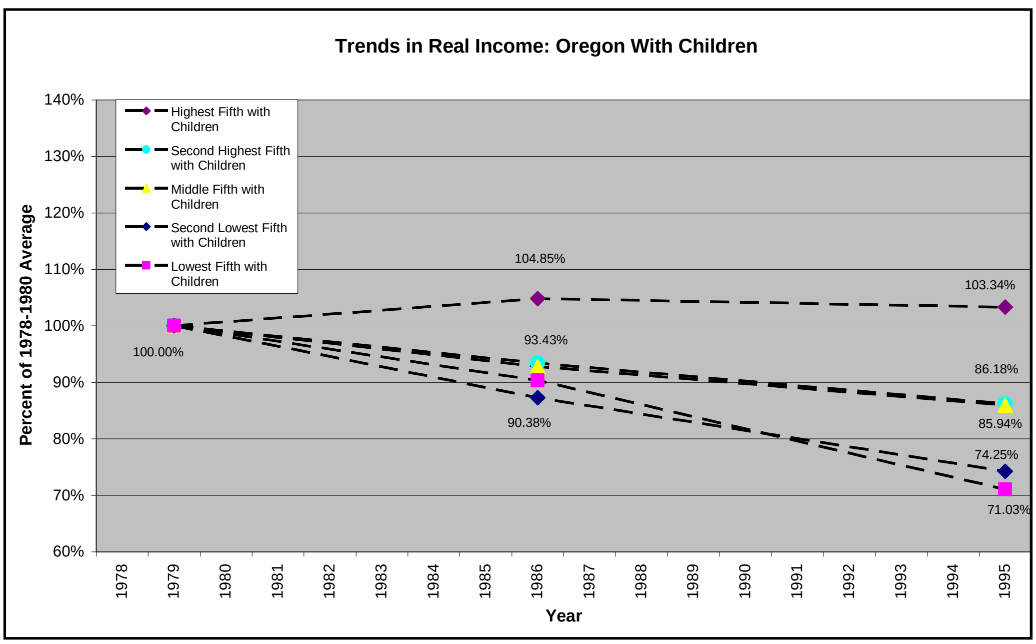

Figure 6: Income Trends - Oregon Families with Children.

- The loss to families with children follows from the increasing transfer of social costs associated with children for payment by their families. This change affects families at all income levels, but particularly families in the bottom eighty percent of the income distribution.

OFFICIAL STATISTICS

At the level of official statistics, it may initially appear that ability to pay is not a growing problem since, according to government statistics, until very recently poverty has been declining. At the same time, since about 1970, and also according to the official statistics, economic inequality has been radically increasing. Figure 7 is a picture of the stories of declining poverty and radically increasing inequality based on official (Congressional Budget Office) statistics.[70]

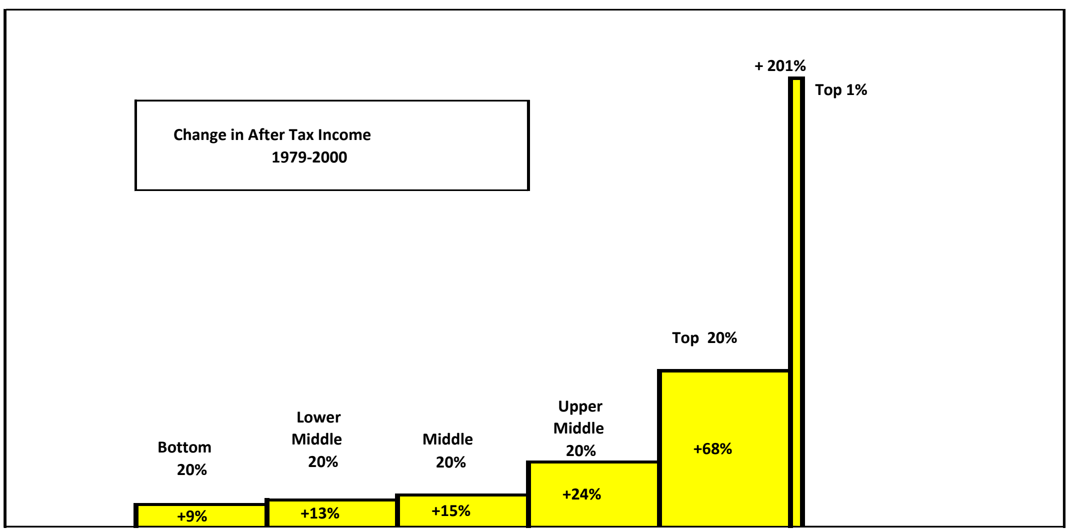

Figure 7: The Official Picture: Decreasing Poverty and Increasing Inequality.

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70 Frank, Robert H., *Falling Behind, How Rising Inequality Harms the Middle Class*. Berkeley, Los Angeles, London: University of California Press, 2007, Pp. 9-10. This figure taken from Greenstein, Robert & Isaac Shapiro, "The New, Definitive CBO Data on Income and Tax Trends," Center on Budget and Policy Priorities, September 23, 2003. Posted online as Figure 1, at www.cbpp.org/9-23-03tax.htm.

In Figure 7, the after-tax income of the bottom 20% of households increased about 9% from 1979 to 2000. In the same period, the increase in after tax income for the lower middle quintile of households by income was 13%; the upper middle quintile increased 24%; and the top quintile increased 68%. During the same period the income of the top one-percent of households increased 201%. The increase for the upper one-tenth of one-percent (not shown) is fantastically higher than these numbers.[71]

The official picture is that while, clearly, those who have more receive more and those who have less receive less (an increase of 200+% for the upper 1% of households, and an increase (on the radically smaller base) of 9% for the bottom quintile of households by income, all groups of households in the picture portrayed by Figure 9 experienced an increase in income.

First, however, note that while the "sound bite" analysis is "income is up," what is really happening is not actually as good as that sounds. In August 2007, the US Census Bureau released data showing that median income increased in 2006, and about that time both radio and TV news reported that "income is up" and "poverty is down."[72] But there is a lot wrong with this picture. In the New York Times article headlined "Modest Rise in U.S. Income," there is contrasting information:

- The percentage of people without life insurance hit a high;
- There is job growth and there are more hours of work, but pay is lower;
- Low and middle income families are not sharing in the gains.

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[71] Whenever income differences are analyzed, it is reasonable to ask about the underlying distribution of wealth. Based on the Federal Reserve's Survey of Consumer Finances, Robert Greenstein reports that about one-third of all wealth in the US is held by the upper one-percent (1%) of households, another on-third is owned by the nine percent of households just below this group, so two-thirds of all wealth is owned by the upper ten percent (10%) of households. The remaining third is owned by the lower ninety percent (90%) of households. Greenstein, Robert, "Testimony of Robert Greenstein, Executive Director, Center on Budget and Policy Priorities, Before the Ways and Means Committee, October 29, 2008. Washington, DC: Center on Budget and Policy Priorities.

[72] Goodenough, Abby, "Census Shows a Modest Rise in U.S. Income," New York Times, August 29, 2007.

At the same time we know a number of other facts that contradict the official picture:

- "Extenders" are being increasingly used in food products.
- The contents of food packages are being shorted, though with inventive rationales – smaller portions (at the same or higher price) will promote health.
- Loss of homes due to inability to pay on mortgages is at a high point.
- Consumer debt is at a high point, and increasing.
- Most federal government human services have been "hollowed out," and while they function they have minimal staff capability to control, innovate, or deal with emergencies.[73]
- Student loan debt is at a high point, and many students today have difficulty paying back their school loans before their own children need school loans.
- About twenty percent of Oregon people are not covered by health insurance, causing a number of deaths each year.
- Typically young people today cannot look forward to the same level of living as the family they grew up in, unless their family is near the top of the income distribution.

All of these factors tend to cast doubt on the government statistics and their official interpretations. For the bottom quintile of households by income, an increase of nine percent (9%) in Figure 7 on a base of approximately five percent (5%) in Figure 4 amounts to an actual increase of just under one-half of one percent of Oregon household income (0.45%). While an increase of 9% on 5% is better than nothing (if it were true), it is not much different than nothing as energy, mortgage, food, and medical bills increase.

This is as far as we can go while staying within the limits of official statistics: the images conveyed by messages from the federal government about income are not true. Real improvement for the bottom quintile did not get delivered. However, as we go deeper than official analysis, the true situation is one of deterioration of real income.

[73] Grieder (1997) introduced the "hollowing out" terminology for what is happening to the economy and to government. Currently, federal human services, including consumer product safety and food inspection are ramshackle affairs, so defunded and functionally de-authorized through short staffing and reporting arrangement that they barely function, or in some cases only present an appearance of function.

TOWARDS REALITY

To this point, we have remained within official statistics. The interpretation to this point could be more correctly made with strictly Oregon data, rather than using a mix of Oregon and US data (and different types of data), though the picture would look the same. The picture developed here is a true one although it is an approximation. One more step is needed to understand why the pictures presented by official statistics on what is happening to income are misleading.

Consider that official unemployment statistics systematically understate unemployment, as is taught in every advanced economics class and in graduate economics courses.[74] Similarly, consider how official employment statistics do not register employment in a way that has basic integrity in making sense to working families.[75] The government numbers do not track employment that offers a living wage, has decent medical benefits, and a defined benefit pension.[76] Given the poor representation of experienced reality and impediments to communication in these two examples having to do with employment and income, it is unsurprising that the Consumer Price Index (CPI) has had so many technical adjustments that make things look better than they are that it is highly divergent from the early Consumer Price Index. Figure 8 shows the divergence of the official consumer price index (CPI-U) from the same index calculated according to the rules and conventions for the index in effect through 1983 (SGS Alternative CPI). In this Figure, the upper curve is the alternative CPI and the bottom curve is the official CPI.

[74] As a rule of thumb, economists know to double whatever the Bureau of Labor Statistics says is the unemployment rate. If the government says it is 6%, it is actually about 12%. If the official unemployment number is 5.5%, the real number is about 11%.

[75] A fact that is usually overlooked in orthodox economics courses, where the official definition is represented as simply a technical definition.

[76] If employment was tracked that way, the numbers would show the US currently in a national severe job-shortage emergency. That is, in commonsense real jobs with real pay and real benefits similar to the job structure of the middle 1960s.

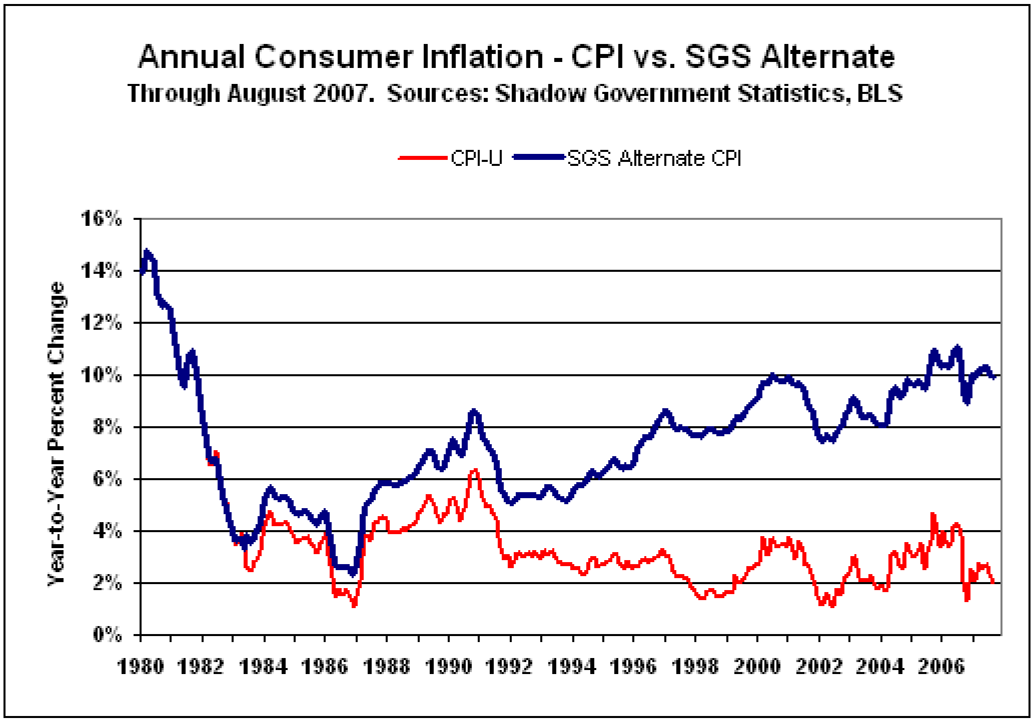

Figure 8: Divergence of the consumer price index.

Note that the two curves are the same from 1980 through 1983 and then begin of diverge as an increasing number of technical adjustments are introduced.[77,78]

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77 Many of these technical adjustments have to do with changes in the market basket of goods that is monitored by the CPI. A standard problem with any kind of price index is that over time some goods are no longer available in the market and are replaced by other goods (black and white TV sets are replaced by color sets; ordinary TVs are replaced by high definition TVs). Because such replacements tend to have more features or be of higher quality, the standard theory is that without corrections a price index would tend to have an upward bias. The technical adjustment is that if the new good may in theory produce more pleasure that the old market basket item for which it is substituted, the price index is corrected by disregarding the part of the price related to the increased pleasure. These hedonic adjustments can produce situations in which an actual price increase is represented by a price decrease for an item in the basket. They also do not take into account the forced nature of some of the "choices" (for example, one may not care to pay for a new high definition TV set if the televised content represented in high definition is as poor as it was before the requirement for high definition – one makes this "choice" by order of the federal government). There are several other problems with the CPI, in particular the way it leaves out actual costs faced by families. For example, it deals with housing costs as equivalent rental value, causing the index to miss the problems in the housing markets of the last several years, even though these have been major realities in household budgets. Then, too, the government and most news programs that follow government scripting for release of

If the SGS Alternate CPI (the CPI as calculated by the government through 1983, but extended to the present using the same method) is true, then everything adjusted by the CPI is now off by a factor of two. That is, for example, every Social Security check is written for about one-half of the value it would have been written for without the series of changes in the method of calculation. This fact, in itself, explains much of the problem of inability to pay energy bills (while balancing other necessary services like medical care, prescriptions, food and housing).

The “factor of two” pattern cuts through many economic relationships; for example the better wage contracts are generally tied to the CPI, and these set the precedent for other wage relationships. If wages were raised to near doubling for the first three quintiles of households (including near doubling of every social security payment) we would return to the capital/labor relationships of approximately 1965 and most energy payment problems would automatically disappear. The “factor of two” is a workable principle for correcting federal poverty misclassifications.

This factor of 2 shows up in other places.

- For example, for low and moderate income families attaining the same level of living as in 1965 takes about twice the labor hours by family members.
- Also, for middle income families, for the most part today, two incomes per family are required to attain approximately the same level of living that was provided by one income in 1965.

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government statistics ask us to disregard the CPI and focus on the “core CPI” which leaves out energy costs (because energy costs are volatile), a recommendation that would not make sense for analyzing ability to pay for energy. While many technical adjustments to the CPI can be argued on academic grounds one way or the other, the general shape of these changes is captured in Figure 6, developed by John Williams (see note below).

[78] The chart show as Figure 3 and the SGS alternate index have been developed by John Williams and are presented in his writings and website, Shadow Government Statistics, Analysis Behind and Beyond Government Economic Reporting (http://www.shadowstats.com/cgi-bin/sgs/data).

Taken together these are equivalent to a wartime labor mobilization, and represent a major transformation of the economy against the interests of families since 1965.

Two further examples illustrate how far the federal poverty metric is corrupted and suggest that when institutions fully come to grips with material affordability problems a very different scale must be used, which puts need at a multiple of the federal metric.

- The situation for weatherization is identical to the problems of income eligibility in the area of public health. In the recent debate over extension of the State Child Health Insurance Program (SCHIP), the proposal sent to the President (and vetoed) requested an extension that would fold in state choice to increase eligibility for child health insurance by multiples of the poverty level at the initiative of individual states. Many states already operate the program at above two-hundred percent (200%) of poverty. California operates the program at two-hundred fifty percent (250%) of poverty and planned to move to three-hundred percent (300%). New York, operating at two-hundred fifty percent (250%) of the federal poverty level wanted to move to four-hundred percent (400%). New Jersey has been operating at three hundred fifty percent (350%) for several years. Pennsylvania runs the program at three hundred percent (300%) of the federal poverty level. These are generally the same households that need utility payment assistance and residential weatherization services.[79]

- Given the great increase in income inequality in the US, a mathematical recalibration of the federal poverty level to its original relation to the level of median income would lead to a criterion that is approximately twice the current criterion, that is, what is now two-hundred percent (200%) of poverty would be the basic poverty level. A similar calculation based on relation to mean income would place it much higher.

[79] SCHIP information from: Pear, Robert, "Rules May Limit Health Program Aiding Children," *New York Times*, August 21, 2007.

- Also, leading private universities have recently announced tuition waivers for qualified undergraduates from what most of us would think of as middle income families. Harvard has announced waiver of tuition for students from families earning $60,000 per year or less. At Stanford, tuition is waived for families earning $100,000 per year or less, and most room and board fees will be waived for families earning $60,000 per year or under.[80]

These examples illustrate the need to break away from the corrupt federal poverty metric and re-center our scale based on material need rather than outdated and abstract federal poverty definitions to deal with actual income insufficiency as experienced by households.

FAMILY BUDGET STUDIES

To deal with the failure of the federal poverty metric to reflect material need, a new standard method has been developed. The self-sufficiency standard is relatively new and not yet reflected in law. However, it is based on one of the earliest measures of poverty used by sociologists and social workers – the family budget. Family budget studies track actual budgets for families of different sizes and compositions in their actual institutional relationships (getting the children ready for school and paying school fees, getting to work, the costs of dressing for work, the actual cost of child care, actual medical and prescription costs, real energy bills, etc.). Thus, the family budget study reflects the real economic situation of a household.

This method is far more accurate[81] and valid[82] than the old federal poverty metric. The federal poverty metric is based on an invalid assumption about the relation of the cost of food to all other costs, the assumption that all families are two parent families with one stay-at-home adult, and a set of other assumptions that were more accurate in the 1950s but are very unrealistic today. The self-sufficiency

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[80] Glater, Jonathan D., "Stanford Set to Raise Aid for Students in Middle," *New York Times,* February 21, 2008.

[81] In the sense of conforming to fact.

[82] In the sense of measuring material need.

standard comes much closer to representing the actual needs of households and families than the federal metric.[83] Table 25 shows typical cost categories included in the family budget method.

Cost Categories (per Month)
Housing
Food
Child Care
Transportation
Health Care
Other Necessities
Taxes
Annual Total

Table 25: Example Cost Categories in the Family Budget Approach.

At the same time, the family budget study method leaves out certain expenses such as a car, the ability to deal with other than minor medical problems, money for a child to attend college, or the ability to put aside some savings toward retirement. These are all reasonable needs and part of normal expectations in our society. When these costs are added in, and translated into federal poverty level, the reasonable upper limit for current program eligibility should be set at least at eighty percent (80%) of state median income, the current Department of Housing and Urban Development (HUD) upper limit of eligibility for public housing.[84]

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83 This method was developed by Wider Opportunities for Women (WOW) with the Ford Foundation, and studies have been carried out in most states and in many counties and cities. For an Internet calculator for basic family budgets and downloadable state tables, see the Economic Policy Institute website (http://epinet.org/content.cfm/datazone_calculators). For an explanation of the methodology, see Allegretto, Sylvia A,. and Yulia Fungard, Family Budget Technical Documentation (http://www.epinet.org/datazone/fambud/fam_bud_calc_tech_doc.pdf).

84 Eighty percent (80%) of state median income is the HUD low-income level.

On P. 13, in Table 2, the estimate of households eligible for Oregon WAP as show about 400,000. On P. 14, in Table 3, the estimate, calculated using a different approach, was 435,000 at the current eligibility guideline of sixty percent (60%) of state median income. Using this second approach, the number of households eligible for Oregon WAP if the eligibility cap were to be moved up to eighty percent (80%) of state median income would be about 579,865 which may be rounded to 580,000.[85] This would be an increase of 145,000 households.

Why increase the target for homes to be served, when the current program capability is a small fraction of eligible households each year? The answer is that the actual need in Oregon is approximately up to and including eighty percent (80%) of median income (the upper level of US Department of Housing and Urban Development eligibility for access to public housing). There are also some households above that level that need weatherization and are unable to provide it. Logically, a needs analysis stands alone, separate from capability. Need has dramatically increased since the sixty percent (60%) of median criterion was put in place.

The eighty percent (80%) of median income eligibility rule is not acceptable within the scope of current federal authorizing legislation for WAP, though it could be included at Oregon initiative using non-federal funds. In some states, separate "Gap" programs are being created to help cover working families.

In addition, the program requires flexibility to address situations above eighty-percent of median income where households face emergency situations. The type of flexibility required is indicated in Figure 9. This figure contains the lowest tier of a low-income tariff ("CAP Rate") adopted by PECO Energy, Division of Exelon , which serves the City of Philadelphia and parts of outlying counties. While this tariff is restricted to fixed bills with no penalties, fees, etc. for customers below twenty-five percent (25%) of the federal poverty level, the basic concept underlying this rate is that

[85] The number of Oregon households in 2007 (1,449,662 +/- 7,388), is taken from the American Community Survey on the Bureau of the Census website using American Factfinder.

households encountering extenuating circumstances may require service. For these households, the tariff temporarily reduces energy bills in part due to extenuating circumstances.

CAP A - PECO Cares Program : Customers with annual household gross incomes at or below 25% of the Federal poverty income guidelines with documented extenuating circumstances will be eligible for CAP A which provides for Residential Rate R customers a nominal bundled rate of $12/month for all usage up to 1,000 KWH; for usage above 1,000 KWH the CAP D rate structure will apply. For Residential Heating customers Rate RH, CAP A provides a nominal bundled rate of $30/month for all usage up to 2,000 KWH in the Winter, 1,000 KWH in the Summer1; for usage above 2,000/1,000 KWH the CAP D rate structure will apply. Extenuating circumstances shall include those individuals who demonstrate an inability to pay the billed rate of CAP B as a result of unique circumstances such as:

- Health related matters:
    - Injury or illness
    - High medical bills
    - Medically related usage
    - Death in the family
- Sudden loss of employment
- Households that include at risk individuals such as:
    - Children below 8 years of age
    - Disabled persons
    - Infirm elderly
- Inability to maintain at least two CAP B payment arrangements
- High usage related to shelter conditions which are not treatable by [Weatherization]

Figure 9: Extenuating Circumstances.

Translating this tariff language over to weatherization, the list of extenuating circumstances provides some example language for creating exceptions. Exceptions could be authorized for households of any income experiencing a set of defined extenuating circumstances such as the list provided in the PECO Cares Program "CAP A" tariff.[86]

[86] The PECO tariff is at http://www.exeloncorp.com. Search for the "CAP A – PECO Cares Program" in the tariff.

Table 26 shows the more detailed eligibility level for the current program (Columns 5 & 6) and the levels for the program run at eighty percent (80%) of state median income as defined by HUD. In terms of the federal poverty metric, the current program could be said to be run at about two-hundred percent (200%) of poverty; however note that it actually runs from one-hundred thirty-one (131%) for a family of eight to two-hundred thirty-eight percent (238%) for a family of one.

OREGON: 2007 HUD Income Median and 2008 Federal Poverty Level

	Poverty	HUD Est. Median Income		60% of Median Income		80% of Median Income	
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8
Number in Family	Annual Poverty Income	Annual Income	Expressed in Federal Poverty Metric	Annual income	Expressed in Federal Poverty Metric	Annual Income	Expressed in Federal Poverty Metric
1	$10,400	$41,167	396%	$24,700	238%	$32,934	317%
2	$14,000	$47,167	337%	$28,300	202%	$37,734	270%
3	$17,600	$53,000	301%	$31,800	181%	$42,400	241%
4	$21,200	$58,833	278%	$35,300	167%	$47,066	222%
5	$24,800	$63,667	257%	$38,200	154%	$50,934	205%
6	$28,400	$68,333	241%	$41,000	144%	$54,666	192%
7	$32,000	$73,000	228%	$43,800	137%	$58,400	183%
8	$35,600	$77,667	218%	$46,600	131%	$62,134	175%
Over 8 add per child	$3,600	n/a	n/a	n/a	n/a	n/a	n/a

Source: Poverty data from *Federal Register*, Vol. 73, No. 15, January 23, 2008, pp. 3971-2. Median household income computed using Dept. of Housing and Urban Development data for Oregon for federal fiscal year 2007.

Table 26: Relation of Median Income Percentages and Federal Poverty Metric.

Similarly, the level recommended in this evaluation (Columns 7 & 8), eighty percent (80%) of state median income (the HUD definition of eligibility), could be said to be roughly equivalent to two-hundred and fifty percent (250%) of the federal poverty level, but actually runs from one-hundred and seventy-five percent (175%) for a family of eight to three-hundred and seventeen percent (317%) for a family of one.[87]

[87] When income insufficiency is determined using family budget studies, it is not typical, yet still noticeably frequent for families to need help at poverty levels of three hundred and fifty percent (350%) of the federal poverty level. Such families should be included in weatherization services due to material need.

Considering that the actual future we face is discontinuous from the past, encompassing all of the interlocking and self-reinforcing disasters of global warming including rapidly rising electricity, oil and gas rates and the need to bring solar energy into weatherization programs as quickly as possible in a cost structure that supports solar energy, Oregon WAP should look long-term to serving the entire community and moving toward more aggressive weatherization measures.

Jus t as the federal poverty metric gives a completely misleading understatement of material need of Oregon households, and the assessment of need must be recalibrated, the vision we hold of the future must be adjusted to take into account the physical realities we face. Necessary infrastructure must be put into place in place over the next fifty years so that it will be there when it is needed. That infrastructure includes weatherization for all homes and the inclusion of distributed solar energy. The Weatherization Assistance Program and the Community Action Agencies are the essential agents for that job.[88] Step by step, it will be necessary to significantly ramp funding for this program area.

OPERATION IMPROVEMENTS

The agencies are highly motivated to make best use of the funding they receive. As such having funds without encumbrances would be beneficial for them. They mentioned that some of the programs have limits on the repair allowance. If the repair allowance were the same from all funding sources that would make allocation easier. In addition if the funding were fuel blind the administrative burden would also be decreased and the funds could be more fully utilized.

We asked program participants for program improvement suggestions. They suggested that reducing the waiting time, having English speaking people on the crews, increasing the timeliness of the inspections,

[88] This vision of the future is based on the Swedish model, which provides welfare to the whole community. Thus, in Sweden, every child receives medical services from birth, every family receives a payment that roughly covers the cost of raising a child, every senior citizen is entitled to assistance from a helper 'down the block,' whether needed or not. With the future we face due to carbon loading of the atmosphere and the oceans, and the initial responses generated by the automatic signaling of the business system (for example, fish stocks are rapidly depleting, so the initial response is to develop more efficient and effective technology for killing fish, etc.) moving forward with a community orientation is essential for survival.

and adding windows to the program where they are not an option would all improve the program from their perspective.

Some funding sources place restrictions on the measures that can be included, for example the natural gas funding only allows 90% efficient furnaces. Unfortunately in many low income situations a 90% efficient furnace is too large to fit into the space; this is especially true for mobile homes. In these cases the agencies would like the ability to put in an 80% efficient furnace which would be far better than the 30 – 40% efficient furnace that currently exists.[89]

The agencies also cited difficulties with the variation in programs. Each utility has its own program design. Agency staff feel that if they were involved in the design of the programs there would be greater consistency across the state in what is offered to low income participants. Currently there is wide variation in the programs across the state. If the low income programs were more consistent it would improve the CAA programs and ease the administration burden for the agencies, allowing them to complete more homes.

When asked how the Oregon Weatherization program could be improved, the OECA Executive Director mentioned two elements. The first is to create a permanent physical training center, and the second it to bring on a full time trainer. OECA is currently in the process of identifying a feasible site for a permanent training center. The OECA board has given its approval and OECA staff is searching for a site. OECA currently borrows trainers from Association Agency staff to run training courses. However, the trainers are not always available and this limits the potential class offerings OECA can offer. If OECA hired their own trainer it would increase the training capacity and the flexibility of the organization. The one full time trainer could be supplemented with borrowed staff to offer a fuller complement of classes for Association members.

[89] The reason a ninety percent (90%) furnace is required is that it is in advance of the current market alternative, the approximately eighty percent (80%) efficient furnace. Thus, it can be justified under the 1980's cost benefit logic of the DSM cost tests, such as the TRC. Putting in the eighty percent (80%) efficient furnace as a replacement is not justified in the 1980's paradigm since under market logic, there is no alternative in the market. However, furnace replace is a key and costly health and safety issue. The physics of low-income households typically require the eighty percent (80%) efficient unit. This is another example of a situation in which economic beliefs and market signals need to be trumped by physical reality.

RATIONING

Weatherization services are not currently a "right" in the sense of an entitlement. Instead, the service system is set up to work on a limited budget each year, based on the contributions of a number of agencies. The Oregon program serves about one and one-half percent of the currently eligible households each year, and follows reasonable and easy-to-understand service priorities established in federal authorization and state guidelines. It is important to recognize this as a form of rationing (as in wartime rationing of scarce goods and services) because many people assume the program is much larger than it is, and basically meets current need.

NET ENERGY SAVINGS

In Section 4, the whole house savings analysis, it was found that the annual *net energy savings* is 76 therms (13.7%) for manufactured homes with gas heat, and 1,645 kWh (10.2%) for manufactured homes with electric heat. Whole *net energy savings* house savings for non-manufactured single family homes is 130 therms (19.8%) for homes with gas heat, and 633 kWh (3.8%) for homes with electric heat.[90]

[90] Apartments were not reported in the whole house analysis, since the number of apartments in the final sample was too small to support the analysis.

XI. APPENDIX

Bonneville Power Administration's Standard Heat Loss Methodology:

What It Was and What It Was Not

Mark Cherniack, New Buildings Institute

I. Introduction

Today's critics of utility demand side management (DSM) initiatives often use data and evaluation results from DSM programs implemented years previously to suggest that savings realization rates were poor. They then conclude that the DSM programs were never cost-effective. Such a use of early program evaluation data, however, can be inappropriate. The analytical methods and models that utilities employed more than 10 years ago were less sophisticated than current analytical tools. These earlier models sometimes had fundamental limitations that reduce the usefulness of results obtained from them.

One target of critics in the DSM field has been the Bonneville Power Administration's (BPA) Standard Heat Loss Methodology (SHLM). In the early 1980s, BPA promoted SHLM as a method to estimate energy use and savings in residential weatherization programs. BPA saw SHLM as a tool for development of a residential load forecast for the region.

The purpose of this paper is to review SHLM's limitations, and to clarify its ultimate usefulness as a regional forecasting tool.

II. Background

BPA developed SHLM for utility personnel conducting on-site energy audits of residential buildings. SHLM was designed to allow utility auditors to estimate space heat savings associated with a list of approved weatherization measures. Auditors also used SHLM to estimate the financial incentive that BPA would pay for installation of measures recommended through the audit.

BPA needed a simple measurement and assessment tool for its residential weatherization program. The agency had to satisfy federal administrative requirements regarding program monitoring, and it needed something that utility auditors could easily use in the field. Auditors often came from the ranks of utility line workers with little additional experience. In addition, BPA needed a tool that utilities could administer at a reasonable cost and which customers could understand; in the early 1980s, a key driver behind utility conservation programs was customer relations.

SHLM fit BPA's administrative as well as customer relations needs. Essentially, SHLM was a checklist with a few simple calculations that allowed rank ordering of weatherization measures quickly.

The auditor reviewed the conditions of the house, identified potential conservation measures, calculated the savings potential, and multiplied the estimated savings by 29.2 cents per kWh. The calculation showed how much money the utility would pay for implementation of the recommended measures. The program allowed bundling of measures, such as an infiltration package. The program also allowed rollover of financial incentives, allocating unspent incentives from one measure to the next. Utilities participating in BPA's weatherization program liked SHLM because it allowed them to look good as providers of financial payments to customers.

III. Challenges to SHLM

Although favored by BPA and other utilities in the early 1980s for its simplicity, the SHLM methodology gradually came under increasingly direct questioning. By 1983 utilities and regulatory agencies around the country were developing new residential energy simulation models to predict baseline energy use and anticipated energy savings from DSM programs. Although empirical energy savings data were available in the residential sector from weatherization programs offered by many utilities in the region, including BPA, it was felt these data were not entirely credible. This was due in part to the small number of homes that had been evaluated pre- and post-weatherization. Major uncertainties also existed regarding estimates of baseline energy use in homes using electricity for space heating. Useful data were almost entirely absent in the commercial and industrial sectors. As a result, analysts at BPA, other utilities, and public interest groups began to raise doubts about over the usefulness of the SHLM methodology.

In 1983, the Northwest Power Planning Council (Council) released its first <u>Northwest Electric Conservation and Power Plan</u> (Power Plan) for BPA. The Power Plan called for an unprecedented and comprehensive approach for characterizing the Pacific Northwest's electricity conservation potential. For the first time anywhere, conservation megawatts were to be used to meet a portion of future load growth. The Power Plan emphasized the need for BPA and the region to expand data collection and conservation program evaluation activities. In response to concerns over SHLM, the Council also urged BPA to develop methods to more accurately estimate the region's conservation resources. The Council was looking for an analytical tool that would accurately characterize current residential space heating loads, estimate savings from weatherization programs, and provide a useful estimate of future space heating requirements following weatherization. With this information, the Council could develop its resource portfolio to meet future load growth using the most cost-effective resources. As was called for in the Power Plan:

> "Bonneville should . . . establish a certification system and training program for auditors which ensures that they will correctly apply the Plan's cost-effectiveness criteria in determining the measures to be installed in each building. *As a part of that process, Bonneville should evaluate methods of calculating energy consumption and savings.*

These methods should be suitable for use by auditors, and the most accurate method for use in the field should be chosen."[91]

IV. Comparing SHLM to Alternative Models

During the early- to mid-1980s, three energy savings models were being commonly used by the energy industry in the Pacific Northwest: DOE-2, SHLM, and SUNDAY.[92] Energy experts considered DOE-2 to be a state-of-the art building energy simulation model; it allowed an analyst to account for many input parameters. SUNDAY, a microcomputer-based energy simulation model, calculated real-time heating and cooling loads. It also allowed for user adjustment of internal and solar gains. DOE-2 differed from SHLM and SUNDAY in that it preformed hourly dynamic heating and cooling load calculations. SHLM used a degree-day based methodology modified by an empirical correction factor correlated to design heat load per unit volume. SHLM had the least flexibility among the three models in terms of being able to modify input assumptions to fit specific circumstances.

SHLM did not require the auditor to conduct a heat balance of the home to establish a heat loss value (UA). The degree-day tables it used were calibrated to 65 degrees Fahrenheit and the design temperature was fixed at 68 degrees Fahrenheit. The model did not allow for nighttime thermostat setback or changes in internal and solar gains. SHLM used a correction factor (C-factor) developed by Pacific Power and Light Company (PP&L). PP&L analysts, using a 60-house metered sample, had calculated the total UA of each house, then multiplied the UA by the difference between inside and outside air temperature over a 24-hour period to calculate the building's total heat load. PP&L analysts compared this result to the average metered use to create a C-factor. The C-factor adjusted the heat load to represent how long the electric furnace in the home had to run to match the metered consumption. PP&L compared 12 months billing data with the metered results.

The C-factor represented the average correction factor across all the studied buildings. However, the variety of conditions found in real houses did not match the average conditions assumed by the C-factor. Those conditions included closed-off, unheated rooms; large amounts of wood heat that either supplemented or supplanted electric space heat; and unpredictable occupant behavior. Although the C-factor included infiltration assumptions for the heat loss, it still could not account for solar or internal heat

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91 Northwest Electric Conservation and Power Plan, ch.10, Residential Programs: Action Item 1.5 (1983) (emphasis added).

92 Akbari, H., Connor, C., and Usebelli, A., Residential Energy Simulations in the Pacific Northwest: A Comparison of Four Widely Used Models, Lawrence Berkeley Laboratory, Energy Analysis Division, LBL 20221 (1985).

gains. The C-factor operated as if the house were in the dark with no occupants. Also, the C-factor could not account for the fact that as the UA decreases, a smaller heat load is needed.

An internal BPA review ultimately found correlations (R^2) of 0.05 for estimated versus predicted long-term average weatherization space heating savings using SHLM. The study found R^2 of less than 0.27-0.39 for predicting long-term average space heating consumption. A comparison of estimated vs. predicted C-factor resulted in an R^2 of 0.0, i.e. no correlation at all with SHLM's most important component. A comparison of estimated vs. predicted UA showed an R^2 of 0.039. Further, the estimated UA was always 40 percent less than predicted UA. This result was unexpected because SHLM UA-factors were supposed to have been corrected using deviation factors from values in the design handbooks. The study concluded that the C-factor correlated poorly with all independent variables tested, although it overestimated space heating by only 12 percent before weatherization and underestimated space heating by 11 percent after weatherization.[93] Despite the study's favorable conclusions about the amount of over- and under-prediction, the consistently low correlations for the key variables indicate SHLM's structural limitations.

The study also noted that institutional effects could affect SHLM results. Factors such as customer take-back, erroneous estimates of pre-weatherization insulation levels (especially in walls), lower post-weatherization effective insulation levels than assumed (installed ceiling insulation of R-38 ended up effectively being R-30 due to tapered eaves, recessed light fixtures, attic access, and knob and tube wiring), could all affect SHLM results. The study concluded that these variables were causing at least a 20 percent deviation between actual and predicted long term average savings. The average observed deviation in fact was 30 percent. The study's authors concluded that "methodological errors are likely present."[94]

The Council suggested that BPA adjust the C-factor to reflect more conservative assumptions (such as wood heat and unoccupied rooms) or calibrate it to actual utility bills. Council staff believed that the C-factor should have been reduced by 50 percent to account for wood heat alone.[95] Initially, BPA and the utilities were reluctant to take action because of the positive customer relations the weatherization programs provided. Reducing the C-factor would decrease the savings predicted from weatherization measures which would reduce financial incentives to customers for weatherization. Eventually, BPA did decrease the C-factor by 50 percent to reduce program costs (which had ballooned to more than $100 million per year). It made no further C-factor adjustments due to strong utility opposition.

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93 Mckinstry, M., and Busse, P., Draft Evaluation of the BPA Standard Heat Loss Methodology Using Data from the BPA Pilot Weatherization Program (1993) (document never finalized).

94 Id. at 2.

95 Tom Eckman, Conservation Manager, Northwest Power Planning Council, personal communication, July 1995.

Beyond its performance shortfalls, SHLM's results did not compare favorably with the results of other models. SHLM could predict kilowatt-hour use in homes with insulation levels at R-11 in walls, R-38 in the ceiling, and R-19 under the floor to be lower than in new homes built to the Council's Model Conservation Standards with R-27 in walls, R-38 in ceilings, and R-30 under the floor. A review of DOE-2, SHLM, and SUNDAY concluded that SHLM under-predicted heating loads by up to 50 percent. It also under-predicted energy savings from a single conservation measure by at least 50 percent. By comparison, SUNDAY was within +/- 20 percent of heating load prediction and +/- 10 percent for a single conservation measure.[96]

In addition to the methodological uncertainty over SHLM, Bonneville did not use SHLM predictions of baseline energy use and savings in its load forecasting process. A senior BPA manager stated that "[T]he heat loss methodology is primarily concerned with predicting the energy savings for single family homes irrespective of current electricity use for space heat. This is not a regional estimate."[97] This statement goes to the heart of the problem with SHLM. First, the model could not accurately estimate the current space heat use, a critical component of the savings analysis. Second, SHLM results could not forecast regional space heat loads because of the lack of accuracy in establishing baseline space heat use.

In the early 1980s, considerable uncertainty existed in the regional load forecasting process. In the 1983 Power Plan, the Council estimated annual space heat use in single family homes to be 14,140 kWh. The 1983 BPA load forecast assumed annual space heat use of 15,000 kWh; SHLM estimated 16,900 kWh, which was too high. Other baseline estimates of space heating use were confounded by increases in residential wood burning as consumers adjusted to 300-400 percent rate increases resulting from the decision to build the Washington Public Power Supply System nuclear plants. Even the Hood River Conservation Project, which paid meticulous attention to statistical data, was not immune from faulty assumptions about space heat use:

> "There was quite a stir on the Hood River Project steering committee when the initial results of the Hood River savings analysis came in and the expected savings from the higher levels of weatherization measures did not materialize. Things got tense between the environmental and utility representatives with accusations about to be hurled until it was discovered that the original baseline space heating assumptions were approximately 30 percent higher than the actual usage. With a faulty baseline established, the estimates of savings and the estimates of future space heat use were seriously in error."[98]

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96 Akbari, Connor, and Usebelli, at page 12

97 Letter to David Goldstein, Natural Resources Defense Council, from Steve Hicock, BPA, re: "Bonneville's Standard Heat Loss Methodology," March 16, 1984.

98 Mark Cherniack, former Conservation Analyst, Northwest Power Planning Council, personal communication, July 1995.

IV. Conclusions

During the 1980s, the Council recognized that the principal use of SHLM was as an administrative tool to identify and rank order weatherization measures in BPA's residential weatherization program. The model was designed to estimate differences between pre-and post-weatherization space heat use. When SHLM was developed however, energy simulation models were in their infancy. SHLM was highly structured, but limited in its predictive methodology:

> "What the Council needed was an estimate of space heat use in existing residential buildings and an estimate of the residual space heating requirement after the thermal integrity of the buildings had been improved through weatherization programs, and the difference between the two. SHLM provided only an estimate of the difference in space heat use pre- and post-weatherization. Based on estimates of post-weatherization usage, the Council could develop its forecast of what new resources, both demand and supply, would be needed to meet future load growth and the cost-effectiveness of those resources. Unfortunately, SHLM systematically underestimated both existing space heat loads and therefore underestimated residual loads. If the Council had used SHLM estimates for the regional forecast, the Power Plan would have forecast a lower demand and therefore would have recommended building fewer new resources, potentially creating a shortfall in power supply. SHLM was not the analytical tool that the Council needed."[99]

The ability to predict energy savings alone is not useful as a planning tool. The Council and BPA needed to be able to forecast future demand by knowing how changes in occupant behavior, internal gains, and other factors would affect future electricity use. SHLM was a useful program ranking tool, but limited as an energy savings predictive tool. Council staff believed that SHLM did not have the flexibility to account for different house and occupancy situations. The Council staff believed that the region needed a tool that could provide for site-specific inputs for many variables including solar gain, internal gains, room closures, and wood heat. Because SHLM could not provide regional forecasting, the Council ultimately chose SUNDAY for analyzing energy use and savings in new residential construction due to its flexibility and accuracy.

[99] Tom Eckman, Conservation Manager, Northwest Power Planning Council, personal communication, July 1995.