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EXECUTIVE SUMMARY

The purpose of this project is to summarize findings reported in the recent literature on nonenergy benefits attributable to the weatherizing of low income homes. This study is a follow-up to the seminal research conducted on the nonenergy benefits attributable to the Department of Energy's national Weatherization Assistance Program by Brown et al. (1993).

For this review, nonenergy benefits were broken into three major categories: (1) ratepayer benefits; (2) household benefits; and (3) societal benefits. The ratepayer benefits can be divided into two main subcategories: payment-related benefits and service provision benefits. Similarly, there are two key types of household benefits: those associated with affordable housing and those related to safety, health, and comfort. Societal benefits can be classified as either environmental, social, or economic.

Fig. E.S. 1 presents point estimates of the average lifetime monetary value per weatherized home resulting from low income weatherization programs for the key benefit types listed above. These benefits represent net present value estimates (i.e., estimates of the current

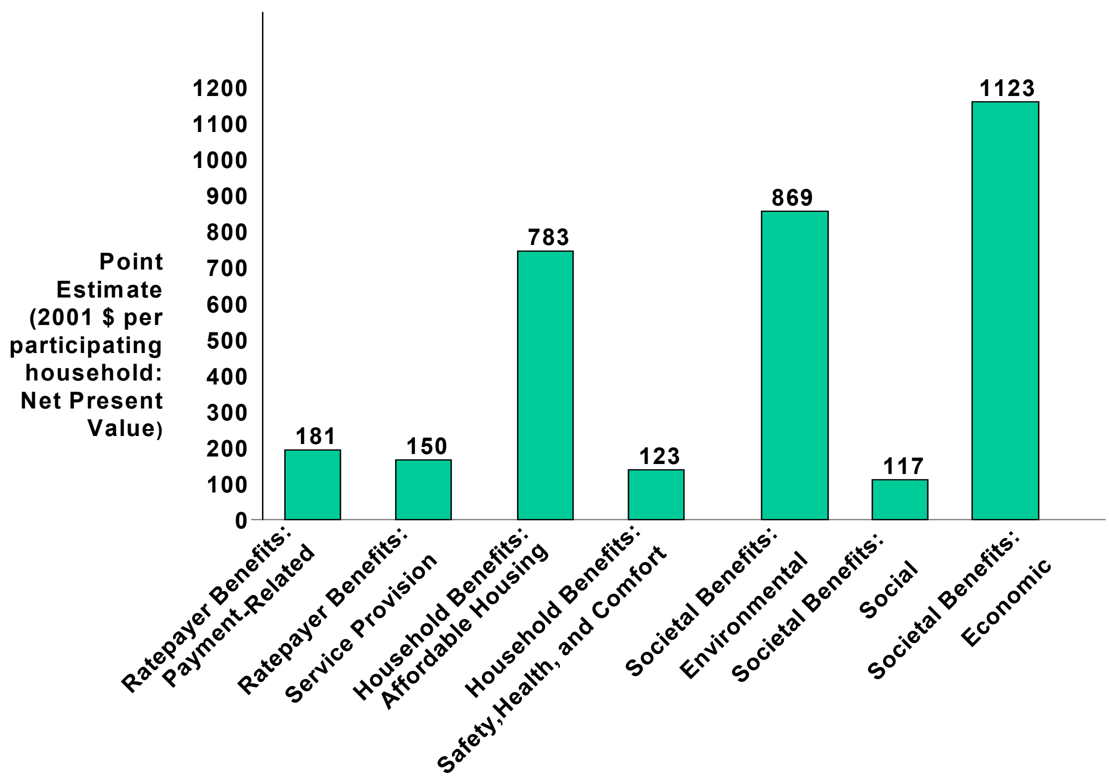

Fig. E.S.1 Summary of Nonenergy Benefits by Category and Subcategory

worth of all benefits expected over the lifetime of the weatherization measures), assuming a 20-year lifetime for installed energy efficiency measures and a 3.2% discount rate. Overall, societal benefits are estimated to be substantially larger than ratepayer and household benefits. *Ranges* for the societal benefits are also much greater than for the other two categories of nonenergy benefits. The total monetized value for all nonenergy benefit categories associated with weatherizing a home is estimated to be $3346, in 2001 dollars. This represents a national average which, like any point estimate, has considerable uncertainty associated with it. This figure is substantially higher than the total value of nonenergy benefits presented a decade ago in the national weatherization evaluation (Brown et al. 1993) because the current study quantified a much broader array of benefits than did the earlier work.

The net present value of $3346 for all nonenergy benefits is slightly greater than the average net present value of energy savings for houses heated by natural gas, which is $3174 in 2001 dollars. In comparison, the average total cost per weatherization is $1779, also in 2001 dollars. The "societal" benefit/cost ratio, which compares *all* benefits to *all* costs, is approximately 3.7. Low and high values for the societal benefit/cost ratio, using low and high nonenergy benefit estimates, are 2.0 and 52.5, respectively. It should be noted that the total monetized nonenergy benefit estimate is lower than it could be because the estimate does not contain some benefits that have not been expressed in monetary terms.

1. INTRODUCTION

1.1 BACKGROUND

The national Weatherization Assistance Program provides energy efficiency improvements for low-income residences throughout the country. The program is sponsored by the U.S. Department of Energy and is implemented by state and local agencies in all 50 states and the District of Columbia. Since its inception in 1976, the Weatherization Assistance Program has weatherized approximately five million dwelling units for their low-income occupants. Common weatherization measures include: caulking and weather stripping around doors and windows and sealing other unnecessary openings to reduce air infiltration; installing attic, wall, and floor insulation; and wrapping water heaters and pipes with insulating material. A national evaluation of the program conducted by Oak Ridge National Laboratory (ORNL) almost a decade ago (Brown et al. 1993) focused on energy and cost savings, but it also contained a detailed discussion of the nonenergy benefits associated with low-income weatherization activities. Since the time of the national evaluation, a substantial amount of research has been conducted to examine the nature and magnitude of the nonenergy benefits that result from weatherization programs. The purpose of this report is to use the findings from the large body of post-1993 research to update ORNL's previous estimates of the Weatherization Assistance Program's nonenergy benefits.

ORNL's national weatherization evaluation (Brown et al. 1993) identified an extensive range of nonenergy benefits associated with the Weatherization Assistance Program. A total of fifteen benefits were identified, but monetized values could be calculated for only about half of them. As shown in Table 1, all the monetized values combined had a net present value, over the lifetime of the weatherization measures installed, of $976 (in 1989 $).

1.2 METHODS

The primary research method used for this study was a comprehensive review of the literature on nonenergy benefits written since the national weatherization evaluation was completed in 1993. Many different articles and reports have been written about the nonenergy benefits of low-income weatherization activities since that time. Some present the findings from primary research conducted on the subject, usually focusing on a weatherization program operated by a given state or utility company (e.g., Magouirk 1995; Blasnik 1997; Hill et al. 1998). Others take a meta-analysis approach and report the findings from a number of studies conducted in different locations (e.g., Riggert et al. 1999; Riggert et al. 2000; Howat and Oppenheim 1999). One set of articles that was especially useful for this study (Skumatz and Dickerson 1997; Skumatz and Dickerson 1998; Skumatz and Dickerson 1999) focused on two

Table 1. Nonenergy Benefits Monetized in National Weatherization Evaluation (1993)

Nonenergy Benefit	**Net Present Value of Benefit per Dwelling (1989 $)**
Enhanced property value and extended lifetime of dwelling	126
Reduced fires	3
Reduced arrearages	32
Federal taxes generated from direct employment	55
Income generated from indirect employment	506
Avoided costs of unemployment benefits	82
Environmental externalities	172
Total of all nonenergy benefits	**$976**

low-income weatherization programs operated by Pacific Gas and Electric Company (PG&E), using primary data pertaining to those programs and also making use of important findings from a comprehensive review of studies performed by other researchers elsewhere in the country. Because much of the information analyzed by Skumatz and Dickerson came from a variety of locations, and because the PG&E programs they studied are very similar to other full-scale weatherization efforts undertaken throughout the country, the findings from the Skumatz and Dickerson articles are considered broadly applicable to DOE's Weatherization Assistance Program.

From a thorough review of the literature, we identified a complete set of nonenergy benefits and organized them into major categories and subcategories. Our approach was informed by the post-1993 articles and reports reviewed as well as by the ideas presented in the national weatherization evaluation (Brown et al. 1993). Then, a range of monetary values was identified for each nonenergy benefit, drawing from all recent studies that provided dollar values for nonenergy benefits and that employed methods that we considered reasonable and legitimate, even if the numbers themselves appeared to be somewhat extreme. In fact, many of the value ranges presented in this report are very broad.

After a range of monetized values was identified from the literature for all nonenergy benefits, we used our professional judgment to select a reasonable point estimate for each one to represent the average value of that benefit associated with weatherization efforts nationwide. Even where the entire continuum of possible values was very large, it was common for *most* of the suggested values to cluster around a fairly narrow range. In such cases, we tended to select a preferred point estimate that was close to the midpoint of the clustered values. Where one extremely high value led to an extended range, it was often the case that the clustered values and our point estimate fell toward the low end of that range. However, it is important to note the inherent uncertainty associated with any point estimate that is made. Clearly, a single point estimate for any given nonenergy benefit cannot represent the benefits associated with every weatherization effort in each separate locale because of the substantial variation that occurs among different programs and geographic areas. Even where, as in this report, a point estimate is based on a number of different studies and is intended to represent a national average, there is still good reason to be cautious. As the name implies, a point estimate is only an *estimate* of a savings value and is based on various assumptions about program operations and effectiveness rather than on systematic measurement, and subsequent weighting and averaging, of program outcomes throughout the country.

Nearly all of the nonenergy benefits addressed in this report occur everywhere, but a couple only apply to certain types of households (i.e., those receiving low-income rate subsidies or those using natural gas). In such cases, the magnitude of the benefits reported in the literature is adjusted downward to make it an average value for the entire nation. Of course, even where benefits do apply universally, the actual magnitude will vary from place to place, as noted above. When point estimates for all the benefits addressed in this report are aggregated, they represent the average benefit for a typical low-income U.S. household. However, that point estimate will not necessarily apply to each individual household. In cases where a particular benefit does not apply, the total value of all nonenergy benefits would tend to be lower than indicated in this report, provided that all other conditions affecting the magnitude of benefits are typical.

Monetary values for the various nonenergy benefits provided in the recent articles and reports that we reviewed are generally treated as if they are in 2001 dollars. We consider this to be a reasonable approach because (1) most of the works reviewed were written during the last two or three years and inflation has been very modest during that period, and (2) the dollar values provided in the literature tend to be estimates and approximations and are not precise enough to warrant adjustment by a few percentage points. The principal exception to this is in the case of values that are taken from the national weatherization evaluation (Brown et al. 1993). Because the data in that study date from 1989, it was considered prudent to adjust the relevant numbers upward, using the inflation factors contained in the Consumer Price Index (Bureau of Labor Statistics 2001).

Many of the monetized values presented in the literature are listed in terms of dollars per participating household per year. We converted those annual benefits into net present value (NPV) per household, assuming that: (1) the useful life of the installed weatherization measures is 20 years (which is consistent with past evaluations of the Weatherization Assistance Program); and (2) the appropriate discount rate is 3.2 % (the rate suggested by the Office of Management and Budget for program evaluation). Based on these assumptions, a benefit that has an annual value of $10 per year would have a NPV of $146. We are aware that different parties are likely to apply different discount rates when calculating the value of a given investment. However, the 3.2% discount rate is used in this report for *all* categories of benefits to be consistent and to reflect the fact that this document is written from the perspective of the federal agency that sponsors the Weatherization Assistance Program.

1.3 SCOPE OF REPORT

The subsequent chapters of this report present key findings from our study of the nonenergy benefits associated with low-income weatherization efforts. In order to present a complete picture of the nonenergy benefits associated with weatherization programs, these benefits are described from three distinct perspectives: that of utility ratepayers; that of participating households; and that of society as a whole. It should be noted that a couple of the nonenergy benefits addressed in this report are discussed under more than one major category, to reflect the fact that there are different groups of beneficiaries. For example, “avoided shut-offs and reconnections” are discussed both from the ratepayer and the household perspective. The value of the benefit received by each set of actors in different, and double-counting is avoided because ratepayers and participating households receive different, and non-overlapping, values from the benefit in question.

Chapter 2 discusses the benefits received by utility companies and passed on to their ratepayers. These fall under the broad headings of benefits related to the payments that utilities receive from their customers and benefits related to the utilities’ provision of services. In this chapter, as in the following ones, each individual benefit is described, a range of possible monetized values and a point estimate are given for each benefit, and a brief explanation is provided of the methods used to calculate the values.

In Chapter 3, benefits experienced by the low-income households that receive weatherization services are described. Such benefits can be grouped into two categories: affordable housing benefits and benefits related to the occupants’ safety, health, and comfort.

Chapter 4 addresses societal benefits, which can be subdivided into environmental benefits, social benefits, and economic benefits.

Finally, Chapter 5 summarizes the full set of nonenergy benefits and their monetary values, examines the relative magnitude of the different types of nonenergy benefits, and compares the size of these benefits with the energy benefits generated by the Weatherization Assistance Program.

2. RATEPAYER BENEFITS

Utility ratepayers receive two distinct types of nonenergy benefits as a result of low-income weatherization efforts. Point estimates of the average lifetime monetary value associated with each type of benefit are shown in Fig. 1. The first type of benefit is related to the payments that utilities receive (or do not receive) from their customers and includes six different items: (1) avoided rate subsidies; (2) lower bad debt write-off; (3) reduced carrying cost on arrearages; (4) fewer notices and customer calls; (5) fewer shut-offs and reconnections for delinquency; and (6) reduced collection costs. The second type of benefit is related to the provision of services and has three components: (1) fewer emergency gas service calls; (2) transmission and distribution (T&D) loss reduction; and (3) insurance savings. While all of the benefits listed above initially accrue to utility companies, they tend to be passed on to the utilities' customers and are therefore classified in this report as ratepayer benefits. Each of these benefits is discussed in more detail below.

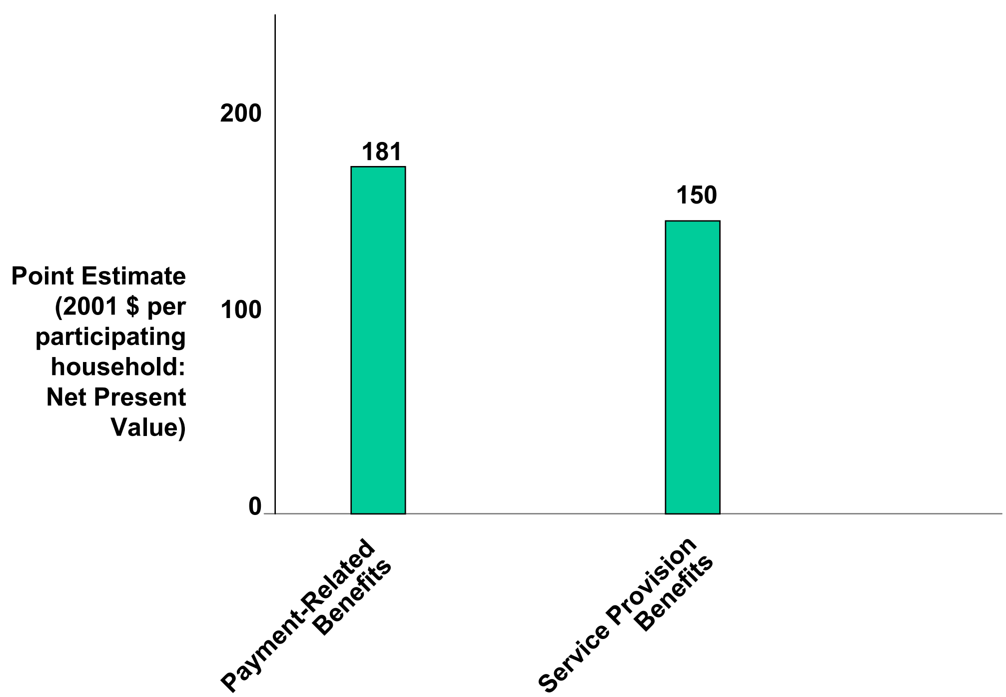

Fig. 1. Average Lifetime Monetary Value of Ratepayer Benefits, by Type

2.1 PAYMENT-RELATED BENEFITS

Rate Subsidies Avoided

Many utilities provide lower, subsidized rates for their low-income customers. Accordingly, each unit of energy consumed by low-income customers represents an expense for the utility and for its other customers, whose payments help subsidize the discount rate. When the amount of energy used by low-income customers is reduced as a result of a weatherization program, the number of subsidized units of energy sold decreases and the utility and its other ratepayers save money.

The literature reviewed for this study presented a number of different estimates of the dollar value of rate subsidies avoided as a result of low-income weatherization programs. Many of these estimates were presented in terms of annual savings per household but, as explained in Chapter 1, these were all converted to net present value over the lifetime of the measures installed. The estimated lifetime savings range from a low of $38 to a high of $467. However, the estimates of benefits found in the literature typically describe only those instances in which rate subsidies are available and used by low-income customers. In order to represent average savings across the nation as a whole, those savings numbers should be adjusted downward to reflect the proportion of low-income customers actually receiving such subsidies. Based on information compiled by the National Center for Appropriate Technology (2001), we know that only about 15% of low-income customers nationwide get rate subsidies. Accordingly, we multiplied the range of benefits presented in the literature by 0.15, resulting in an adjusted range of $6 to $70 (Table 2). Our preferred point estimate for this benefit is $21 but, as explained previously, any single estimate made for the entire low-income Weatherization Assistance Program is necessarily imprecise and the associated uncertainty must be recognized.

Table 2. Ratepayer Benefits: Payment-Related

Nonenergy Benefit	**Range of Benefits (in 2001 $ per participating household: Net Present Value)**	**Point Estimate of Benefits (in 2001 $ per participating household: Net Present Value)**
Rate subsidies avoided	6 - 70	21
Lower bad debt write-off	15-3462	89
Reduced carrying cost on arrearages	4-110	57
Fewer notices and customer calls	0-23	6
Fewer shut-offs and reconnections for delinquency	2-15	8
Reduced collection costs	Not Available	Not Available

The point estimate of $21 suggested above is derived from the midpoint of the range of possible dollar savings from avoided rate subsidies presented by Skumatz and Dickerson (1999) for the Low-Income Weatherization Program operated by PG&E. The savings estimate was calculated by taking the average rate subsidy received by participating households and multiplying it by the amount (in percentage terms) by which participants' energy use is likely to be reduced. We then adjusted this amount downward, as described above, to make it represent the average savings distributed over *all* low-income customers and not just those receiving rate discounts.

Lower Bad Debt Write-off

When customers cannot pay all or part of their bills for an extended period of time, the utility might have to write off the unpaid portion as bad debt. When the occupants of weatherized units experience reductions in their utility bills, they are better able to make their payments and the amount of bad debt written off is likely to decrease. Actually, there are two parts to this reduction in bad debt: a decrease in the average size of bad debt written off and a decline in the number of such accounts.

The range of possible dollar benefits presented in the literature for lower bad debt write-off was extremely broad, with a minimum NPV of $15 and a maximum of $3462 (Table 2). Although one very high value was noted, all the other benefit levels described in the literature clustered at the lower end of the range. We suggest a point estimate of $89, based on the findings from a well-designed study of the nonenergy benefits resulting from Public Service Company of Colorado's Energy $avings Partners Program (Magouirk 1995). That study measured the post-weatherization reduction in the *amount* of bad debt written off by participating households. In addition, the decrease in the *number* of accounts that were written off was measured. The two factors combined yielded the $89 NPV reported above. That number is near the high end of the range suggested by Skumatz and Dickerson (1999) for two California low-income programs but at the low end of the range suggested in an extensive study of the values of nonenergy benefits conducted for the state of California (TecMRKT Works et al. 2001).

Reduced Carrying Cost on Arrearages

Weatherization programs lower energy consumption for participating customers, thereby reducing the size of their energy bills and making it possible for them to pay a larger portion of those bills. This in turn reduces the amount of customers' bills that are in arrears. As these arrearages decline, the carrying costs borne by utilities (i.e., the interest on the amount in arrears) are also reduced.

According to the literature reviewed, the net present value of this benefit ranges from $4 to $110 (Table 2). As a point estimate, we chose $57, which is the midpoint of the savings calculated by Skumatz and Dickerson (1999) for two low-income programs in California. (PG&E's Low-Income Weatherization Program and its Venture Partners Pilot Program). The Skumatz and Dickerson study calculated savings based on likely program-induced reductions in arrearage balances, the magnitude of pre-weatherization arrearages in eligible households, and prevailing interest rates.

Fewer Notices and Customer Calls

As noted above, households that receive weatherization services tend to lower their energy consumption as a result, leading to lower energy bills, which are easier for them to pay. Consequently, utilities are required to send out fewer notices in response to late payments and will receive fewer customer calls regarding these situations. All of this results in a savings to utilities for staff time and materials.

As shown in Table 2, the NPV of this benefit reported in the literature ranges from $0 to $23. Our suggested point estimate is $6, which is at the high end of the range suggested by Skumatz and Dickerson (1999) but toward the lower end of the full range of benefits reported when other studies are included. The monetized benefits reported here represent a combination of the numbers calculated separately for late payment notices and for customer calls. An 18% reduction in the number of notices and calls was assumed, based on previous empirical findings on the incidence of reductions in the number of accounts written off for bad debt as a result of weatherization efforts (Magouirk 1995). This was multiplied by the annual cost per household of notices and customer calls to produce an estimate of savings per participant.

Fewer Shut-offs and Reconnections for Delinquency

As explained above, weatherized households are less likely to fall behind on their bill payments, meaning that they are less likely to have their utility service cut off for nonpayment. Because utilities incur costs to disconnect customers and to reconnect those households in the future, they experience a monetary savings as the result of customers being better able to pay their bills and retain service.

The net present value of this benefit ranges from $2 to $15 (Table 2). As a point estimate, we chose $8, which is the midpoint of the range of potential savings calculated by Skumatz and Dickerson (1999) for two PG&E low-income programs. This value is also very close to the benefits reported in several other studies of low-income weatherization efforts. The savings reported here were estimated based on the weatherization-induced reduction in the incidence of disconnections and the estimated costs of service shutoff and the portion of reconnection costs not covered by the customer.

Reduced Collection Costs

If fewer customer payments are delinquent, utilities spend less time and resources trying to collect what is owed them. However, it can be difficult to separate these reduced collection costs from the benefit associated with fewer late notices and customer calls, discussed above. A few of the reports reviewed for this study estimated collection costs *per incident* but did not put this in terms of the dollar value per all weatherized households. Because of the current lack of reliable estimates for this benefit, we will not attempt to assign it a monetary value.

2.2 SERVICE PROVISION BENEFITS

Fewer Emergency Gas Service Calls

As part of the home weatherization process, deteriorating or malfunctioning gas appliances can be serviced or replaced and new connectors can be installed. This proactive service reduces the subsequent need for utilities to make emergency service calls when appliances or connectors break or malfunction. By avoiding these emergency calls, utilities save staff time and resources, which constitutes a monetary benefit.

The literature reports that the NPV of this benefit ranges from $77 to $394. However, because this benefit can only occur where houses are fueled by natural gas, the reported values must be adjusted downward if they are to describe the nation as a whole. To reflect the fact that 50.9% of U.S. households are heated by natural gas (U.S. Energy Information Administration 2000), the numbers reported above were multiplied by 0.509, yielding an adjusted range of $39 to $201 for this benefit, as shown in Table 3. We suggest $101 as a reasonable point estimate. This number is at the midpoint of the range of values reported by Skumatz and Dickerson (1999) for two PG&E low-income programs and near the midpoint reported in the TecMRKT Works (2001) study (after their adjustment to reflect natural gas usage). The range of numbers reported in the Skumatz and Dickerson paper were calculated based on plausible ranges of service call costs and weatherization-induced reductions in the incidence of such calls (which dropped from 27% of households before weatherization to only 7% afterward, according to Magouirk, 1995).

Table 3. Ratepayer Benefits: Service Provision

Nonenergy Benefit	Range of Benefits (in 2001 $ per participating household: Net Present Value)	Point Estimate of Benefits (in 2001 $ per participating household: Net Present Value)
Fewer emergency gas service calls	39 - 201	101
T&D loss reduction	33-80	48
Insurance savings	0-2	1

Transmission and Distribution Loss Reduction

As a natural consequence of transporting electric power along transmission and distribution lines, a certain amount of energy is lost. These T&D losses are borne by the responsible utility and its customers. Because weatherization programs cause reductions in household electricity use, they likewise reduce the amount of electricity that must be transported and this results in a decrease in the T&D losses that occur. These savings often occur even in dwellings that are not electrically heated, because electricity usage for a number of purposes (e.g., furnace fans and pumps, air conditioning, lighting) can be affected by home weatherization measures.

The net present value of T&D loss reductions reported in the literature range from $33 to $88 (Table 3). Our suggested point estimate is $48, the midpoint of the possible benefit values reported by Skumatz and Dickerson (1999) for PG&E's Low Income Weatherization and Venture Partners Pilot Programs. The monetized value of the T&D losses reported here were calculated by multiplying the percentage of power that is typically lost through transmission and distribution (approximately 10%) by the avoided cost of power.

Insurance Savings

To the extent that the services performed by weatherization programs include the fixing of gas leaks and the repair or replacement of faulty appliances, the result is likely to be a reduction in the risk of household explosions and fires. This, in turn, would tend to lower the utility's insurance costs. Such cost savings are expected to occur whether the utility is self-insuring or buys coverage from another company.

The net present value of this benefit ranges from $0 to $2 (Table 3). As a point estimate, we chose $1, which is the midpoint of this range of potential savings values. The savings in insurance expenses reported here were estimated based on the magnitude of claims made in a typical year and the risk reduction associated with weatherization efforts. Skumatz and Dickerson (1999) assumed that the reduction in claims would fall by roughly the same factor that gas emergency calls would be reduced, as reported by Magouirk (1995).

3. BENEFITS TO HOUSEHOLDS

Low-income households that participate in weatherization programs are the recipients of two different types of nonenergy benefits. Point estimates of the average lifetime value of each are provided in Fig. 2. First, there are benefits that relate in some way to the affordability of low-income housing. These include: (1) water and sewer savings; (2) property value benefits; (3) avoided shut-offs and reconnections; (4) reduced mobility; and (5) reduced transaction costs. The other type of household benefit concerns the safety, health, and comfort of residents and has three components: (1) fewer fires; (2) fewer illnesses; and (3) improved comfort and related factors. Each of these household benefits is discussed in its own section, below.

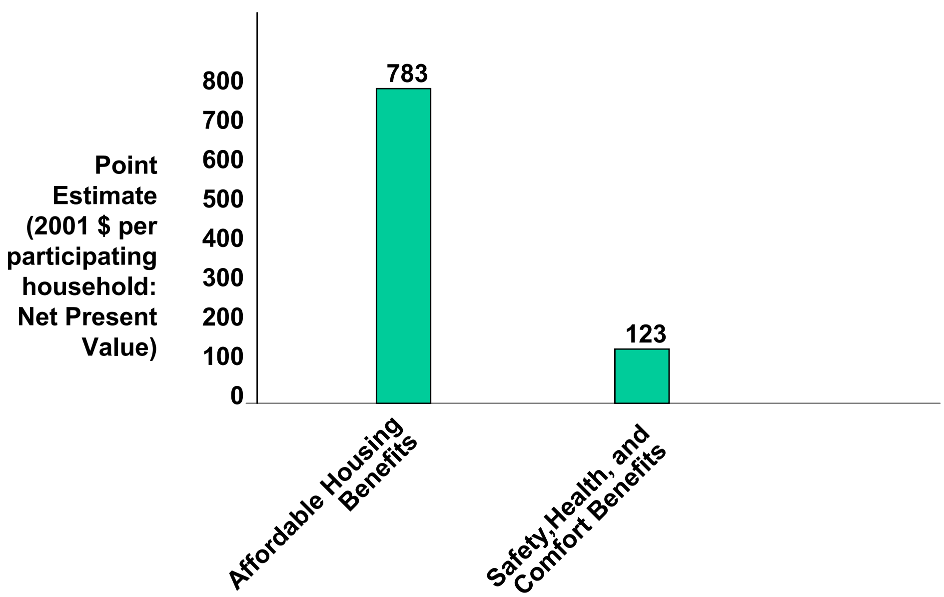

Fig. 2. Average Lifetime Monetary Value of Household Benefits, by Type

3.1 AFFORDABLE HOUSING BENEFITS

Water and Sewer Savings

Many of the homes serviced by a weatherization program receive low-flow showerhead and faucet aerator retrofits as part of the package of energy-efficiency measures installed. In addition to saving energy, these measures result in reduced household water use. Accordingly, households receiving these services save money on their water bills and, because sewer charges are generally based on the amount of water consumption, on their sewer bills as well.

A number of different estimates of the magnitude of water and sewer savings was presented in the literature reviewed for this study. Although most of those estimates were presented in terms of annual savings per household, they are presented here in terms of their net present value over the lifetime of the measures installed. The NPV of these savings ranges from $62 to $1607 (Table 4). Our best current estimate for this benefit is $271 but, as explained previously, there is substantial uncertainty associated with any point estimate made for the entire low-income Weatherization Assistance Program.

Table 4. Household Benefits: Affordable Housing

Nonenergy Benefit	Range of Benefits (in 2001 $ per participating household: Net Present Value)	Point Estimate of Benefits (in 2001 $ per participating household: Net Present Value)
Water and sewer savings	62-1607	271
Property value benefits†	0-5413	180
Avoided shut-offs and reconnections	0-52	17
Reduced mobility	0-1460	278
Reduced transaction costs	0-131	37

†occurs one time only in year weatherization is performed

The point estimate of $271 suggested above is based on information provided by Skumatz (2001) on average annual water savings per participating household resulting from the installation of faucet aerators and low-flow showerheads. This average household savings number was multiplied by the mean cost per gallon of water nationwide (U.S. Environmental Protection Agency 1997). The resulting number was updated to 2001 dollars using the multiplier suggested by the Consumer Price Index (Bureau of Labor Statistics 2001).

Property Value Benefits

In many cases, weatherization programs make some structural repairs and improvements to the houses they service in addition to installing energy efficiency measures. The structural improvements that are provided typically increase the property value of the homes receiving them. This represents a monetary benefit for the affected households that goes beyond the dollar savings associated with the energy efficiency improvements that are made. In addition, structural repairs can extend the useful lifetime of the affected dwellings and preserve the existing stock of affordable low-income housing.

According to the literature reviewed, the property value increase associated with home weatherization ranges from a minimum net present value of $0 to a maximum of $5413 (Table 4). Although one document (Riggert et al. 1999) suggests using the high value shown at the top of the range, all the other articles and reports reviewed for this study present values that cluster around the lower end of the scale. Those lower values are typically based on the assumption that the property value increase is equal to the cost of structural repairs made to the home in question. We suggest a point estimate of $180 for this benefit, based on the findings of the national weatherization evaluation (Brown et al. 1993). That study found that, in 1989, the average amount spent on materials for structural repairs nationally was $126. By adjusting that figure to 2001 dollars using the multiplier of 1.428 suggested by the Consumer Price Index (Bureau of Labor Statistics 2001), we get the $180 noted above.

Avoided Shut-offs and Reconnections

As explained in Chapter 2, weatherization programs result in decreased energy consumption for the homes serviced and this, in turn, means lower energy bills. Accordingly, weatherized households are less likely to fall behind on their bill payments and are less likely to have their utility service shut off for nonpayment. By avoiding service terminations, low-income customers experience a two-fold benefit. First, they get to retain the full use of their dwelling unit, the value of which is equivalent to the rent that would be "lost" if it were paid for a house (or portion of a house) that was unusable due to the lack of utility service. Also, the affected customers avoid having to pay a subsequent restart fee. While some authors include the perceived "value of service" experienced by the customer (i.e, how much it is worth to the customer to avoid a service disruption) as an additional benefit, this measure is not included here because of the difficulty of objectively assigning a dollar value to it.

The values for avoided shut-offs and reconnections presented in the literature range from $0 to $52 (Table 4). These numbers exclude the "value of service" benefit described in some studies, as noted above. A reasonable point estimate for this benefit is $17, which represents the upper end of the range given by Skumatz and Dickerson (1999) for lost rental value and cost to restart in their study of PG&E's Venture Partners Pilot Program. This value is considered reasonable to use here because a newer study (TecMRKT works et al. 2001) suggests a somewhat higher value for this benefit, putting the $17 figure roughly in the middle of the full range. Skumatz and Dickerson calculated lost rental value based on the likely reduction in termination rates and the assumed rent for a housing unit over a limited shut-off period. The cost to restart service was based on the projected reduction in termination rates and the restart costs per household, which include a reconnection fee and the value of lost work time.

Reduced Mobility

When household energy costs are high, less money is available for other purposes, including paying rent or making mortgage payments. This can be especially difficult for low-income households, where funds are very limited. In some cases, high energy costs can lead occupants to voluntarily move out of their current dwelling in favor of one with lower energy bills. In other instances, households with insufficient funds to cover all their expenses can be evicted for a failure to make housing payments or can be forced to move after utility service is discontinued. While the freedom to choose to be mobile is generally considered desirable, the mobility discussed here is associated with economic hardship and a lack of options. This kind of mobility, which is characterized by frequent and unwanted moves, can have the side effect of increasing school drop-out rates in the affected households. In turn, this can lead to a lifetime of lower earnings for those who prematurely terminate their education. By lowering household energy bills, weatherization programs can reduce mobility, thereby preventing some youth from dropping out of school and increasing their earning potential. That increase in earnings is a monetary benefit of weatherization that can be quantified.

The values for reduced mobility presented in the literature range from $0 to $1,460 (Table 4). Our suggested point estimate for this benefit is $278, which is the average of the point estimates presented by Skumatz (2001) for two different low-income weatherization programs. Skumatz calculated the value of reduced mobility based on: (1) the estimated effect of weatherization efforts on reducing the school drop-out rate; and (2) the estimated difference in lifetime earnings between high school graduates and drop-outs.

Reduced Transaction Costs

If they were not served by a weatherization program, some low-income households might choose to install certain energy-efficiency measures on their own. However, to do so, they would first have to become familiar with the needed retrofit measures and locate the necessary materials. The time and effort required for that represent a set of “transaction costs” for low-income households, and avoiding those transaction costs amounts to a benefit for those receiving weatherization services. By assigning a monetary value (approximating minimum wage) to the time saved by participants, the magnitude of transaction costs can be identified.

As shown in Table 4, the net present value of reduced transaction costs reported in the literature range from $0 to $131. Our suggested point estimate is $37, the midpoint of the possible benefit values reported by Skumatz and Dickerson (1999) for PG&E’s Low Income Weatherization and Venture Partners Pilot Programs. The reduced transaction costs reported here were calculated based on the number of compact fluorescent lamps installed per household under the programs studied and the estimated reduced transaction costs per bulb. That monetized benefit was then doubled to reflect the fact that weatherization programs include many more measures than compact fluorescent bulbs alone. The resulting value seems conservative in light of the fact that home weatherization involves the installation of a number of different products (e.g., insulation, sealants, low-flow showerheads, storm windows, programmable thermostats) which consumers would have to locate and learn about if they were to perform the work themselves.

3.2 SAFETY, HEALTH, AND COMFORT BENEFITS

Fewer Fires

Many low-income homes have old and poorly-maintained space and water heating systems. These present a risk of fire resulting from gas leaks. Also, low-income households sometimes use dangerous supplemental heat sources like gas grills or electric space heaters, and this is especially problematic in those instances where the primary heating source is disconnected due to nonpayment. Weatherization programs can improve the operation of space and water heating systems and reduce the need for supplemental heating. As a result, fewer fires occur in weatherized homes, and this represents a real benefit to the affected households.

The net present value of fewer fires reported in the literature ranges from $0 to $555 (Table 5). We suggest using $68 as a point estimate for this benefit. This value of fewer fires over the lifetime of the weatherization measures installed is based on the annual per household value for this benefit presented by Brown et al. (1993) in the national weatherization evaluation, adjusted to 2001 dollars using the multiplier suggested by the Consumer Price Index (Bureau of Labor Statistics 2001). The study by Brown et al. estimated the number of fires prevented by the national Weatherization Assistance Program, using national statistics on the occurrence of fires and fire death rates, and attributed a value to the associated property damage and deaths based on residential fire-loss statistics and the projected value of future lifetime earnings.

Table 5. Household Benefits: Safety, Health, and Comfort

Nonenergy Benefit	Range of Benefits (in 2001 $ per participating household: Net Present Value)	Point Estimate of Benefits (in 2001 $ per participating household: Net Present Value)
Fewer fires	0-555	68
Fewer illnesses	0-2191	55
Improved comfort and related factors	Not Available	Not Available

Fewer Illnesses

Some authors have suggested that people living in houses with sufficient and continuous heat during the colder months of the year are likely to get fewer colds. When adults get fewer colds, it means that they experience fewer lost days of work and the accompanying loss of wages. In addition, when children are sick, a parent or guardian often has to miss work to care for them, again at the cost of lost wages. Accordingly, weatherization improvements that result in warmer and less drafty homes could lead to fewer illnesses and the monetary benefits that go along with that. It should be noted that tightening up homes could lead to increases in indoor air pollution and associated illnesses. However, properly conducted energy audits allow for adequate air changes in the home to minimize this risk.

The net present values reported in the literature for fewer illnesses range from a low of $0 to a high of $2191. We suggest a point estimate of $55. This value was calculated using the method described in Skumatz (2001). Skumatz developed a point estimate for the benefit of fewer illnesses associated with low-income weatherization efforts, based on survey findings regarding the number of lost workdays avoided and an assumed average wage earned by the affected workers.

Improved Comfort and Related Factors

Because houses tend to become warmer and less drafty after they are weatherized, their occupants are likely to experience increased comfort levels. In addition, the improvements made to homes during the weatherization process often make them less noisy and can improve their appearance. All of these represent benefits that are real but are very difficult to measure objectively. Some innovative work has been performed in this area, most notably in the form of survey research that asks respondents to characterize the value of various nonenergy benefits relative to the energy savings that they have received as a result of program participation (Skumatz et al. 2000). However, it is not clear whether the values calculated by such approaches, which assign a dollar value to a given benefit based on its perceived importance to the recipient, are either valid or reliable given the very hypothetical nature of the task set to the respondents. Accordingly, we will not attempt to assign a dollar value to comfort, noise, and aesthetic benefits at this time.

Improved indoor air quality is another benefit associated with weatherization programs. Faulty furnaces can release carbon monoxide into houses, with very negative health effects. Improvements to heating equipment made during the weatherization process can prevent such releases, and the installation of carbon monoxide monitors can alert household occupants to the presence of this dangerous gas. Despite its importance, we will not attempt to assign a monetary value to the benefit of improved indoor air quality because of the current lack of reliable estimates.

Weatherization providers are required to give a booklet on the hazards of lead-based paint (U.S. Environmental Protection Agency 2001) to households in which such paint could be present. This booklet presents information on the dangers of lead poisoning and how they can be reduced or eliminated. Because lead can have very adverse impacts on those exposed to it–especially children–educational efforts like the one described above can have the positive effect of protecting the health of household residents. Due to a lack of information on the monetary value of this benefit, we do not attempt to quantify its worth.

4.0 SOCIETAL BENEFITS

Following the literature, the *societal* nonenergy benefits attributable to weatherizing low income homes are broken into three categories: environmental, social and economic. Fig. 3 gives point estimates of the average lifetime monetary value associated with each of the three benefit types. The findings distilled from the literature are reported in sub-sections 4.1, 4.2, and 4.3, respectively.

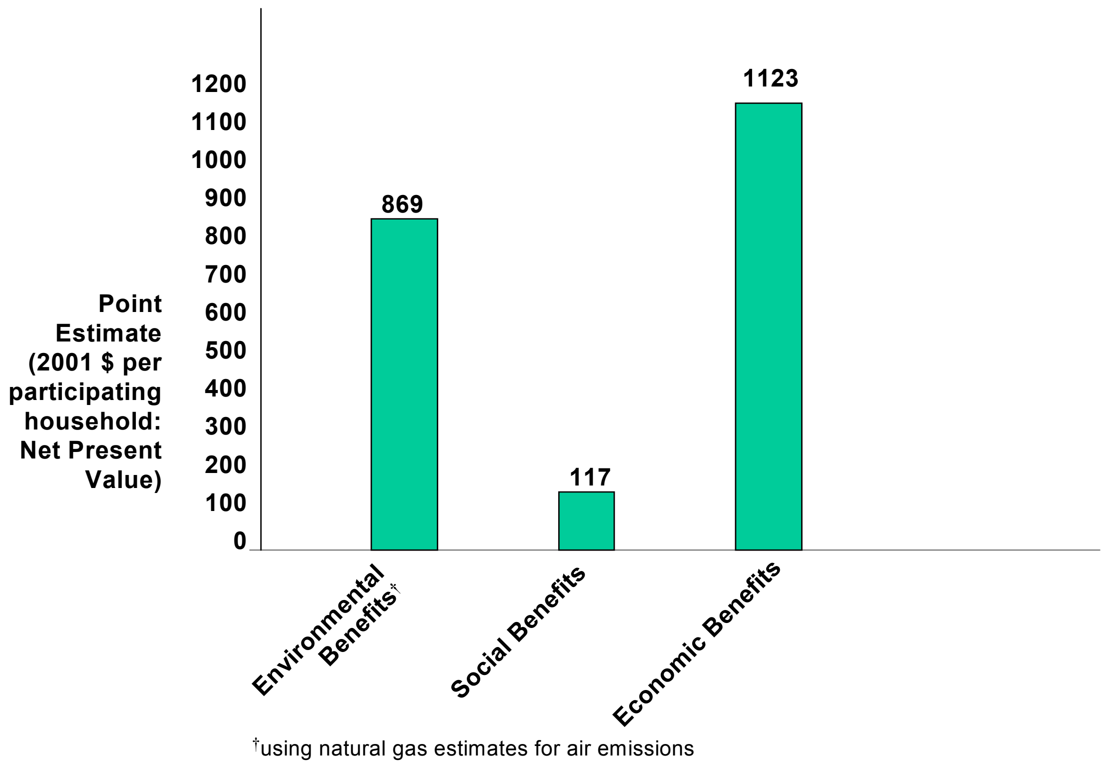

Fig. 3. Average Lifetime Monetary Value of Societal Benefits, by Type

4.1 ENVIRONMENTAL BENEFITS

Environmental benefits pertain to how the environment can be improved by weatherizing low income homes. The most frequently studied environmental benefits arise from the reduction of air pollutants due to the reduction in the burning of fossil fuels, either in the home (e.g., natural gas) or at central power stations to produce electricity. Other categories of environmental benefits quantified in the literature include less impingements upon fish around power plant water sources, and reduced water use and, subsequently, less sewage. Table 6 provides ranges and point estimates for these environmental benefits.

Table 6. Environmental Benefits

Nonenergy Benefit	Range of Benefits (in 2001 $ per participating household: Net Present Value)	Point Estimate of Benefits (in 2001 $ per participating household: Net Present Value)
Air Emissions - Natural Gas		
Carbon (CO_2)	40 - 32,189	102
Sulfur Oxides (SO_x)	.02 - 6015	23
Nitrogen Oxides (NO_x)	.02 - 2254	48
Carbon Monoxide (CO)	.21 - 758	46
Methane (CH_4)	.07 - 269	92
Particulate Matter (PM)	.01 - 6983	9
Subtotal	40 - 49,176	320
Air Emissions - Electricity		
Carbon (CO_2)	167 - 97,857	305
Sulfur Oxides (SO_x)	31 - 40,872	92
Nitrogen Oxides (NO_x)	11 - 17,290	523
Carbon Monoxide (CO)	36 - 81	39
Methane (CH_4)	.68 - 1.15	.91
Particulate Matter (PM)	.27 - 704	14
Subtotal	246 - 156,805	974
Other Benefits		
Heavy Metals (air emissions)	1.39 - 17,205	380
Fish Impingement	23.44 - 23.44	23.44
Waste Water and Sewage	3.36 - 657	146
Subtotal	28 - 17,885	549
Total†	68 - 67,061	869

† uses natural gas estimates for air emissions

With respect to air emissions, the literature contains a wide range of estimates for several factors that are needed to estimate benefits. These factors include (1) the number of pounds of pollutants emitted per unit of energy service delivered (e.g., lbs/ mmbtu), (2) average energy savings per weatherized home, (3) reductions in pounds of pollutants emitted per weatherization, and (4) value in dollars associated with reducing units of air pollutants (e.g., $/ton of carbon dioxide emissions reduced). The approach followed to estimate the range of benefits was to take the lowest (highest) value for each factor to calculate the lower (upper) bound. The approach taken to develop a point estimate varied by each type of air emission. In general, mid-range and frequently mentioned estimates were used. Sources used for the environmental benefit review include: Brown et al. (1993), Berry (1997), Skumatz and Dickerson (1997, 1999), Skumatz (2000), Riggert et al. (1999), Riggert et al. (2000), Hill et al. (1999), Burtraw et al. (1997), Burtraw and Toman (1997), TecMRKT Works et al. (2001), Biewald et al. (1995), and National Research Council (2001).

The ranges in benefits associated with reducing air emissions are large and arise due to a host of methodological issues. Two key problems are related to choice of benefit estimation method and where studies had been conducted. The former problem is particularly acute with respect to valuing emission reductions. Generally, one of two methodological approaches is taken. One approach is to value emission reductions equal to the value of emission permits that are being traded in an emissions market (or the expected value for such permits if the market does not yet exist). This value approximates the cost faced by emitters for complying with emission reduction regulations. These values are attractive for benefit estimation exercises because they can be documented, if the market exists, or closely estimated, if the market does not yet exist.

The market valuation method tends to yield lower values for emission reductions than the second method, which calls for a comprehensive estimation of the benefits associated with emission reductions. In other words, a drawback to using the market values of emissions permits is that these values do not directly encompass important benefits accruable to society from the emissions reductions. For example, the market values do not reflect improvements to human health and ecosystems or decreasing rates of deterioration of the exterior of buildings and other materials exposed to the pollutants. Estimating all these benefits can lead to dramatically higher values for reducing harmful emissions to the air. The large ranges in benefits shown in Table 6 are mostly attributable to studies that adopted one or the other of the two methodologies. It must be noted that adopting a comprehensive benefits estimation methodology also increases the uncertainty in the valuation process because estimating health and ecosystem benefits is extraordinarily difficult. Because each method has significant strengths and weakness, neither has been universally accepted and wide ranges of benefits estimation can be expected to continue into the foreseeable future. In this study, we tended to favor the market valuation approach when generating point estimates of environmental benefits.

Where studies have been done is a second source of variation in the numbers presented in Table 6. This is because spatial factors can greatly impact the reductions in emissions per weatherized home. It is well known that the number of heating degree days, which vary across the country, is tightly correlated with energy savings and, ultimately, with air emission reductions due to weatherization. Thus, findings by studies done in California will be different from studies done in Vermont; both may not be generalizable to the entire country but a value somewhere in the range probably is. Cooling degree days also vary by climate zone but these savings are usually not included in energy savings estimates, and, conversely, not in air emission reduction estimates.

Fuel used for heating also varies across the country. Studies conducted in areas dominated by natural gas are different than studies done in areas more reliant on electricity. What types of fuels are used to generate electricity are also important, as coal types vary considerably and coal is considerably different from natural gas, for example. Generally, emission reduction estimates do not encompass homes that use multiple fuels for heating (e.g., electricity and wood are common in the Pacific Northwest). Impacts upon other energy end uses, such as air conditioning, are also not incorporated in these analyses. Studies done in limited market areas with unique fuel mixes and climate yield large ranges in results and this is also indicated in the ranges exhibited in Table 6.

It should also be noted that the environmental benefits listed in Table 6 are not comprehensive. Categories of environmental benefits not apparently quantified in the literature include reductions in water pollution (e.g., from run-offs from power plant sites, leaching of toxics into the groundwater from mining operations), land use changes (e.g., associated with extraction of natural resources), and solid waste (e.g., fly-ash from electric generation plants). The literature also does not include complete life cycle assessments that would encompass all pollutants associated with each phase of a home heating fuel (i.e., from extraction of raw materials to materials processing to consumption of the fuel to waste disposal issues) to allow comparison with the environmental implications associated with materials used to weatherize homes (e.g., assessing the life cycle emissions -- extraction, processing, manufacturing, transportation, use, and end-of-life disposal of insulation). For example, not included in this analysis are environmental costs associated with the production of fiber glass insulation, epoxy-based window caulking, double-pane windows, and other measures commonly installed in weatherized homes.

4.2 SOCIAL BENEFITS

Social benefits represent a catch-all category of benefits attributable to weatherization that are clearly not environmental or economic. In this sub-section we will focus on one such benefit that is discussed in the literature and for which the effects have been monetized: avoided unemployment benefits. This refers to the employment of people in the course of weatherizing homes who would have been unemployed otherwise. Sources for these benefits include Brown et al. (1993), Skumatz and Dickerson (1999), and Riggert et al. (1999). Other social benefits which have not been monetized include: social equity (Berry et al. 1997, National Consumer Law Center 1999), and improvement in community pride through improvement in the local housing stock.

The range for avoided unemployment benefits (Table 7) was developed by using the low and high estimates found in the literature. To establish a point estimate, the value reported by Brown et al. (1993) was adjusted to 2001 dollars based on the Consumer Price Index (Bureau of Labor Statistics 2001). Factors that impact the reliability of estimated benefits include the availability of jobs in various areas of the country and over time. In areas having numerous job opportunities, it is harder to argue that there are avoided unemployment benefits. However, since low income weatherizations are often conducted in economically distressed communities that typically do not benefit from national or even regional upturns in the economy, it can be more strongly argued that avoided unemployment benefits are valid.

Table 7. Social Benefits

Nonenergy Benefit	Range of Benefits (in 2001 $ per participating household: Net Present Value)	Point Estimate of Benefits (in 2001 $ per participating household: Net Present Value)
Avoided Unemployment Benefits†	0 - 183	117

† occurs one time only in year weatherization is performed

4.3 ECONOMIC BENEFITS

Weatherizing low income homes can yield a variety of economic benefits. One group of benefits is related to spending money on weatherization. These expenditures can directly result in new jobs and increases in personal income which can translate into increases in federal income tax collections. Additionally, weatherization expenditures can impact the local economy as a portion of every dollar prevented from leaving the community to import energy is spent within the community. This is known as the multiplier effect. Most studies only focus on the impacts within economically distressed areas and do not address the broader economy, where jobs and incomes may be lost, for example in energy production and distribution operations. Given the scale and scope of the energy production and distribution industries and the fact that energy consumption has continued to increase over time, it is highly unlikely that any job losses in those industries can be attributed to weatherization activities.

Of course, saving energy has national security implications, too, by reducing the need for energy imports. Lastly, it has been hypothesized that owners of rental units may benefit from the weatherization of rental units if the low income households save enough money on energy bills to better be able to pay their monthly rents.

Table 8 contains ranges and estimates for the economic-related factors listed above. Sources for these estimates include the Weatherization Network (1999), Nevin et al. (1998), Brown et al. (1993), TecMRKT Works et al. (2001), Riggert et al. (1999), Skumatz and

Dickerson (1997), Skumatz (2001 and 1998), Berry et al. (1997), Hill et al. (1998), RPM Systems (1995), Galvin (1999), National Research Council (2001), and Office of Transportation Technology (2001). Table 8 indicates that the direct and indirect economic benefits of low income weatherization programs can be quite significant.

Table 8. Economic Benefits

Nonenergy Benefit	**Range of Benefits (in 2001 $ per participating household: Net Present Value)**	**Point Estimate of Benefits (in 2001 $ per participating household: Net Present Value)**
Direct and Indirect Employment†	115 - 4354	801
Lost Rental	0 - 2.19	1.14
National Security	75 - 3286	321
Total	190 - 7642	1123

†occurs one time only in year weatherization is performed

Numerous factors impact the validity of the estimates contained in Table 8. As discussed above, the availability of jobs in an area impacts the job creation and increased federal benefits. The degree to which a local economy is sheltered from needing to import goods and services will impact the local multiplier effect, and housing availability will impact the lost rental benefit.

5. SUMMARY AND CONCLUSIONS

Table 9 summarizes the results of the literature review presented in the preceding three chapters. Overall, societal benefits are estimated to be substantially larger than ratepayer and household benefits. *Ranges* for the societal benefits are also much greater than for the other two categories of nonenergy benefits. The total point estimate for nonenergy benefits in all categories associated with weatherizing a home is $3346, in 2001 dollars. As explained in Chapter 1, this represents a national average figure which, like any point estimate, has substantial uncertainty

Table 9. Summary of Benefits for Each Major Category and Subcategory

Nonenergy Benefit Category/Subcategory	**Range of Benefits (in 2001 $ per participating household: Net Present Value)**	**Point Estimate of Benefits (in 2001 $ per participating household: Net Present Value)**
Ratepayer Benefits		
Payment-Related Benefits	27-3680	181
Service Provision Benefits	72-283	150
Total for this Category	99-3963	331
Household Benefits		
Affordable Housing Benefits	62-8663	783
Safety, Health, and Comfort Benefits	0-2746	123
Total for this Category	62-11,409	906
Societal Benefits		
Environmental Benefits	68-67,061	869
Social Benefits	0-183	117
Economic Benefits	190-7642	1123
Total for this Category	258-74,886	2109
Total for All Benefit Categories	419-90,258	3346

associated with it. Actual benefits will be higher or lower in specific households and locales based on what programs exist, what fuels are used, the magnitude of energy savings, and other factors. More important than the precise dollar figures is the indisputable fact that nonenergy benefits represent a significant addition to the energy savings benefit achieved by the Weatherization Assistance Program.

The point estimate for total nonenergy benefits given above is substantially higher than the total value presented a decade ago in ORNL's national weatherization evaluation (Brown et al. 1993). The magnitude of all nonenergy benefits discussed in that study, when adjusted for inflation, is $1394 in 2001 dollars. The difference between that figure and the $3346 reported in this document is due almost entirely to the fact that our study quantified a much broader array of nonenergy benefits than was addressed in the earlier work. For instance, the only ratepayer benefit discussed in the national evaluation was the reduced carrying cost on arrearages. In contrast, our treatment of this topic also included avoided rate subsidies, lower bad debt write-off, fewer emergency gas service calls, transmission and distribution loss reduction, and several other factors. Similarly, our examination of household benefits included a number of factors—such as water and sewer savings, reduced mobility, and fewer illnesses—that were not considered in the earlier work. In the realm of societal benefits, our values are very similar to those presented in the earlier study for both social and economic factors. For environmental benefits, the values reported in this document are substantially higher than those presented in the earlier report but, once again, this is largely due to our treatment of additional factors. While Brown et al. only assessed the benefits of reductions in two types of air emissions, sulfur dioxide (SO_2) and NO_x, our study looked at a variety of other air emissions (e.g., CO_2, CO, CH_4) plus other environmental factors such as heavy metals and fish impingement. An additional explanation for the difference between the value of environmental benefits reported in the two documents is that our study was based on an updated, and substantially higher, amount of average household energy savings, which directly affects the magnitude of emissions reductions. In all nonenergy benefit categories, where our report dealt with the same specific benefits addressed by Brown et al., our values tended to be very similar.

The combined net present value of $3346 for all nonenergy benefit categories compares to an average net present value of energy savings of $3174 and an average total cost per weatherization of $1779, once again in 2001 dollars. The energy savings figure is based on the value of savings for houses heated by natural gas taken from a meta-evaluation of the Weatherization Assistance Program performed by ORNL (Berry et al. 1997) to update findings from the national evaluation. The value of annual energy savings reported in that study was inflated to account for future energy prices using long-term projections developed by the U.S. Energy Information Administration (2001) and discounted using the discount rate recommended by the Office of Management and Budget. The figure used here for weatherization costs represents *total* costs (including labor and materials as well as program overhead and management) for the average weatherized dwelling and was generated by taking the most recent available information from the Weatherization Assistance Program's grants management data system and adjusting the average cost per weatherized unit to 2001 dollars using the Consumer Price Index multiplier.

It is important to note that total estimated nonenergy benefits are slightly greater than the value of energy savings over the lifetime of the weatherization measures installed. The benefit/cost ratio for gas-heated houses, combining both energy and nonenergy benefits and comparing that figure to total costs (labor, materials, and overhead) for the average weatherized home, is approximately 3.7, meaning that $3.70 in benefits are realized for every dollar spent. This comparison of *all* benefits to *all* costs is referred to as the "societal perspective." Low and high values for the societal benefit/cost ratio, using low and high nonenergy benefit estimates, are 2.0 and 52.5, respectively.

Whatever assumptions are made, the total estimated value for all nonenergy benefit categories combined is lower than it could be, because the estimate does not contain some benefits that have not been monetized. It must also be noted that there are numerous uncertainties in the estimates reported above. The environmental benefit calculations in particular are subject to wide ranges in assumptions about air emissions prevented per weatherized home and the dollar values associated with reducing each air pollutant. In addition, nonenergy benefits in many different categories are likely to vary widely by climate, fuel type, and local economic conditions. In general, our point estimates are conservative and tend to be much closer to the lower than the upper end of the full range of values presented in the literature.

Potentially important future research projects on the subject of nonenergy benefits include the following: assessing subjective nonenergy benefits that participants receive from weatherization (e.g., improved comfort); following a panel of weatherized homes over time to assess the benefits of weatherization provided to successive occupants; and conducting comprehensive life cycle assessments to better understand all the environmental benefits and costs associated with energy use reductions and installation of energy efficiency measures.

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