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Addressing Non-Energy Impacts of Weatherization

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OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE US DEPARTMENT OF ENERGY

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Buildings and Transportation Science Division

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ABBREVIATIONS AND ACRONYMS

ACPU	Average Cost Per Unit
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
CDC	Centers for Disease Control and Prevention
CFR	Code of Federal Regulations
DOE	US Department of Energy
HVAC	Heating, Ventilation, and Air Conditioning
IAQ	Indoor Air Quality
IRM	Incidental Repair Measure
NEB	Non-Energy Benefit
NEI	Non-Energy Impact
ORNL	Oak Ridge National Laboratory
SIR	Savings to Investment Ratio
WAP	Weatherization Assistance Program
WPN	Weatherization Program Notice

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EXECUTIVE SUMMARY

This study discusses various issues related to incorporating non-energy impacts (NEIs) into cost-effectiveness screening and measure selection in the Weatherization Assistance Program (WAP). It also provides an annotated bibliography of literature associated with home weatherization and NEIs.

A growing body of research shows that energy efficiency improvements can lead to benefits beyond energy savings. There is a long history of efforts to identify and monetize a wide variety of weatherization NEIs (sometimes referred to as non-energy benefits, or NEBs) for participants, energy providers, and society. Most NEI studies are oriented toward the contribution of NEIs to overall program cost-effectiveness and do not discuss linking NEIs to specific measures or incorporating NEIs in measure selection. However, some NEIs are naturally associated with specific measures, or can be allocated at the measure level based on energy savings. There is a wide range of reported monetization values for individual NEIs, owing to different methods and assumptions used, as well as to differences in the households, housing stock, climate, and associated programs.

The current legislative language implies that the US Department of Energy (DOE) can amend regulations to allow for the inclusion of NEIs but is not required to. This gives DOE wide discretion to choose how to amend the current program regulations to address NEIs.

Incorporating NEIs in WAP will require decisions about what types of NEIs to include, what level of monetization uncertainty is tolerable, the extent to which NEI valuations should be customized at the regional, grantee, and household levels, and how to incorporate NEIs into the existing suite of approved energy auditing software packages. The literature includes several monetization methods (measured changes in incidence and valuation, national data extrapolation to determine incidence, and participant surveys to directly value NEIs). A review of monetization methods and values for various NEIs would be required for each potential NEI considered for program inclusion, in addition to their linkage to a particular weatherization measure, if applicable. DOE will need to decide how much freedom Grantees will have to propose NEIs and their valuations and provide them with guidelines for the supporting information Grantees are expected to provide to DOE. Integrating NEIs into WAP could be done in phases. Software retooling will likely be needed to accommodate the incorporation of NEIs into WAP.

The inclusion of NEIs in the program could potentially impact overall character of WAP. For approaches such as providing a whole-home NEI credit or incorporating NEIs that are strongly tied to energy savings, such as emissions benefits, the regulations, as currently written, would likely limit the impact on the program. The largest potential for change is associated with individual measures that can be ascribed large (generally health) benefits but provide low or moderate energy savings. Phased or rolling adoption of NEIs could allow DOE to slowly make these changes while monitoring and maintaining the overall character of the program.

1. INTRODUCTION

The Weatherization Assistance Program (WAP) came into being after the 1973 oil embargo when energy prices and unemployment were exceedingly high. It was designed to reduce heating bills for low-income families by increasing the efficiency of their homes ("weatherizing"). The program has evolved as times have changed, expanding from its initial focus on temporary measures such as caulking and weatherizing windows with plastic film to a broad range of measures addressing energy, health, and safety. Its fundamental objective, however, remains "to **increase the energy efficiency of dwellings** owned or occupied by low-income persons or to provide such persons renewable energy systems or technologies, reduce their total residential expenditures, and improve their health and safety, especially low-income persons who are particularly vulnerable such as the elderly, persons with disabilities, families with children, high residential energy users, and households with high energy burden" (Department of Energy n.d.).

This current language, while clearly stating that the program exists to increase the energy efficiency of homes and reduce the energy expenditures of low-income families, leaves the door open for non-energy impacts (NEIs) by explicitly working to "reduce their total residential expenditures," including "health and safety" and acknowledging different levels of vulnerabilities that exist within the population served by the program.

A growing body of research shows that energy efficiency improvements can also improve indoor environments with benefits to the health of the home's occupants. State WAP administrators are looking for synergies between weatherization measures and health benefits, raising the question: how can NEIs be included with energy benefits in determining the cost-effectiveness of weatherization measures under WAP?

The House Energy and Water Committee encouraged the US DOE to explore the possibility of including health benefits (specifically from eliminating window-related lead exposure) in the calculation of savings-to-investment (SIR) ratios for weatherization measures under WAP and how this might impact the program. Oak Ridge National Laboratory (ORNL) contacted Slipstream, one of the independent evaluators[1] for the national evaluation of WAP, for assistance in reviewing current research on NEIs associated with weatherization to provide guidance to DOE on issues related to integrating NEIs into the program. In addition to its experience on the multi-year national WAP evaluation, Slipstream has an ongoing role with the State of Wisconsin to lead the biennial review of the program's energy and cost savings and has provided training and technical expertise since 1991.

[1] The Energy Center of Wisconsin (ECW) was a core member of the team of independent evaluators leading the national evaluation with ORNL. Scott Pigg led ECWs team. The Energy Center of Wisconsin changed its name to Seventhwave in 2015 and in 2019 merged with the Wisconsin Energy Conservation Corporation to become Slipstream.

2. LITERATURE REVIEW

Slipstream conducted a literature review focusing on papers and reports published on NEIs from the past 20 years, though a few seminal works from the late 1990s were also included. An initial search was performed using Science Direct and EBSCO databases for peer-reviewed articles. We also searched relevant conference proceedings: ACEEE Summer Study on Buildings, International Energy Program Evaluation Conference, Home Performance Conference, and International Energy Policy & Programme Evaluation Conference. The search was constructed to address the following specific issue areas: non-energy impacts (NEIs) and non-energy benefits, monetization, SIR, program character, lead painted windows, and legislation. Once a core group of papers addressing each issue area was identified, we mined the references for additional literature. Ultimately, we identified 74 documents for review.

A full annotated bibliography is included in Appendix A. The abstracts published in this annotated bibliography are not copyright protected. To achieve this open source status, Slipstream staff read each of the documents and wrote a synopsis of the paper/article/report. Each document was tagged with a key word or words that characterize the issue(s) it addresses (see Table 1).

Table 1. Topics covered by the annotated bibliography

Tag Name	Frequency	Description
NEIs	40	Literature that helps narrow the list of NEIs
Monetization	21	Literature that addresses monetization of NEIs
SIR	5	Literature that establishes criteria for including NEIs in SIR calculations
Program Character	31	Literature on the effect of including NEIs on the nature of the program and program metrics
Lead Painted Windows	9	Literature on the health benefits from replacing lead painted windows
Legislation	3	Literature on legislative actions needed to allow NEIs in the program

3. ISSUES

Current research on non-energy impacts (NEIs) associated with weatherization was reviewed to provide guidance to DOE on issues related to integrating NEIs into the program. The following issues are discussed in this paper:

- Is legislative action needed to allow using NEIs in the program?
- How to narrow the list of NEIs that could be allowed in the program?
- How to monetize the NEIs allowed in the program?
- What criteria should be used to include NEIs in SIR calculations?
- What effect including NEIs has on program character and metrics?

3.1 REGULATORY CONTEXT FOR NEIS FOR WAP

WAP was established through the Energy Conservation in Existing Buildings Act of 1976. This legislation acknowledged the linkage between energy conservation and health by requiring the federal government to develop program regulations prescribing "standards for weatherization materials, energy conservation techniques, and balanced combinations thereof, which are designed to achieve a balance of a healthful dwelling environment and maximum practicable energy conservation" (Energy Conservation and Production Act 1976). This legislation directed DOE to publish a regulation within the Code of Federal Regulations detailing the requirements of the program.

Current regulatory guidelines for WAP do not address the inclusion of NEIs in measure cost-effectiveness calculations. To move forward, DOE will need to determine the flexibility they have to include NEIs in the program and monitor new legislation regarding the flexibility to do so. This section provides an overview of the current legislation and the language around health and safety. The wording and interpretation of any current or future legislation will strongly affect the manner and degree that NEIs can be incorporated into the program.

3.1.1 Current Regulatory Framework

The codified federal regulation, CFR §440.18, requires that energy conservation measures must be individually cost-effective based on energy savings alone. The language states that installations "must result in energy cost savings over the lifetime of the measure(s), discounted to present value, that equal or exceed the cost of materials, installation, and on-site supervisory personnel." (Department of Energy n.d.). The CFR does not identify any other potential savings explicitly, including NEIs.

However, the regulation allows for spending on health and safety measures to eliminate any hazards prohibiting the installation of weatherization materials (Department of Energy n.d.). Over the years, determining the types of activities which can be undertaken for health-and-safety reasons and under what circumstances has been refined. Current Weatherization Program Notices (WPNs) explicitly state that health and safety spending can only include work necessary to "effectively perform weatherization work" or necessary "as a result of weatherization work (Department of Energy 2017)." For example, the WPNs mention that a gas leak on the customer side of the meter may be fixed to allow for effective weatherization, and that the removal of hazardous materials after weatherization can be incorporated into health and safety spending. Most health and safety measures do not save any energy; however, a new furnace or water heater installed for health and safety reasons could lead to energy savings.

Furthermore, some health and safety measures may even increase energy use each year. For example, WPNs allow for repair or replacement of non-functional heating systems and, for "at risk" clients in appropriate climates, repair, replacement, or installation of cooling systems.

WPNs also allow for the inclusion of measures that have both energy efficiency and health and safety benefits, such as heating system or water heater replacements. For these measures, WPNs state that measures must be treated as conservation measures if they can be cost-justified as such, and only treated as a health and safety measure if they cannot be cost justified on the basis of energy savings (Department of Energy 2017).

The federal regulation also sets a limit on the average cost per unit (ACPU), which is adjusted for inflation each year. The PY2020 limit was set at $7,669 (Department of Energy 2019). Health and safety measure costs may either be included in the ACPU or not. When treated separately (outside the ACPU), DOE generally allows health and safety spending of up to 15 percent of the total budget—though grantees can request additional funds in their health and safety plans (Department of Energy 2017).

3.1.2 Recent Legislative Updates

In December 2020, as part of the "Consolidated Appropriations Act, 2021", language was included to reauthorize the Weatherization Assistance Program and to allow for the consideration of health and safety and non-energy impacts. This language mirrored the wording of other introduced legislation from the past two years.

The language included in this act specifically states that the Department of Energy Secretary "may amend the regulations prescribed…to provide that the standards…take into consideration improvements in the health and safety of occupants of dwelling units, and other non-energy benefits, from weatherization" (H.R. 133). The language also specifically allows for the implementation of measures that will improve indoor air quality, accessibility, and the healthiness of homes.

This language comes directly from several other acts previously introduced in the House or Senate but never passed. One of the earliest bills including this language, the Weatherization Enhancement and Local Energy Efficiency Investment and Accountability Act (H.R. 2041), was introduced in the House of Representatives in April 2019. After that, several more acts included the weatherization language in more comprehensive bills.

The language of the "Consolidated Appropriations Act, 2021" implies that the DOE can amend regulations to allow for NEIs but is not required to. This gives DOE wide discretion to choose how to amend the current program regulations to address NEIs. DOE should review this language and the recommendations below to determine how to proceed.

3.2 SELECTION OF NON-ENERGY IMPACTS

Many different NEIs from weatherization have been hypothesized and studied since the 1990s (Skumatz 2015), but at present, there is no widely accepted list of NEIs, and most studies create their own list, with some overlap. Studies have focused on identifying, quantifying, monetizing, and understanding NEIs on weatherization, energy efficiency programs, and stakeholders. NEIs are typically placed into three broad categories: participants, utility, and society (Skumatz 2015). The benefits are categorized based on the "primary recipient of the value of the benefit" (Hall 2000). For example, participant (sometimes referred to as customer or household) NEIs affect the program participant directly. Meanwhile, utility NEIs benefit the associated utility and society NEIs deliver benefits to society generally rather than an individual or organization (Hall 2000). Some NEIs could be listed under more than one category because they deliver benefits to multiple groups. For example, avoided utility shut-offs and reconnections benefit both utilities and participants (Schweitzer and Tonn 2002). In this situation, each recipient receives a different valued

benefit and double-counting is avoided because different recipients receive different, non-overlapping values for each NEI (Schweitzer and Tonn 2002).

Several NEI examples are presented in Table 2, as described in the most recent national WAP evaluation report titled, Health and Household-Related Benefits Attributable to the Weatherization Assessment Program (Tonn et al. 2014). The list in Table 2 provides common NEI examples found throughout the literature but is not comprehensive. It is important to note that NEIs associated with energy efficient programs for the general public may be quite different than those associated with low-income programs (Sutter et al. 2020).

Table 2: NEI examples

Description	Examples
Participant/Household	
Physical Changes to Home	Reduced energy costs, increase in property values
Income	Reduced energy and water bills, reduced missed days of work, avoided late utility payments, avoided shut-offs and reconnections
Household	Expenditures – ability to afford food and prescriptions
Health & Safety	Improved health; reduced hospitalizations and emergency room visits due to thermal stress, asthma conditions, carbon monoxide poisoning; or home fire prevention
Well-Being	Improved comfort, reduced stress
Society	
Economic	Job creation, avoided unemployment benefits
Environmental	Avoided emissions, reduced water and sewer demand
Medical and Social Service Costs	Reduced medical system expenses, reduced need for food assistance
Utility	
Utility Costs	Avoided transmission and distribution supply costs, reduced customer collection costs, fewer shut-offs and reconnections for delinquency

Source: (Tonn et al. 2014)

Weatherizing homes can provide many direct benefits to households and indirect benefits to society. (Tonn et al. 2014). Participant and societal related NEIs are more directly relevant to WAP, which will be the focus for this paper. Utility related NEIs are not directly relevant to WAP and will not be discussed further.

DOE may want to define criteria to determine when an NEI could be included in WAP. This could reduce the number of NEIs able to be included in WAP and make it easier, at least initially, for DOE to manage NEIs. DOE could follow a similar approach used when integrating health and safety measures into WAP; namely, provide guidance on the allowable NEIs and implementation approaches, etc.

One criteria DOE could use to reduce the number of NEIs allowed to be included in WAP is define the eligible types: participant, societal and utility, and then use other criteria to further refine the list of eligible NEIs. Other potential criteria will be discussed in more detail in the paper including: the ability to

accurately monetize NEIs, and the ability to incorporate NEIs in existing SIR tests at the job and/or measure level.

3.3 MONETIZATION

Researchers have been presenting methods to monetize NEIs for at least thirty years (Brown 1993). These methods vary in rigor and address a wide variety of NEIs. The level of uncertainty of the estimates stems largely from the method used and data available. This section provides an overview of methods used to monetize both participant and societal benefits and then discusses the uncertainty surrounding these estimates and potential solutions to dealing with the uncertainty.

3.3.1 Monetization Methods

Participant level benefits have been typically valued using one of three methods. As discussed in more detail in the SIR section, these methods are largely oriented around whole-home estimates of NEIs. Measure-level estimates require additional analysis that is difficult to achieve and rarely done.

Two of the methods estimate the expected change in incidence of each NEI due to weatherization, which is then multiplied by an estimated cost per incidence. Incidence refers to the frequency of an event, such as a trip to the emergency room, an asthma attack, or a day missed at work. The third method uses participant surveys to directly value NEIs. The three approaches, listed in terms of analytical rigor, are described in more depth below:

1. **Measured changes in incidence and valuation**: This method estimates the change in incidence rate due to weatherization using measured data on houses or from households receiving weatherization as well as a comparison group. This information is then multiplied by an estimated cost per incidence, using national or regional-specific cost data. Previous research has relied on two different sources of data to estimate the change in incidence rates due to weatherization: (1) direct measurement over time through field monitoring or access to household records to estimate changes in incidence before and after weatherization, and (2) use of pre- and post-weatherization participant surveys to estimate changes in incidence due to weatherization.

   In an example of the direct measurement approach, researchers in New Zealand used anonymized national medical records for pre- and post-weatherization periods for a treatment and comparison group to calculate the change in hospitalizations and prescription use following weatherization. They then applied average national costs to monetize the changes (Barnard et al. 2011). This method is the ideal way to monetize non-energy impacts. However, it is costly to do so and difficult to execute in many countries due to data privacy laws, such as the Health Insurance Portability and Accountability Act.

   As an example of relying on participant surveys, Tonn et al. 2014 utilized a survey that asked participants from a weatherized group and a control group how many days of work they missed due to illness or injury. Using these answers, they estimated the decrease in days of work missed for employed persons and multiplied that by an average hourly wage to monetize the impact of weatherization on reducing illness and injuries that led to missed days of work.

2. **National data extrapolation to determine incidence:** This method utilizes data on weatherized houses or their occupants along with national or regional data on prevalence of an event occurring to estimate weatherization's benefit from impacting the event.

For example, Tonn 2014 used this method to calculate the monetized benefit from reduced carbon monoxide poisonings due to the installation of carbon monoxide monitors. To estimate the number of avoided carbon monoxide poisonings in a year and the monetized value of reduced poisonings, researchers collected data on the number of homes receiving weatherization that had combustion heating systems with no carbon monoxide monitors present in the house, literature on how often a carbon monoxide monitor prevents poisoning, national hospital data on carbon monoxide admissions and deaths, and national data on costs for hospital visits and deaths. This method makes use of less participant-specific data and more extrapolation from national estimates, increasing the uncertainty of the direct impact compared to the first method.

3. **Participant surveys to directly value NEIs:** This method uses surveys that ask participants to value the NEIs relative to other services, such as energy savings (Skumatz 2015). These surveys are most often used for NEIs, such as thermal comfort and noise, that are more difficult to estimate using an incidence rate and cost per incident (Skumatz 2014). This method is the least direct method of monetization as it relies on participants' opinion on the value of weatherization rather than measurable outcomes. As an example, Smith-McClain, Skumatz, and Gardner 2006 summarized the results from a survey of 362 participants in a state low-income weatherization program. The survey asked participants how much they value non-energy benefits relative to the energy savings they experienced. The results found that participants valued non-energy impacts at about $230 per household per year.

Societal benefits have well-documented methods for monetization. Namely, there are well-established current-year emissions factors for carbon and criteria pollutants and well-cited monetary estimates per ton of emissions (Carroll and Ucar 2014), which allows for monetization when energy savings are known. For example, Carroll and Ucar 2014 used emission factors from the Environmental Protection Agency (EPA) to convert fuel oil, electricity, and natural gas savings from the national WAP evaluation into tons of reduced emissions. Then, they converted the tons of reduced emissions into monetary savings using regional estimates on the monetary value of four major criteria air pollutants and national guidance on the monetary value of carbon dioxide. Furthermore, a number of states are already incorporating emissions benefits into state efficiency programs – either through the use of an emissions percentage adder or through direct calculation of tons saved and carbon prices (Skumatz 2014). These methods typically use simplifying assumptions for future emissions factors.

Similarly, societal economic benefits are commonly calculated with input-output models, a well-cited method to estimate job and gross domestic product (GDP) impacts (Hall 2000; Riggert 2000; Skumatz 2014, 2015).

3.3.2 Monetization Uncertainty

The monetization of NEIs have varying levels of uncertainty associated with them. Although not always addressed explicitly, some studies directly recognize this uncertainty, such as by reporting values by tier of certainty (Tonn et al. 2014). More often, however, NEI uncertainty is revealed in the form of meta-analyses and literature surveys showing a wide range of values across studies. For example, Skumatz (2014) reports a range of $3 to $54 in saved water utility costs per participant. Ranges of this magnitude can be the result of either differences in the methods and assumptions used, or the differences in the households, housing stock, climate, and measures under study.

A lack of rigorous peer review in the NEI literature contributes to methodological uncertainty: of the 74 articles reviewed for this study and presented in Appendix A, only about a third were peer reviewed. Of the peer-reviewed articles, only three provide monetization values. These were primarily focused on lead

hazard reduction or greenhouse gas emissions. Freed and Felder (2017) further supports this claim, finding that many articles on NEIs cite benefit estimates from 20 years ago, and few define the methods used to quantify the benefits in a transparent way.

Another contribution to uncertainty for some NEIs is the inclusion of loss-of-life calculations, which are (thankfully) rare events with high consequence. As the value of a statistical life saved is generally estimated at between $6 and $9 million, it does not take many projected saved lives to make for large average NEI valuations. For example, Tonn et al. (2014) estimates the benefit of avoided cold-related thermal stress as $172 per household with the value of life excluded and $3,911 with the value of life included. Yet the fact that loss of life in situations like this is rare also makes it difficult to reliably assess the impact that weatherization might have on it. An uncertain effect of weatherization on incidence multiplied by a large per-incident valuation will inevitably yield highly uncertain avoided-loss-of-life estimates.

Even for societal benefits with well-defined methods, such as emissions, a wide range of monetary estimates have been reported (Imbierowicz 2004). One reason for this is regional and timeframe differences. For example, avoided carbon emissions often take account of regional differences in the carbon intensity of electricity (Bradshaw, Bou-Zeid, and Harris 2016; Carroll and Ucar 2014) as well as projections for changing carbon intensity over time.

One approach that has been adopted for utility programs in some states is to use conservative adders (or percentage multipliers) to at least account for stakeholder acknowledgement of *some* level of positive benefits beyond energy savings alone (NEEP 2017; Skumatz 2015). These are typically applied at the project or program level, but the notion of using conservative values that can be revisited in the future as more studies are done could just as easily be applied for measure-level NEI estimates.

It is also important to put NEI uncertainty in the context of other sources of uncertainty associated with measure or program cost effectiveness. While the evidence that WAP produces significant energy savings is incontrovertible, the accuracy of estimated savings for a given measure in a given home is less precise. Studies have shown that computer audit estimates of consumption and savings can have inaccuracies and some tools have been shown to be systematically inaccurate in some respects.[2] There would be little reason to insist on better NEI accuracy and precision than exists for energy savings estimates.

However, a key difference between uncertainty in energy savings and that of NEIs is that standing behind the former is a large body of knowledge of thermodynamics and engineering that provides a logical and defensible basis for these estimations, even if they are not wholly accurate in every case. In contrast, NEI valuations derived from surveys or other methods that provide estimated magnitudes with only vague notions for causal mechanisms are inherently less defensible. DOE could thus place a premium on NEI valuations with clear and quantifiable linkages between measures and resulting NEI impacts. For example, Fabian et al. (2014) describes a detailed asthma epidemiology simulation model that could potentially be combined with data on how the program affects air leakage and mechanical ventilation to model the impact of weatherization on asthma triggers and health costs in different regions and housing stocks. (Although Fabian et al. suggest that "weatherization" has an adverse impact on asthma, it is not clear how weatherization was defined in that study and does not appear to have incorporated the effects of the continuous mechanical ventilation that is now commonly installed under WAP.)

[2] For example, see "Energy Performance Score: 2008 Pilot," a report prepared by Earth Advantage Institute and Conservation Services Group for the Oregon Energy Trust in August 2009; and "Validation of the Manufactured Home Energy Audit (MHEA)," Oak Ridge National Laboratory Report ORNL/CON-501 by Mark Ternes (November 2007).

Uncertainty in NEI valuations can also be viewed in the context of measure selection. Many measures are generally cost effective based on energy savings alone and would be unaffected by including NEIs in the calculations. Others may not be cost effective even if high-end NEI estimates were factored in. Attention about NEI uncertainty could thus be focused on measures and NEIs where the plausible range of NEI valuations would result in large differences in estimated measure installation depending on the NEI valuation.

3.3.3 Monetization Summary

As part of the process of identifying which NEIs will be allowed to be used within WAP, DOE could start by reviewing monetization methods and values for various NEIs that it has identified as being potential candidates per the discussion in Section 3.2. After a rigorous review of methods is completed, DOE could then recommend NEIs with well-defined and accurate monetization methods. This would likely include those that come from studies that are able to measure the change in incidence through direct measurement or surveys. While considering the accuracy needed in NEI monetization calculations for NEIs to be included in the program, DOE should keep in mind the precision for measure energy saving estimates. As noted above, these estimates often have uncertainty associated with them and there is little reason to insist on higher standards for NEIs than energy savings. Lastly, additional research is needed for those NEIs considered for inclusion in WAP but lacking a viable monetization method.

3.4 SIR CALCULATIONS

In addition to determining which NEIs will be allowed by the program, it must be decided how to attribute NEIs to specific energy efficiency measures and whether all NEIs will be calculated equally for each home. This section discusses issues related to incorporating NEIs in SIR calculations associated with selecting measures for individual weatherization jobs. The discussion focuses primarily on two key sub-issues identified as the most relevant to WAP. The first relates to how the monetary value of NEIs can be incorporated in the cost-effectiveness evaluation at the scale of individual measures. The second relates to whether and how occupant characteristics, like occupant health and age, and house characteristics, like geography, affecting NEIs would be incorporated into job-level calculations.

3.4.1 Linking NEIs to Individual Weatherization Measures

Much of the weatherization NEI literature addresses the general impact of weatherization on various NEIs for low-income households (Brown 1993; Skumatz 2015; Tonn et al. 2014). Weatherization programs typically install a suite of energy efficiency measures in each home, making it difficult to tease out the effects of individual measures on NEIs without a controlled study (Smith-McClain, Skumatz, and Gardner 2006). In addition, some health-related NEIs likely derive at least partially from purely health and safety measures commonly installed under the program (e.g., carbon monoxide monitors, repairing non-functional heating and cooling systems). This further complicates attributing NEIs to energy efficiency measures (Freed and Felder 2017). The bulk of research on NEIs over the past 30 years helps bolster the general case for the value of weatherization beyond energy savings but provides limited insights regarding attributing specific NEIs to specific energy efficiency measures (Skumatz 2016).

A few studies have attempted to disaggregate NEIs through use of statistical models (Poortinga et al. 2018; Smith-McClain et al. 2006) or by assigning NEIs proportionally to energy savings (Hawkins 2016; Three3 Inc. and NMR Group, Inc. 2018); however, this work has been relatively limited.

Some non-health NEIs can be readily attributed to specific energy efficiency measures. For example, water and sewer cost savings are solely due to the installation of showerheads and aerators. This example may be of limited usefulness, however, because these water-saving measures belong to the class of

general heat waste measures that are generally cost-effective and thus often not evaluated on an individual basis. As already noted, societal emissions benefits can be derived from measure-level estimates of fuel-specific savings and assumptions about regional emissions factors for the affected fuels.

Among health-related NEIs directly impacting participants, however, lead painted window replacement as an energy measure stands as one of the few energy measures with a fairly direct linkage to health impacts. Lead painted window replacement has been shown to reduce lead dust levels in homes (Dixon et al. 2012; Jacobs et al. 2016). Dust levels, in turn, have been shown to correlate to blood serum lead levels, and blood serum lead levels have been shown to correlate with cognitive abilities and health (Jacobs and Nevin 2006; Nevin et al. 2008).

Some NEIs, such as improved health due to increased ability to afford prescriptions, arise because weatherization reduces participant utility costs, which in-turn increases the household's ability to purchase other necessities, like prescriptions. To the extent that these NEIs can be quantified and linked to energy cost savings, they can plausibly be allocated to individual measures in proportion to each measure's contribution to energy cost savings. Since approximately 2016, utility efficiency program administrators in Massachusetts have been incorporating NEIs in benefit-to-cost ratio calculations using a similar approach (NMR 2011, Hawkins 2016; Tetra Tech 2018). In this case, the mean estimated household-level value of NEIs such as comfort, health and property values from weatherization was apportioned to measures based on each measure's average contribution to bill savings (NMR 2011, Massachusetts Electric and Gas Energy Efficiency Program Administrators, 2015). For NEIs with a demonstrated causal link to bill savings, WAP might be able to use audit savings estimates to allocate NEI-related benefits to specific measures. However, more research is needed to justify using this approach broadly.

Most health-related NEIs are the result of complex interplays among the mix of measures installed, the regional climate, the occupant characteristics, and the household environment. For example, weatherization has been shown to reduce occupant thermal stress by contributing to safer indoor temperatures. But indoor temperatures in various rooms are affected in complex ways by various insulation, air-sealing, and HVAC measures installed in many combinations in homes with widely varying existing conditions in a variety of climates (Nadel 2020; Tonn et al. 2014). For example, the age of occupant affects the health implications of resolving thermally challenged indoor environments. Elderly occupants typically have a narrower comfort range, are more susceptible to extreme temperatures, and have greater thermal stress-related NEIs than younger households. All of this makes it difficult to derive a monetized estimate of the thermal-stress health benefits from a specific energy efficiency measure (e.g., installing ceiling insulation) in a specific home.

Similarly, some research has suggested that weatherization on aggregate can improve indoor air quality and alleviate respiratory diseases like asthma as measured by reduced rates of hospitalization (Breysse et al. 2014; Doll, Davison, and Painting 2016; Rose et al. 2015). Predicting the impact of asthma benefits for a specific household or attributing asthma impacts to individual measures is not straightforward, however. Asthma is affected by multiple triggers (humidity, dust mites, particulates, etc.), not all of which are directly impacted by weatherization. In addition, a few studies have suggested air sealing implemented without providing continuous mechanical ventilation meeting ASHRAE standards can have deleterious impacts on indoor air quality (IAQ) (Fabian et al. 2014; Pigg et al. 2014, Francisco et al. 2017). This exemplifies the inherent tension existing between reducing air exchange rates in order to save energy and providing adequate air exchange to preserve health—and highlights the complex interplay among air-sealing, mechanical ventilation, levels of indoor and outdoor pollutants, and occupant characteristics that determine respiratory health impacts.

Following from this lack of clarity for how to attribute NEIs to specific weatherization measures, existing methods for incorporating NEI values in cost-effectiveness calculations for utility programs do so at the program level (Amann 2006; NEEP 2017; Skumatz 2015; Vine n.d.). A recent report on monetizing NEIs for income-eligible utility efficiency programs in Illinois recommended *against* monetizing NEIs at the measure-level because it was the combination of measures rather than individual measure that provided benefits (Ma et al. 2018). Rather than incentivizing specific measures, NEIs are more commonly used to incentivize programs serving low-income participants who typically receive disproportionately greater non-energy benefits from weatherization (NEEP 2017). This suggests that, 1) based on WAP's target demographic, it likely has higher NEI values than general energy-efficiency programs and 2) perhaps NEIs should only apply to groups of measures, such as the combination of air-sealing, insulation and ASHRAE 62.2-compliant ventilation.

Household-level NEIs could play a limited role in WAP in terms of affecting spending on incidental repair measures (IRMs), which are defined under the program as "those repairs necessary for the effective performance or preservation of weatherization materials," 10 CFR 440.3 (Department of Energy n.d.). Under current program rules, the cost of IRMs must be included in job-level cost-effectiveness testing, and some homes are deferred from treatment by the presence of needed IRMs that would drive the job SIR below 1.0. Whole-home NEI valuations could potentially increase allowable IRM costs to some degree and thus prevent deferral of some jobs.

3.4.2 Linking NEIs to Occupant and House Characteristics

The primary driver of program impact due to incorporating NEIs will be in the monetization of the NEIs. As noted, not all NEIs have the same impact on the same occupant populations or all homes. Therefore, before NEIs are incorporated, it must be determined whether all NEIs will be monetized equally, regardless of permanent home characteristics (such as location/climate zone or type of heating system installed) or characteristics of the current occupants (who may not live in the house for the NEI's full lifetime). NEIs could also be monetized differently according to whether the residence was owned or rented. DOE would need to carefully consider whether to monetize NEIs equally across the program, and if not, how to determine which NEIs are relevant to each home and its current occupants.

DOE may also consider occupant and house characteristics and/or geographical location of the residence when deciding whether an NEI is applicable and how it should be monetized in SIR calculations. Certain interventions have been shown to have a greater impact on certain demographic groups, such as children, the elderly, and those with pre-existing health conditions. As an obvious example, any asthma benefits from weatherization will only be applicable for households with occupants suffering from the condition. Similarly, the benefits from lead painted window replacements will be greatest for households with young children, and the benefits from installing CO monitors will especially be applicable to homes with fossil-fuel heating systems or appliances. Recent research also indicates that households with elderly occupants often benefit more from the health, safety, and income related benefits of weatherization (Nadel 2020).

NEIs may also vary by region and climate. Reduced thermal stress benefits from retrofits may be greater in more extreme climates (Apprise 2018). Similarly, there is some evidence that race and age-related demographics that vary by geographic region can affect NEIs such as hospital visits from asthma and thermal stress (Tonn et al. 2014). As previously noted, any NEIs resulting from emissions reductions will also vary by regional electric grids.

Although evidence suggests household characteristics are important drivers of realized NEIs, it is less clear what characteristics should be included in an SIR calculation and how they should be used in monetization calculations. Like the issue of linking NEIs to weatherization measures, more research is needed in this area. Assuming that the most relevant characteristics were identified for inclusion in the

SIR, data could be collected at the current occupant or regional population level. Each would have pros and cons. For example, if a measure or combination of measures is shown to reduce childhood asthma, should all participating homes get this NEI, or only homes currently occupied by a child with asthma? Would a home with two elderly occupants also include NEIs with positive outcomes for children with asthma? Given that houses are not usually revisited by the program, assuming only the current residents may result in leaving out NEIs that would benefit future residents.

Including current occupant -specific factors in NEI SIR calculations would facilitate targeting measures with substantial NEI benefits to households that would most benefit from them. However, this would complicate current data collection and measure selection procedures – specifics would need to be provided for data inputs that need to be collected. Currently WAP grantees and subgrantees cannot require the disclosure of the occupant medical history information based on HIPPA requirements so any reporting of any health conditions relevant to NEIs may have to be voluntary. This would likely pose a significant obstacle to consistently adjusting NEI SIR factors based on occupant health conditions like asthma and COPD.

Even with data collected at the level of current occupant, generating an NEI estimate for a given household might require translating some population-based NEI estimates to per-relevant-household terms. For example, estimating the asthma-related NEI of weatherization for a household with a child with asthma would require using a population-based estimate of the asthma benefits of weatherization for homes with children. As previously discussed there remains significant uncertainty around the magnitude of this NEI and how it should be monetized. DOE would need to address this uncertainty in selecting a reasonable asthma-related NEI value per home and update this value based on new research.

Occupant-specific calculations of NEI benefits might also create an argument for separate measure lifetimes for NEI versus energy savings calculations—though this would surely increase the complexity of life-cycle costing calculations, and could be difficult to implement within the current suite of energy-audit software tools approved for the program. Households are likely to change prior to the full life of a measure, so the health benefits may have a shorter life than the energy savings from weatherization, which can be expected to persist across households. In contrast, NEIs based on population averages would already account for the fact that not all households will experience these benefits.

On the other hand, basing NEI SIR calculations on regional population averages instead of current occupant specific factors would simplify these characteristics in the SIR calculations. For example, national and state-level estimates of asthma rates broken down by demographic groupings, such as age and poverty level, are available from the CDC (Centers for Disease Control and Prevention n.d.). The asthma-related NEI of weatherization could be adjusted regionally in SIR calculations based on a combination of these state-level rates and more granular census tract data indicating the mean poverty level and number of children per a household.

Applying these regional averages, however, would preclude targeting measures to participating households that might benefit the most. In addition, this method can introduce additional uncertainty in SIR calculations and relevant population data would need to be regularly updated to reflect changing demographics and new research. As an example, the CDC 2018 published estimate of national childhood asthma rate of was 7.7% ± 0.20 S.E. but the rates for children in different age and poverty-level groups vary between 3.8% and 11% (Centers for Disease Control and Prevention n.d.). These data are based on annual National Health Institute Surveys which release new data every few years.

As a final note, there is some precedence in WAP program rules for tailoring health-related NEIs to current occupant characteristics. For example, the installation of mechanical ventilation is based on the

current actual number of occupants in cases where the number of occupants exceeds the number of bedrooms plus one. Also, the assessment of at-risk factors for health and safety measures such as installation of cooling systems is based on current occupants at the time of weatherization.

3.4.3 SIR Summary

Most NEIs are affected by a complex interplay between combinations of measures installed, regional climate, occupant characteristics (e.g., age, income, health), and house characteristics. Based on current research, it is not possible to estimate the relative contribution of specific energy efficiency measures to most health-related NEIs and use this value to prioritize measures in SIR rankings that include NEIs. Possible exceptions include the NEIs associated with replacing lead painted windows and installing water saving measures.

Even if NEIs are only incorporated in SIR tests at the whole-home level, DOE will also need to decide how allowable NEIs and their value should be adjusted based on current occupant characteristics. Some potential ways of handling this issue include either using information from specific households (e.g., self-reporting the number of children with asthma) or applying regional population estimates for those relevant characteristics.

3.5 INCORPORATING NEI CALCULATIONS INTO THE PROGRAM

NEIs have been incorporated into on-going cost-effectiveness calculations of energy efficiency programs (Skumatz 2014), but certainly none for a program with the scope and diversity of WAP. State regulators of utility programs are constantly changing how they incorporate NEIs into regulatory cost benefit tests used to ensure programs are cost effective as new research is available. Skumatz 2014 shares four methods and lists states using the method at that time, which may be different now:

- incorporating a simple "adder" typically focused on incorporating benefits from omitted emissions effects
- a flexible approach with "easy to measure" benefits, such as water bill savings
- a hybrid approach including both an adder and measured benefits
- trying to include all NEIs or leading NEIs.

There is a range of options for how DOE might go about introducing NEIs into the program. At one end of the spectrum, DOE could fully specify—nationally or at a regional level—what NEIs would be allowable, their monetization values, and how they are to be incorporated into SIR calculations. At the other extreme, DOE could provide guidelines regarding potential inclusion of NEIs, leaving it up to individual Grantees to make specific NEI proposals that DOE could review in the context of the regular five-year audit approval process required of all Grantees. Between these extremes, DOE could potentially pre-approve certain NEIs, monetization values, and SIR calculation procedures, but also allow Grantees to propose additions or alternatives for DOE to review on a case-by-case basis. All these options have some precedent in various elements of the current program.

DOE could use a phased approach, along with one of the above approaches, to implement NEIs into WAP allowing DOE more control over the implementation process. In a phased approach, DOE would initially allow only a few NEIs that they have the most confidence in to be included in the program rather than allowing a comprehensive list of NEIs at the start. A few years later, more NEIs could then be allowed to be used in the program, after the impact of including these initial NEIs on the program is understood.

To the extent that DOE chooses to allow Grantees to propose NEIs and monetization values, it would be beneficial for DOE to develop and communicate general guidelines regarding the supporting information for proposed NEIs. This might include requiring documentation of:

- the research or other evidence for an NEI benefit (e.g., observational study versus randomized control trial) and the extent to which this has been peer reviewed or otherwise vetted for validity;
- the monetized value for the NEI, the method used to determine the monetized value, and the range of uncertainty associated with the monetized value;
- the demographic, geographic and housing stock applicability of the estimated NEI benefit; and,
- the research and evidence for how an NEI is linked to a specific measure or group of measures.

Federal regulations and DOE program guidance place a clear priority on achieving energy savings from the program. There may be ways to include NEIs in cost-effectiveness calculations while still maintaining the primacy of energy savings in measure selection. For example, DOE could continue to stipulate that all measures meeting an energy-only SIR of 1.0 be installed (subject to existing measure-skipping guidelines), but also allow for the *optional* installation of measures meeting an acceptable energy-plus-NEIs SIR based on DOE-approved NEI valuations. This would prioritize the installation of measures that are cost-effective based on energy savings alone, while still allowing for the potential installation of additional measures that are cost effective when NEI values are included—and ensuring that the overall energy-plus-NEI SIR for the job is 1.0 or higher. Grantees would still be responsible for meeting established overall average-cost-per-unit limits.

It is also important to recognize the need for—and limits to—software retooling that will likely arise with the incorporation of NEIs in the program. Although incorporating NEI benefits into cost-effectiveness calculations is not difficult in a mathematical sense, there could be significant implementation hurdles with the software packages that are used in the program. Federal funding would be needed for retooling WAP's in-house energy auditing tool, Weatherization Assistant, to allow it to fully handle the data entry and computations needed to incorporate NEIs into cost-effectiveness calculations—though in the near term, there may be ways to treat some NEIs as negative "itemized costs" in a way that allows them to offset IRM and measure costs. The situation is further complicated for WAP by the fact that more than a dozen third-party software packages have been approved by DOE for use in the program. Many of these tools are used widely in non-WAP programs and applications, and software vendors may be reluctant to retool their products to provide NEI functionality that is only being called for under WAP. This could lead to Grantees and software vendors proposing workarounds to account for the value of NEIs without extensive software retooling. Workarounds might include reducing allowable SIRs to less than unity, artificially reducing the costs of measures to try to account for the value of NEIs, or including NEIs as special "measures" that provide benefits without adding to job costs. Depending on the approach, such workarounds may distort the contributions of NEIs to a greater or lesser degree in different situations and may not appropriately account for measure-level contributions to NEIs. DOE would need to consider whether it would allow such workarounds and if so, under what circumstances and constraints.

3.6 PROGRAM CHARACTER

WAP is an established program with a well-developed program character. While program changes have been made over time through Memoranda, Program Notices, and other guidance, these have all been in pursuit of the goals set out in the original WAP legislation. This section aims to identify at which point the overall program character is likely to shift because of the inclusion of NEIs.

The extent to which inclusion of NEIs in the program changes its impact and character depends to a great extent on the details of how they are applied—and to what measures. An expansive interpretation of the WAP-enabling legislative language that the purpose of the program is in part to "improve…health and

safety" could potentially lead to a significant increase in health-related measures with little or no associated energy savings. Incorporation of these measures could result in a significant shift in the basic character of the program, from a primarily energy program to an "energy plus health" program (Capps 2019) or "weatherization plus health" (Energy Program 2019). The list of acceptable NEIs will need to be chosen carefully to ensure that WAP remains an energy-efficiency program.

WAP currently delivers some NEIs, like emissions, which require no additional program costs and including them would not fundamentally alter the program's character. It is apparent that some small health and safety measures may be included in the program without fundamentally altering its character or increasing the cost per home significantly. For example, a three-year pilot program coupled burn prevention services with WAP in New York. It found that this inclusion did not impact program metrics and added minimal cost and time per home visit (Simon et al. 1993).

However, including NEIs in the program will generally add some, if not substantial, cost to the total cost required to weatherize a home because inclusion of the NEI benefits will allow measures to be performed that were not previously cost-effective. Broadly speaking, without an increase in funding, greater cost per home translates to fewer homes served by the program. This may, in turn, have a negative impact on the public perception of the program. For example, the program currently provides weatherization services to approximately 35,000 homes every year using DOE funds and the average weatherization cost per unit is $4,695 (Weatherization Assistance Program 2019). Inclusion of NEIs that increase the average cost per unit by $100 would reduce the number of homes weatherized annually by about 2%, a modest change. But inclusion of NEIs that increase the average cost per unit by $500 would reduce the number of homes weatherized by about 10%, and an increase in the average cost per unit of $2000 due to NEIs would reduce the number of weatherized homes by about 30%.

However, the current detailed regulations and guidance for the program clearly frames it as an energy-savings program, with detailed rules regarding spending on items that are not directly for energy conservation measures, along with strict limits on overall average spending per home. To the degree that these regulations and guidance are maintained in the future, they may limit the extent to which NEIs might radically alter the character of the program. On the other hand, if program regulations and guidance are modified to accommodate NEIs (e.g., average spending limit per home increased to accommodate additional measures justified by NEIs), then the character of the program may change. As another option, non-WAP funding, which does not need to follow DOE WAP rules, could used to fund these additional measures. Braiding funding sources in this way could increase program impact (Capps 2019) without impacting the portion of the program directly funded by DOE.

DOE could consider whether to incorporate NEIs based on the current occupants of a home or whether to apply all NEIs equally to all residences. Applying all NEIs equally to all residences means that all homes would be assessed and NEIs incorporated based on the characteristics of the specific home but not the current occupants. There may still be differences between the measures that even neighboring homes receive, but this is also true of the current program, and this will likely represent a smaller shift in the character of the program than if NEIs are based on current occupants.

It is thus worth considering how inclusion of NEIs at the whole-house or individual measure level might affect the program under current program guidelines. Three scenarios are explored in more detail below.

First, as noted previously, there is much more literature on the overall value of NEIs from weatherization in general than there is for monetizing NEI impacts from individual measures. If DOE were to allow a blanket whole-home NEI credit of some kind, the effect would be to increase overall job cost-effectiveness across the board as all homes are given additional credit for the general existence of positive NEIs from existing measures installed under the program. This would not directly affect measure

selection, but could indirectly do so to some degree by raising the ceiling on IRMs. [3] This in turn could reduce deferral rates, which is a long-term goal of WAP and provides a positive reason for WAP to include NEIs into the program. Current program rules require that the package of weatherization measures and IRMs have an SIR of 1.0 or greater, which sets a limit on how much can be spent on IRMs for a given weatherization job. A whole-home NEI credit would raise this ceiling and could enable the installation of measures that would otherwise not be installed due to the need for repairs beyond what could be cost justified without the additional NEI credit. However, any IRMs would presumably still be subject to DOE requirements that they be associated with specific energy conservation measures or that IRMs be necessary in order to either implement the measures or be needed for the preservation of the installed measures. Average-cost-per-unit limits would also still need to be maintained, and—even if the NEI credit was substantial—expensive repairs may still be deemed beyond the definition of "incidental" and not allowed under the program. All of this suggests that while a whole-home credit for NEIs could have some effect on IRM spending and energy conservation measure selection, it would not necessarily have a large impact on the character of the program.

Second, some NEIs can plausibly be attributed to individual measures in proportion to their fuel and energy-cost savings, and it is worth considering how these might affect the nature of the program. Societal emissions come to mind here, since there are well-established assumptions and procedures for translating fuel savings into emissions benefits. In addition, some NEIs, such as the increased ability to afford prescriptions and put food on the table, derive indirectly from the energy-cost savings from weatherization; benefits from these can also reasonably be allocated to individual measures based on expected energy-cost savings. Allocating benefits from these types of NEIs to individual measures in SIR calculations would not change the basic character of the program, since the benefits scale more or less directly with energy savings. But it could increase the number of measures installed by making some measures cost-effective than would otherwise be cost-ineffective based on energy savings alone. There is also potential to change the mix of measures installed given, for example, different emissions valuations for different fuels.

Finally, there is the case of (generally health-related) NEIs that can be directly attributed to specific measures that otherwise have low or moderate energy savings. Replacement of lead-painted windows is the leading candidate for such a measure: window replacement is an expensive proposition that is often cost-ineffective solely from an energy-savings standpoint. However, several studies have looked at NEIs for lead-painted window replacement, namely improved market value and increased earning potential from improved cognitive potential (Dixon et al. 2012; Jacobs et al. 2016; Nevin et al. 2008). The study that was in closest alignment with a WAP window-replacement scenario (Nevin et al. 2008) was estimated to have a benefit-cost ratio of 1.2 or above for most homes at an estimated replacement cost of $1,000 per window. With this relatively high SIR and cost per window, this could result in large-scale replacement of windows under WAP and the program could quickly run into issues with the current ACPU. This would necessitate either raising the allowable ACPU or reducing spending on homes without lead-painted windows in order to offset high spending on those with such windows. For a fixed overall program budget, either course would reduce the overall energy cost-effectiveness of the program.

In summary, incorporating NEIs into the program in any manner will have some effect on program cost-effectiveness from an energy-only standpoint. Every dollar spent on energy conservation measures that are only justifiable with NEIs included or IRMs is a dollar not spent on an energy conservation measure that can be justified on energy savings alone (albeit in another home). This would reduce the energy-only cost effectiveness of the program to some degree. While there are a number of ways that NEIs could

[3] Spending on health and safety measures could also be affected in this way for Grantees that elect not to create a separate budget category for these measures because these are treated in the same way as IRMs under current guidelines.

certainly affect the number and mix of measures installed under the program, current program rules and guidelines may prevent a wholesale change in the basic character of the program from emphasizing energy savings. Individual measures with large health NEI valuations and low energy savings have the most potential to affect the nature of the program, and thus need to be considered carefully.

4. CONCLUSIONS

Many different NEIs from weatherization have been studied, but there is no widely accepted list of NEIs. Some NEIs have more well-defined and consistent calculation methods and cost estimates than others, requiring thoughtful consideration for integrating NEIs into WAP. This study explores research from the past 30 years, including NEI estimates from the recent national WAP evaluation effort. Incorporating NEIs into WAP is complex with various issues to consider and potential pathways DOE could explore, as summarized below.

Regulations: Current legislative language implies that DOE can amend regulations to allow for the inclusions of NEIs but is not required to. This gives DOE wide discretion to choose how to amend the current program regulations to address NEIs. DOE should review this recently passed language and determine how to proceed.

Selection of NEIs: Defining criteria and guidelines for incorporating NEIs into WAP will make it easier for DOE to manage, similar to how health and safety measures are handled in WAP. Potential criteria could include the types of eligible NEIs, the ability to accurately monetize NEIs, and the ability to incorporate NEIs in existing SIR calculations at the whole house and/or measure level.

Monetization: NEIs have been valued using a variety of methods, which have varying levels of rigor. This leads to some NEIs having more well-defined and consistent calculation methods and cost estimates than others. DOE could start by reviewing monetization methods and values for various NEIs. As many measures are generally cost-effective based on only energy savings, this review could be focused on measures and NEIs where the plausible range of NEI valuations would result in large differences in estimated measure installation depending on the NEI valuation.

After a rigorous review of methods is completed, DOE could then recommend NEIs with well-defined and accurate monetization methods. This would likely include those that come from studies that are able to measure the change in incidence through direct measurement or surveys. Lastly, additional research is needed for those NEIs considered for inclusion in WAP but lacking a viable monetization method.

SIRs: Most NEIs are affected by a complex interplay among combinations of measures installed, regional climate, occupant characteristics (e.g., age, income, health) and house characteristics. Based on current research, it is not possible to estimate the relative contribution of specific energy conservation measures to most health-related NEIs and use this value to prioritize measures via SIR rankings that include NEIs. Possible exceptions include the NEIs associated with replacing lead painted windows and installing water saving measures.

Even if NEIs are only incorporated in SIR calculations at the whole home level, DOE will also need to decide how allowable NEIs and their value should be adjusted based on current occupant characteristics. Some potential ways of handling this issue include either using information from specific households (e.g., number of children with asthma) or apply regional population estimates for those relevant characteristics. Whole-home NEI valuations could potentially increase allowable IRM costs to some degree and thus prevent deferral of some jobs.

Integrating NEIs into WAP: There is a range of options for how DOE might go about introducing NEIs into the program. DOE will need to decide how much freedom Grantees will

have to propose NEIs and their valuations and provide them with guidelines for the supporting information. Integrating NEIs into WAP could be done in phases. Software retooling will likely be needed to accommodate the incorporation of NEIs into WAP.

Program character: The choice of what NEIs to include—and how to incorporate them into the program—strongly affects the potential impact on the nature of WAP. For approaches such as providing a whole-home NEI credit or incorporating NEIs that are strongly tied to energy savings, such as emissions benefits, current program rules and guidelines would likely limit the impact on the program. The largest potential for change is associated with individual measures that can be ascribed large health benefits but provide low or moderate energy savings.

While there is much complexity and uncertainty associated with identifying and valuing NEIs associated with weatherization, there also appear to be pathways to begin to introduce NEIs into program decision-making in limited ways without disrupting the program's basic emphasis on achieving cost-effective energy savings.

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Rose, Erin, Beth Hawkins, Bruce Tonn, Debbie Paton, and Lorena Shah. 2015. "Exploring Potential Impacts of Weatherization and Healthy Homes Interventions on Asthma-Related Medicaid Claims and Costs in a Small Cohort in Washington State." Oak Ridge National Laboratory. https://weatherization.ornl.gov/wp-content/uploads/pdf/WAPRecoveryActEvalFinalReports/ORNL_TM-2015_213.pdf.

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APPENDIX A: ANNOTATED BIBLIOGRAPHY ADDRESSING NON-ENERGY IMPACTS OF WEATHERIZATION

ABSTRACTS AND CITATIONS FOR THE IDENTIFIED REFERENCES

Ahrentzen, Sherry, J. Erickson, and E. Fonseca. 2015. "Thermal and Health Outcomes of Energy Efficiency Retrofits of Homes of Older Adults." Indoor Air 26 (4): 582–93. https://doi.org/10.1111/ina.12239.

Study on whether energy retrofits in affordable multi-family housing for older adults in Arizona can improve indoor climate conditions and whether those improvements corresponded with improved resident health and comfort. The research used a longitudinal panel design to measure results from pre- and post-retrofit data from 57 residents living in 53 units. Data included pre- and post-retrofit temperature, humidity, and air infiltration testing in all units and resident interviews to measure health impacts. The study results focused on quantifying the impact of using retrofits to mitigate thermal stress for occupants.

Tags: NEIs

Amann, Jennifer Thorne. 2006. "Valuation of Non-Energy Benefits to Determine Cost-Effectiveness of Whole-House Retrofits Programs: A Literature Review." American Council for an Energy Efficient Economy. https://www.aceee.org/sites/default/files/publications/researchreports/a061.pdf.

The paper shares the results from the first phase of a three-phase project - a national literature review focused on identifying and quantifying non-energy impacts from residential retrofits and ways to incorporate the NEBs into cost-benefit tests. The goal is to inform a proposed methodology for incorporating NEBs into cost-benefit tests. Non-energy benefits for low-income weatherization programs provide a valuable framework for valuation methodologies to consider NEBs in all home retrofit programs. Quantified non-energy impacts for weatherization programs are included for the northeast and California.

Tags: monetization; NEIs; SIR

Andrews, Clinton, Jie Gong, Gedi Mainelis, Jennifer Senick, MaryAnn Sorensen Allacci, Deborah Plotnik, Leonardo Calderon, Mengyang Guo, Mimala Thomas, Yi Yu, Brian Pavilonis, Prathana Raja, and Bingsheng Liu. 2017. "Cost-Effective Detection of Multi-Family Housing-Related Health and Safety Standards." HUD. http://rcgb.rutgers.edu/wp-content/uploads/2017/09/HUD-Cost-Effective-Detection-of-MF-Housing-2017_01_27.pdf.

The field study tested the efficacy of integrated laser scanning and thermal imaging to identify housing-related health and safety standards on two high-rise multi-family low-income residential buildings in New York City. The approach was being tested for commercialization consideration with weatherization identified as a target market. The study integrated data from thermal images, interviews, IAQ, and building related data and concludes that building defects, such as missing insulation, have a direct effect on residents' well-being.

Tags: NEIs

Andrews, Clinton, Gedi Mainelis, Richard Wener, MaryAnn Sorensen Allacci, Deborah Plotnik, Jennifer Senick, Irina Feygina, Olga Autote, Swetha Ramkumar, Tiffany Pryce, Rewa Marathe, and Jiayi Ding. 2013. "Expanding the Definition of Green: Impacts of Green and Active Living Design on Health in Low Income Housing: Added Value of Behavioral Interventions as Part of an Integrated Service Delivery Model." HUD. http://rcgb.rutgers.edu/wp-content/uploads/2013/11/HUD-Expanding-the-Definition-of-Green-Healthy-Families-Study-2013_FINAL_revised.pdf.

Study of how IAQ, occupant health and energy use are affected by targeted interventions for a sample of 40 residents in a 127-unit ENERGY STAR rated affordable multifamily housing building in South Bronx, NY. The goal of the research was "to determine whether green building objectives were in conflict with or complementary to health-related objectives for residents." The researchers surveyed residents and took IAQ measurements before and after targeted interventions. Interventions were mostly behavioral, including things like education on IAQ management, low-VOC cleaning supplies, healthy behaviors, and energy conservation. They identified some green building objectives that might conflict with health such as low ventilation rates negatively affecting IAQ and potentially contributing to asthma problems. Also, they suggest that encouraging energy conversation behaviors may cause residents to use the AC less which could negatively affect IAQ and health. Positive impacts were associated with the roof-top garden and use of low-VOC materials.

Tags: program character; NEIs

Apprise. 2018. "Non-Energy Benefits of WAP Estimated with the Client Longitudinal Survey Final Report." http://www.appriseinc.org/researchhighlights/.

Results from analyzing pre- and post-WAP treatment occupant survey data from the National Weatherization Assistance Program (WAP) Evaluation with a focus on affordability, home condition, home comfort, health, and safety benefits. The study used a treatment and comparison group and focused on identifying non-energy benefits and found some are more pronounced in some climate zones. This report is an independent analysis of the National WAP Evaluation Occupant Survey data, separate from the ORNL analysis.

Tags: program character; NEIs

Barnard, Lucy Telfar, Nick Preval, Philippa Howden-Chapman, Richard Arnold, Chris Young, Arthur Grimes, and Tim Denne. 2011. "The Impact of Retrofitted Insulation and New Heaters on Health Services Utilisation and Costs, Pharmaceutical Costs and Mortality." New Zealand Ministry of Economic Development. http://www.healthyhousing.org.nz/wp-content/uploads/2012/03/NZIF_Health_report-Final.pdf.

This article evaluated the impact of insulation and a new heating system on hospitalizations, deaths, and pharmaceutical costs for homes in New Zealand. The study serves as part three of an overall evaluation of the effect of these installations and focuses specifically on health outcomes. The researchers utilized a treatment group of 37,163 homes and over 100,000 comparison homes and were able to access tracked health data on hospitalizations and prescriptions. The homes had been treated between July 2009 and May 2010. Using this data set and a matching protocol, the authors estimated the change in hospitalization and prescription occurrences as well as costs. They found that homes that received weatherization had statistically significant lower hospitalization and pharmaceutical costs in the post period.

Tags: NEIs

Bradshaw, Jonathan L., Elie Bou-Zeid, and Robert H. Harris. 2016. "Greenhouse Gas Mitigation Benefits and Cost-Effectiveness of Weatherization Treatments for Low-Income, American, Urban Housing Stocks." *Energy and Buildings* 128 (September): 911–20. doi.org/10.1016/j.enbuild.2016.07.020.

This article explores the variation in weatherization cost effectiveness across six US cities. The goal of the article is to address a gap in the weatherization research by evaluating how the monetized benefits of weatherization vary geographically. The authors model energy usage for low-income households in Orlando, Seattle, Long Beach, Milwaukee, Detroit, and Philadelphia using housing demographic data specific to each location. To estimate the impact

of weatherization, they model fuel-specific savings from air sealing, smart thermostats, and attic insulation. Using 2012 state-specific energy prices and electric emissions factors, they estimate the cost effectiveness of each measure. They find significant variation in the cost effectiveness by region, due to the differences in both primary fuels used, amount of savings achieved, and local fuel prices.

Tags: monetization; NEIs

Breysse, Jill, Sherry L. Dixon, David E. Jacobs, Jorge Lopez, and William Weber. 2015. "Self-Reported Health Outcomes Associated With Green-Renovated Public Housing Among Primarily Elderly Residents." Journal of Public Health Management and Practice 21 (4): 355–367. https://doi.org/10.1097/PHH.0000000000000199.

Summarizes an investigation into the impact of green renovations on the physical and mental health of residents in low-income multifamily housing in Mankato, Minnesota. Impacts were measured using resident interviews, housing visual assessments, indoor environmental sampling, and building performance testing. The study concluded green healthy housing renovation may result in improved mental and physical health, prevented falls, and reduced exposure to tobacco smoke.

Tags: NEIs

Breysse, Jill, Sherry Dixon, Joel Gregory, Miriam Philby, David E. Jacobs, and James Krieger. 2014. "Effect of Weatherization Combined With Community Health Worker In-Home Education on Asthma Control." *American Journal of Public Health* 104 (1): e57–64. https://doi.org/10.2105/AJPH.2013.301402.

This article is an evaluation of the impact of a weatherization plus health program on childhood asthma. The goal of the program was to see if adding weatherization to a home health education program could improve childhood asthma outcomes. The report evaluates a pilot program in King County, Washington that enrolled 45 households in 2009 and 2010. The study compared the treatment households to a comparison group of households that received home health visits between 2002 and 2004 in the same county. It used propensity-score matching to compare the outcomes of the treatment and comparison group. The results focused on only health impacts and found that adding weatherization leads to improved asthma control and caregiver quality of life.

Tags: program character

Brown, Marilyn, Anmol Soni, Melissa Lapsa, and Katie Southworth. 2020. "Low-Income Energy Affordability: Conclusions from a Literature Review." Oak Ridge National Laboratory. https://doi.org/10.2172/1607178.

This paper examines the persistent problem of high energy burdens among low-income households, based on a review of more than 180 publications that pointed to several promising opportunities to address energy affordability including inclusive solar programs, leveraged health care benefits, and behavioral economics using an equity and affordability lens. Even after decades of weatherization and bill-payment programs, low-income households, on average, continue to spend a higher share of their income on electricity and natural gas bills than any other income group. Energy burden for low-income households is not declining, and it remains persistently high, particularly in the South, in rural America, among minority households, and those with children and elderly residents. On a per household basis, utility companies spend less on energy-efficiency programs for low-income households than for other income groups. In addition, government and utility programs that promote rooftop solar power, electric vehicles, and home energy storage are largely inaccessible to low-income households. This paper identifies

promising opportunities to address energy affordability including inclusive solar programs, leveraged health care benefits, behavioral economics, data analytics, advanced information and communication technologies, and grid resiliency. Scalable approaches require linking implementing agencies, programs, and policies to tackle the complex web of causes and impacts on low-income households with high energy burdens.

Tags: program character; SIR

Brown, Marilyn, Linda Berry, Richard Balzer, and Ellen Faby. 1993. "National Impacts of the Weatherization Assistance Program in Single-Family and Small Multifamily Dwellings." Oak Ridge National Laboratory. https://www.osti.gov/servlets/purl/10179419.

This report details the results of an evaluation of the 1989 program year of the national low-income weatherization program. The goal of the report is to serve as an updated comprehensive assessment of the national weatherization program after several program changes were implemented. The article focuses on single-family homes, manufactured homes, and 2-4-unit multifamily buildings heated with either natural gas or electricity. It reports the characteristics of the homes weatherized in 1989 and then details the first-year energy savings, non-energy impacts, and cost effectiveness of the program. The discussion of non-energy impacts first identifies the impacts and describes how the weatherization program influences each one. It then monetizes a select number of the identified NEIs and discusses the impact on the cost effectiveness tests, finding that the inclusion of non-energy impacts increased the cost-benefit ratio for both gas and electricity.

Tags: monetization; program character

Campbell, Nina, Lisa Ryan, Vida Rozite, Eoin Lees, and Grayson Heffner. 2014. "Capturing the Multiple Benefits of Energy Efficiency." International Energy Agency. http://euase.net/wp-content/uploads/2017/07/Captur_the_MultiplBenef_ofEnergyEficiency.pdf.

This document provides an international perspective on ways to integrate "multiple benefits" in the energy efficiency policy process with in-depth analysis of five benefit areas: macroeconomic development, public budgets, health and well-being, industry productivity, and energy delivery. Benefits from reductions in energy demand and GHG emissions have been measured systematically to date and it examines methodologies to assess the multiple benefits energy efficiency delivers for the economy and society based on an extensive literature review and discussions with more than 300 people from 27 countries.

Tags: NEIs

Capps, Laura, Liz Curry, and Emily Levin. 2019. "Energy-Plus-Health Playbook." Vermont Energy Investment Corporation. https://www.veic.org/clients-results/reports/energy-plus-health-playbook.

The report provides practical guidance to EE program administrators to understand opportunities for integrating health and safety measures and associated benefits in EE program design and delivery. The authors summarize some relevant literature, interview key stakeholders and share case-studies that illustrate different models for integrating health and safety measures in weatherization programs. The bulk of their information and recommendations come from interviews with program administrators. The examples are organized in three tiers of increasing integration of EE programs with the health care community. The geographic scope of the report is national, and the overall purpose is to help increase the integration of health and safety measures in weatherization programs by clearly presenting the benefits of doing so and providing practical guidance.

Tags: program character

Carroll, David, and Ferit Ucar. 2014. "Environmental Emissions Nonenergy Benefits: Working Paper." Oak Ridge National Laboratory. https://weatherization.ornl.gov/wp-content/uploads/pdf/WAPRetroEvalFinalReports/ORNL_TM-2015_126.pdf.

This report identifies and monetizes the emissions benefits associated with weatherization. The authors use billing analysis to estimate the energy savings during the 2008 program year of the national Weatherization Assistance Program. Using those energy values, they then estimate the monetary value of the associated CO2, SOx, NOx, VOC, and PM2.5 emission reductions for the entire program and for a representative household. The authors estimated emissions reductions for each state using NERC region specific data for electricity and standard emissions factors for other fuels. The monetary value per ton came from the Air Pollution Emissions Experiments and Policy model for SO2, NOx, VOC, and PM2.5 and from the Office of Management and Budget for CO2 equivalents. They found that the 2008 WAP aggregate impact of avoided emissions is over $250 million and the average value per housing unit is $2,932.

Tags: monetization

Cluett, Rachel, Abby Fleisch, Kathy Decker, Eric Frohmberg, and Andrew E. Smith. 2019. "Findings of a Statewide Environmental Lead Inspection Program Targeting Homes of Children With Blood Lead Levels as Low as 5 Mg/DL." *Journal of Public Health Management and Practice* 25 (February): S76. https://doi.org/10.1097/PHH.0000000000000869.

This article compared the residential inspection reports for children within two blood lead level categories. The two categories were children falling above 10 ug/dL, a typical threshold set in states, and children between 5 and 9 ug/dL, a new threshold recommended by the CDC. The objective of the study was to analyze how often lead hazards that required abatement were identified for children in the lower group and to see how and if the hazards identified differed between the two groups. The study analyzed records of 340 inspections between 2016 and 2018 in the state of Maine. A notable finding, related to weatherization, is that window dust was positively correlated with lead levels in children in both categories - leading to the need for either window repair or window replacement. The article found that the number of hazards in the home were lower for children with lower lead blood levels, but that the homes still needed abatement 77 percent of the time.

Tags: lead painted windows

Cohen, Mark. 1998. "The Monetary Value of Saving a High-Risk Youth." Journal of Quantitative Criminology 14 (1). 10.1023/A:1023092324459.

This article provides an overview of the monetary value associated with keeping a youth from engaging in criminal activity, dropping out of high school, or becoming a heavy drug user. Lead blood poisoning has been linked to increased criminal activity as well as lower cognitive ability resulting in higher rates of high school dropout. Combined with estimates on the reduction in prevalence of crime or high school dropouts from replacing lead painted windows provides a way to quantify these benefits. The article uses point estimates from other literature to estimate these social benefits and finds that an intervention that prevents any of these could save several hundred thousand dollars.

Tags: monetization; lead painted windows

Colton, Meryl, Jose Guillermo Cedeno Laurent, Piers MacNaughton, John Kane, Mae Bennett-Fripp, John Spengler, and Gary Adamkiewicz. 2015. "Health Benefits of Green Public Housing: Associations with Asthma Morbidity and Building-Related Symptoms." American Journal of Public Health 105 (12): 2482–89. 10.2105/AJPH.2015.302793.

The research study included a statistical analysis of visual home inspections and surveys to compare indoor environmental conditions and health outcomes between residents living in green and conventional low-income multifamily public housing developments in Boston, Massachusetts. The study used two control groups and two treatment groups across three buildings, with treatment participants living in a unit that received "green" renovations. Multiple interventions were used in the study including building design, policies, and resident education to better understand the cumulative effects of the multicomponent intervention rather than the effect of individual interventions.

Tags: NEIs

Coombs, Kanistha, Ginger Chew, Christopher Schaffer, Patrick Ryan, Cole Brokamp, Sergey Grinshpun, Gary Adamkiewicz, Steve Chillrud, Curtis Hedman, Meryl Colton, Jamie Ross, and Tiina Reponen. 2016. "Indoor Air Quality in Green-Renovated vs. Non-Green Low-Income Homes of Children Living in a Temperate Region of US (Ohio)." Science of the Total Environment 554–555 (June 1): 178–85. https://doi.org/10.1016/j.scitotenv.2016.02.136.

The research study is a subset of the Green Housing Study (GHS), a multi-site study designed by the CDC and HUD, with a goal to investigate how green housing factors are associated with IAQ and children's respiratory health. The study included 28 green and 14 non-green units in low-income multi-family housing complexes in Cincinnati, Ohio, with a child ages 7-12 years diagnosed with asthma residing in the unit. Data included measurement of six indoor pollutants, temperature, and relative humidity, and questionnaires to determine if occupant behavior had an impact on IAQ. Home visits occurred immediately after renovation, 6 months after renovation, and 12 months after renovation, with 8 homes receiving a pre-renovation home visit. The study concludes that careful selection of indoor building materials and ensuring sufficient ventilation are important to reduce IAQ problems and potentially improve health.

Tags: NEIs

De Souza, Rachael, Robin Evans-Agnew, and Christine Espina. 2019. "Federal Weatherization and Health Education Team up: Process Evaluation of a New Strategy to Improve Health Equity for People With Asthma and Chronic Obstructive Pulmonary Disease." *Journal of Public Health Management and Practice* 25 (1): E21. https://doi.org/10.1097/PHH.0000000000000786.

Unhealthy housing is a major cause of respiratory health inequity. In-home health education improves health equity for low-income and minority populations with asthma and chronic obstructive pulmonary disease. Yet, outcomes of educational interventions are limited by poor housing conditions. Federal weatherization programs represent a promising source of funding for home repairs. Innovative legislation in Washington State integrates the 2 interventions as "Weatherization Plus Health," offering environmental health education in partnership with the Weatherization Assistance Program for low-income families with respiratory disease. This practice brief describes process evaluation results of a Weatherization Plus Health program in Pierce County, Washington. Evaluation data were gathered via interviews with service providers and ethnographic observation. Workers report that the combined intervention expanded their understanding of their practice, skills, and feelings of efficacy in meeting client needs. Integrating federally funded home weatherization with health education shows promise for building public health system capacity and increasing health equity.

Tags: program character

Dixon, Sherry L., David E. Jacobs, Jonathan W. Wilson, Judith Y. Akoto, Rick Nevin, and C. Scott Clark. 2012. "Window Replacement and Residential Lead Paint Hazard Control 12 Years Later." Environmental Research 113 (February): 14–20. https://pubmed.ncbi.nlm.nih.gov/22325333/.

This article analyzes the impacts of lead hazard abatement twelve years after the initial inspection. The sample included 189 homes across four different geographies: Vermont, Cleveland, Chicago, and Minnesota. The objective of the study was to examine results after a longer time period and compare the results for non-replacement and full replacement of windows. It categorized homes into one of three categories: full replacement of windows, partial replacement of windows, and window repair instead of replacement. The researchers performed in-depth inspections of homes that received lead intervention twelve years previously and also identified the benefits associated with window replacement. The article found that all homes had lower levels of lead dust twelve years after intervention and that full replacement of windows reduced floor and sill dust by a significantly higher percent than non-replacement of windows. Full replacement of windows also leads to net benefits when compared to non-replacement or repair work for windows.

Tags: lead painted windows

Doll, S. C., E. L. Davison, and B. R. Painting. 2016. "Weatherization Impacts and Baseline Indoor Environmental Quality in Low Income Single-Family Homes." Building and Environment 107 (October): 181–90. https://doi.org/10.1016/j.buildenv.2016.06.021.

This field study examined indoor air quality conditions of 69 homes in North Carolina that received weatherization services. The objective of the article was to identify how weatherization impacted indoor air quality compliance rates and if there was a significant difference in indoor air pollutant levels pre- and post-weatherization. The article summarized basic household characteristics as well as the impact on CO2, CO, NO2, temperature, humidity, radon, formaldehyde, and particulate matter. The researchers monitored pollutant levels for 5 to 6 days pre and post weatherization in each home and completed the study during cooling and heating seasons in the years 2012 to 2015. The researchers found that the number of homes with acceptable indoor air quality levels increased or stayed the same for all parameters other than temperature.

Tags: program character; NEIs

Drehobl, Ariel, and Lauren Ross. n.d. "Lifting the High Energy Burden in America's Largest Cities: How Energy Efficiency Can Improve Low-Income and Underserved Communities." American Council for an Energy Efficient Economy. https://www.aceee.org/sites/default/files/publications/researchreports/u1602.pdf.

The article highlights the high energy burden that low-income households face and proposes potential ways to decrease the burden. The goal of the report is to examine the energy burden across the United States and to discuss strategies for alleviating the burden, with a focus on relying more on energy efficiency initiatives. It starts by exploring the energy burden of low-income households in 48 of the largest US cities by analyzing 2011 and 2013 Census and US Department of Housing and Development data. It then proposes several solutions, which focus predominately on energy efficiency investments as high energy burden is directly related to the inefficiency of low-income homes. In its discussion of solutions, it recommends recognizing the non-energy benefits of efficiency programs as they can have a significant and positive impact on program metrics.

Tags: program character

Elevate Energy. 2014. Preserving Affordable Multifamily Housing through Energy Efficiency. Elevate Energy. https://sahlln.energyefficiencyforall.org/sites/default/files/Preserving_Affordable_Multifamily_Housing_through_Energy_Efficiency_Final_2.18.14.pdf.

The case study evaluates the building owner and tenant non-energy benefits of energy retrofits in 70 units across three affordable multifamily buildings in Chicago. The study focused on measuring building and owner cost savings by analyzing building-level construction, energy use, and tenant and owner surveys data. Measures installed in the building focused on saving natural gas and included air sealing, roof cavity insulation, and furnace replacement. Tenants were responsible for paying for electricity and natural gas and saw a 19 percent reduction in gas usage post-retrofit. Buildings saw a 17 percent reduction in maintenance costs one-year post-retrofit and tenants reported feeling their units stayed cooler in the summer and warmer in the winter.

Tags: NEIs

Energy Program Washington State University, State of Washington Department of Commerce, Pierce County Human Services, and Tacoma-Pierce County Health Department. 2019. "Washington State Weatherization Plus Health Program Pilot: Pierce County Healthy Homes Case Study." Washington State University Energy Program. http://www.commerce.wa.gov/wp-content/uploads/2019/02/Pierce-County-Healthy-Homes-Case-Study-Jan-31-2019-final-1.pdf.

This report provides an overview of a weatherization plus health pilot program in Washington state. It directly addresses how non-energy benefits can be included in a weatherization program as well as the impact of the joint program. The program, piloted in 2017, provided weatherization and health provider engagement services to 53 households in Pierce County, Washington. The report summarizes the demographics of the households surveyed and highlights only the impact on health-related measures. The health-related impacts were measured from follow-up surveys and home visits. It found that the program led to lower use of medical services and improved quality of life for participants.

Tags: program character

Fabian, Maria Patricia, Gary Adamkiewicz, Natasha Kay Stout, Megan Sandel, and Jonathan Ian Levy. 2014. "A Simulation Model of Building Intervention Impacts on Indoor Environmental Quality, Pediatric Asthma, and Costs." *The Journal of Allergy and Clinical Immunology* 133 (1). https://doi.org/10.1016/j.jaci.2013.06.003

This study uses a simulation model to analyze the impact of various interventions on childhood asthma severity in low-income multifamily housing. The authors utilized a simulated cohort of 1 million children to estimate how interventions impacted indoor allergens and dampness and the resulting impact on use of medication and number of doctor or hospital visits. One key intervention was weatherization, which addresses the impact of weatherization on non-energy impacts directly. The baseline cohort was modeled using demographic data drawn from Boston public housing studies (1997) and assumptions about asthma severity levels. The authors found that while numerous environmental interventions had a positive impact on asthma severity, traditional weatherization efforts increased the level of indoor air allergens resulting in more asthma symptom days and serious asthma events. Considering these impacts, the payback period for weatherization, even when considering energy savings, was greater than 10 years. Even when coupled with other interventions, this relationship existed.

Tags: program character

Fisk, William, Brett Singer, and Wanyu Chan. 2020. "Association of residential energy efficiency retrofits with indoor environmental quality, comfort, and health: A review of empirical data." Building and Environment 180. https://doi.org/10.1016/j.buildenv.2020.107067

This article reviews previous empirical research on the influence of weatherization on indoor air quality and health conditions. The authors reviewed 36 studies, completed in the United States or Europe, that analyzed the impact of energy efficiency upgrades on at least one indoor air quality or health condition. The goal was to determine how retrofits impact these conditions and if the results vary for different types of retrofit, such as retrofits focused on energy only, retrofits focused on health only, or retrofits with a joint objective. The study found that indoor radon, formaldehyde, and carbon dioxide concentrations increase after weatherization if mechanical ventilation is not added. However, indoor temperatures, indoor dampness and mold, and subjectively-reported health outcomes all improve after a retrofit. There was insufficient data to determine if health and comfort results vary across retrofit types.

Tags: NEIs

Francisco, P. W., D. E. Jacobs, L. Targos, S. L. Dixon, J. Breysse, W. Rose, and S. Cali. 2017. "Ventilation, Indoor Air Quality, and Health in Homes Undergoing Weatherization." Indoor Air 27 (2): 463–77. https://doi.org/10.1111/ina.12325.

The randomized study was designed to fill the knowledge gap on residential ventilation and health outcomes in the context of weatherization. The study compared the effect of weatherization using two different ASHRAE ventilation standards on homes in Indiana and Cook County, Illinois. The results showed indoor air quality and health improve when weatherization is accompanied by an ASHRAE residential ventilation standard.

Tags: program character; NEIs

Frank, Deborah A., Nicole B. Neault, Anne Skalicky, John T. Cook, Jacqueline D. Wilson, Suzette Levenson, Alan F. Meyers, Timothy Heeren, Diana B. Cutts, Patrick H. Casey, Maureen M. Black, and Carol Berkowitz. 2006. "Heat or Eat: The Low Income Home Energy Assistance Program and Nutritional and Health Risks among Children Less than 3 Years of Age." Pediatrics 118 (5): e1293-1302. https://doi.org/10.1542/peds.2005-2943.

Evaluates the association between a family's participation in the Low Income Home Energy Assistance Program (LIHEAP) and their children's health by reviewing cross-sectional survey results from 7,074 caregivers in 5 urban locations. Households receiving LIHEAP assistance with children aged 2-3 years old showed less anthropometric evidence of undernutrition, were not more likely to be overweight, and had lower odds of acute hospitalization from an emergency department visit among young children in low-income renter households.

Tags: program character; NEIs

Freed, Michael, and Frank A. Felder. 2017. "Non-Energy Benefits: Workhorse or Unicorn of Energy Efficiency Programs?" The Electricity Journal 30 (1): 43–46. https://doi.org/10.1016/j.tej.2016.12.004.

Provides insight into non-energy benefit research results and why states are not including NEBs in cost-benefit analysis based on a national literature review. The article identified a need for more updated empirical research to improve the definition, attribution, and quantification of the benefits and costs for both non-EE and EE measures.

Tags: monetization; program character; NEIs

Frey, S, H. Destaillats, S. Cohn, S. Ahrentzen, and M. P. Fraser. 2014. "The Effects of an Energy Efficiency Retrofit on Indoor Air Quality." Indoor Air 25 (2): 210–19. https://doi.org/10.1016/j.egypro.2016.09.134.

This report summarized the impacts of an energy efficiency retrofit, indoor air quality and resident health program in a low-income senior housing complex in Arizona. The energy efficiency improvements included: PTAC units, windows and sliding glass door, ENERGY STAR appliances and a bedroom ceiling fan. Other improvements included: low VOC flooring, cabinets, paint, carpet and carpet pad. Indoor and outdoor air was tested three times in 2010 (pre-renovation), 2011 (post renovation) and 2012 (a year after renovation) and a questionnaire was given to residents. Measured formaldehyde levels seemed to correlate with self-reported quality of life and emotional distress in resident interviews. However, the researchers indicated that a larger sample would be needed for conclusive findings. The indoor air quality testing in this study was a subset of a larger scale study in which cost efficiency and health benefits from renovations were analyzed (Ahrentzen et al. 2013). The research was funded by the US Department of Housing and Urban Development.

Tags: NEIs

Gould, Elise. 2009. "Childhood Lead Poisoning: Conservative Estimates of the Social and Economic Benefits of Lead Hazard Control." *Environmental Health Perspectives* 117 (7): 1162–67. https://doi.org/10.1289/ehp.0800408.

This article details the costs and benefits associated with minimizing childhood exposure to lead paint. The goal of the article is to update estimates on the monetary value for the benefits of reducing childhood lead exposure, specifically through lead paint hazard control. The benefits monetized included avoidance of healthcare costs, avoidance of lower lifetime earnings and tax revenue, and avoidance of associated costs with special education, ADHD, and crime. The article concludes by comparing the cost to mitigate lead exposure compared to these benefits, finding that every dollar spent on controlling lead hazards returns between $17 and $221 of benefits. It is indirectly related to weatherization as it provides information on how to monetize the benefit of removing lead painted windows.

Tags: monetization; lead painted windows

Grosse, Scott D, Thomas D Matte, Joel Schwartz, and Richard J Jackson. 2002. "Economic Gains Resulting from the Reduction in Children's Exposure to Lead in the United States." *Environmental Health Perspectives* 110 (6): 563–69. 10.1289/ehp.02110563.

This peer-reviewed article quantified the economic benefits resulting from the reduction in children's exposure to lead over time. The paper's objective was to expand on previous research on this topic and to place a monetary value on the societal gains from lead control efforts in the U.S. The paper, published in 2001, used data on blood lead levels in 1976 compared to blood lead levels in the 1990s to estimate how the decline in lead exposure impacted worker productivity. The model assumed that lead levels in children impacts cognitive ability which then impacts individual productivity and expected earnings. The article finds that the cohort of children born after lead control efforts could gain somewhere between $110 to $318 billion in earning power compared to the generation born in the 1970s. This paper addresses how to quantify the non-energy benefit of reduced lead exposure from removing lead painted windows during weatherization.

Tags: monetization; lead painted windows

Hall, Nick, and Jeff Riggert. 2000. "Beyond Energy Savings: A Review of the Non-Energy Benefits Estimated for Three Low-Income Programs." ACEEE Summer Study on Buildings. https://www.aceee.org/files/proceedings/2002/data/papers/SS02_Panel10_Paper10.pdf.

The report compares the treatment of NEIs across three evaluations of low-income weatherization programs. The three evaluations were completed between 1999 and 2001 and covered a California program, a Vermont program, and a Cinergy Corp (Ohio) program. The goals of the report were threefold: (1) to provide an overview of estimation methods, (2) to describe why each program included certain non-energy impacts, and (3) to compare the results of the three evaluation methods. To do this, the article provided detailed information on 25 NEIs, each of which was categorized by whether it was a utility, participant, or societal benefit. It summarized which of the NEIs each program included and how they monetized the value if included. It concluded by summarizing the total value from including NEIs, finding that the value from non-energy impacts was larger than the value of energy savings for each of the three programs.

Tags: monetization; NEIs

Hawkins, Beth, Bruce Tonn, Erin Rose, Greg Clendenning, and Lauren Abraham. 2016. "Low-Income Single-Family Health- and Safety-Related Non-Energy Impacts (NEIs) Study." Massachusetts Program Administrators. https://rieermc.ri.gov/ma-low-income-single-family-health-and-safety-non-energy-impacts-study/.

This report summarizes the findings of a study on the health and safety-related benefits from weatherization of low-income homes in Massachusetts and recommends which of the findings to incorporate into cost-effectiveness tests in the state. The evaluation of the MA program, completed in 2016, monetizes eight health and safety related non-energy impacts. The study utilizes a subset of data from the national Occupant Survey completed for the national WAP program to estimate incidence of the benefit. To monetize the benefits, the researchers use secondary literature on Massachusetts specific costs. It separates the monetary values into household and societal values as well as into three tiers of certainty. The evaluators recommend that Massachusetts uses 7 of the 8 monetized values in some capacity, which totals to a $1,000 in health benefits from weatherization.

Tags: monetization; program character; NEIs

Hayes, S., Cassandra Kubes, and Christine Gerbode. 2020. "Making Health Count: Monetizing the Health Benefits of In-Home Services Delivered by Energy Efficiency Programs." American Council for an Energy Efficient Economy. https://www.aceee.org/research-report/h2001.

This article, published in 2020, summarizes previous research on health benefits from weatherization and provides a generalized method to estimate the monetized benefit of four health benefits. The objective of the article is to help bolster the case for comprehensive in-home health and energy programs. The authors list several of the health benefits identified in previous research and present a theory of change for the weatherization network to be used as an in-home preventative care strategy. The authors then present a simplified method to use secondary research to monetize the potential benefits from reducing asthma prevalence, thermal stress, and trip-and-fall injuries through weatherization. They find that targeting these health risks as part of weatherization could generate $228 million in health savings annually in the United States.

Tags: monetization; program character; NEIs

Health Impact Project, Robert Wood Johnson Foundation, and The PEW Charitable Trusts. 2017. "10 Policies to Prevent and Respond to Childhood Lead Exposure: An Assessment of the Risks Communities Face and Key Federal, State, and Local Solutions." The Pew Charitable Trusts. https://www.pewtrusts.org/-/media/assets/2017/08/hip_childhood_lead_poisoning_report.pdf.

This report provides detailed information on childhood lead exposure and recommends ten policies to implement to prevent lead exposure. It provides a history of lead levels in the United States and background on the detrimental impacts of lead exposure. The researchers then monetize the benefits and costs associated with four prevention strategies and provide an in-depth overview of data gaps and ways to support children who have already been exposed. The report concludes by recommending the adoption of ten policies: three priority prevention strategies, three secondary prevention strategies, two poison response strategies, and two ways to improve data and research on the topic. The authors found that addressing lead paint in homes, through window replacement or other strategies, would provide $3.5 billion in future benefits.

Tags: monetization; legislation

Hernández, Diana, and Douglas Phillips. 2015. "Benefit or Burden? Perceptions of Energy Efficiency Efforts among Low-Income Housing Residents in New York City." *Energy Research & Social Science* 8 (July): 52–59. https://doi.org/10.1016/j.erss.2015.04.010.

This article summarizes the direct and indirect impacts of a weatherization program in New York City. It identifies the non-energy impacts associated with energy efficiency upgrades and qualitatively describes the impact of the program on participants. The study included 20 households in the South Bronx neighborhood of New York City that received weatherization services in 2013 and 2014. It utilized interviews and surveys to evaluate the impact of the program on thermal comfort, energy savings, and health and safety. It found that most participants experienced improved thermal comfort, lower energy bills, an enhanced sense of safety, and less anxiety. However, the authors did find that some households experienced unintended negative consequences, including problems with new technology or more heating concerns due to increased landlord control.

Tags: program character; NEIs

Imbierowicz, Karen and Lisa Skumatz. 2004. "The Most Volatile Non-Energy Benefits (NEBs): New Research Results 'Homing In' on Environmental and Economic Impacts." ACEEE Summer Study on Buildings. https://www.aceee.org/files/proceedings/2004/data/papers/SS04_Panel8_Paper14.pdf.

Summarizes analysis focused on improving NEI estimates for two of the largest NEI areas: societal economic impacts and environmental/emission impacts. Completed a literature review and developed an input-output model for economic impacts and a model for environmental impacts using improved emissions estimates. Nationwide and some statewide level data was used in the analysis. The research sought to "develop more reliable and defensible non-energy impact estimates."

Tags: monetization; NEIs

Jacobs, David E, Matthew Tobin, Loreen Targos, Dale Clarkson, Sherry L Dixon, Jill Breysse, Preethi Pratap, and Salvatore Cali. 2016. "Replacing Windows Reduces Childhood Lead Exposure: Results From a State-Funded Program." Journal of Public Health Management and Practice : JPHMP 22 (5): 482–91. https://doi.org/10.1097/PHH.0000000000000389.

The article evaluates the impact of a state-funded window replacement program by analyzing the change in lead hazards and health and housing conditions 1 year after intervention. The program, initiated in 2007, targeted low-income, high-risk neighborhoods in a proactive manner rather than

in response to children who already have high blood lead levels. The methods included surveying and performing lead dust tests in 49 households in Peoria, IL and 47 households in Chicago, IL. The study concluded that homes that received replacements had significantly lower dust levels on interior floors, interior sills, and interior troughs that persisted at least 1-year post intervention. It also found that participants experienced some self-reported comfort and health improvements after replacement. The article also included a short overview of the economic benefits by using previous research's valuation methodology. This included cognitive benefits from lower lead and energy savings and higher property value from more efficient windows. It found that the program led to about $2.4 million in economic benefits.

Tags: lead painted windows

Jacobs, David E., Jill Breysse, Sherry Dixon, Susan Aceti, Carol Kawecki, Mark James, and Jay Wilson. 2014. "Health and Housing Outcomes From Green Renovation of Low-Income Housing in Washington, DC." *Journal of Environmental Health* 76 (7): 8–16. https://doi.org/10.1097/PHH.0000000000000389.

This report summarizes the findings of a study on green building certification and self-reported resident health outcomes in a low-income housing renovation in Washington, DC. Residents were interviewed pre- and post- renovation. The interview guide used an adaption of the Nation Health Interview Survey, the Behavioral Risk Factor Surveillance System, and the National Survey of Lead and Allergens in Housing. Settled dust sampling was conducted in a random sample of units using the HUD standard method. Residents self-reported general health improved from 59% to 67%; low allergen loadings were sustained for at last a year; energy savings were 16% and water cost savings were 54%. This study concludes that green building certified renovations improves general health of the buildings occupants and improved the building itself and recommends that such certifications standards be included in the design of low-income housing renovation projects.

Tags: NEIs

Jacobs, David E., and Rick Nevin. 2006. "Validation of a 20-Year Forecast of US Childhood Lead Poisoning: Updated Prospects for 2010." *Environmental Research* 102 (3): 352–64. https://doi.org/10.1016/j.envres.2005.12.015.

Using data from three different housing data sets (American Housing Survey, Residential Energy Consumption Survey, and National Lead Paint Survey), combined with blood lead data from the National Health and Nutrition Examination Survey, the authors forecast the childhood lead poisoning and residential lead paint hazard prevalence for 1990-2010. Results from the model show that dramatic reductions in lead poisoning between 1990 and 2000 can be attributed to window replacement.

Tags: lead painted windows; NEIs

Kravatz, Mark, Eric Belliveau, Bruce Tonn, and Greg Clendenning. 2018. "Co-Funded Health-Focused Housing Intervention Measure Benefits: Establishing a Co-Funded Low-Income Residential Program Model." ACEEE Summer Study on Buildings. https://www.optenergy.com/wp-content/uploads/2018/12/Kravatz-Belliveau-Tonn-Clendenning-Co-Funded-Housing-Intervention.pdf.

This short literature review summarizes the financial challenges facing the EE and health care fields and proposes some general models for how these groups could work together and mutually benefit from EE programs that target measures that have the greatest health and safety impacts. They identify important NEIs that connect the health care field, discuss how these NEIs could be included in a weatherization program and how their inclusion might affect program cost-effectiveness and outcomes. However, specific examples are not provided as this is more of a

conceptual paper. The geographic scope is national and the authors point to some initial program examples in Maryland, Connecticut and Vermont, but they are not described in any detail. The overall purpose of the article is to show the potential mutual benefits of collaboration between the health care community and EE field in designing and delivering weatherization programs and to advocate for more work researching and developing economic models for how this could be realized in programs.

Tags: program character; NEIs

Kuholski, Kate, Ellen Tohn, and Rebecca Morley. 2010. "Healthy Energy-Efficient Housing: Using a One-Touch Approach to Maximize Public Health, Energy, and Housing Programs and Policies." Journal of Public Health Management and Practice 16 (5): S68. https://doi.org/10.1097/PHH.0b013e3181ef4aca.

Literature review and concept paper that proposes a model for "one-touch" low-income weatherization and health programs. Authors review the literature on the ways that homes impact the health and well-being of low-income and vulnerable occupants through illnesses such as asthma, lead poisoning, hunger, and economic hardship (due to high-energy burdens). They then provide an overview of state and national weatherization programs, identify some of the positive and negative impacts of weatherization on health, and discuss ways that the scope of the programs might be expanded to include more non-energy measures targeted at occupant health and well-being. The article ends with a hypothetical story where a mother and son suffering with asthma in a moldy rental are helped with a "one-touch" program. The purpose of the article is to make the case for new, integrated weatherization-health-social service programs at the state and national level.

Tags: program character

Ma, Jennifer, Patricia Plympton, Jessica Minor-Baetens, Chelsea Lamar, and Katherine Johnson. 2018. "Quantifying Non-Energy Benefits from ComEd's Income Eligible Programs: Findings and Recommendations from Secondary Research." Navigant.

This article describes a planned approach to monetize non-energy impacts for an utility in Illinois. It describes the main categories of non-energy impacts, how other states quantify NEIs, and previous research on non-energy benefits. The authors then detail their methodology for quantifying utility and participant non-energy impacts in Illinois. Their approach includes calculating primary data for utility and participant NEIs and using the same methodology as the national WAP evaluation for health and safety NEIs. Notably, the authors do not recommend trying to monetize NEIs on a measure-level and do not recommend the inclusion of societal benefits in the quantification of income-eligible programs.

Tags: monetization

Major, Jennifer L., and Gerald W. Boese. 2017. "Cross Section of Legislative Approaches to Reducing Indoor Dampness and Mold." *Journal of Public Health Management and Practice* 23 (4): 388–395. https://doi.org/10.1097/PHH.0000000000000491.

The article provides an overview of legislative approaches taken by states to address indoor dampness and mold. The policies previously enacted include addressing language in current rental laws to explicitly mention mold or dampness, adding requirements into building codes, creating certain remediation standards, and requiring disclosure of mold at time of sale or rental. These policies have been enacted at the state level and municipal level between 2005 and now. The article then provides recommendations on how states can address mold and dampness moving forward. One of the recommendations is to couple these indoor air quality policies with energy efficiency programs, allowing for a greater impact on health and well-being.

Tags: legislation

Nadel, Steven. 2020. "Weatherization and Home Improvements: A Promising Path for Improving Health and Reducing Medical Costs for Older Adults." American Council for an Energy Efficiency Economy. https://www.aceee.org/sites/default/files/pdfs/weatherization_and_home_improvements.pdf.

This white paper reviews the literature on the NEIs of low-income weatherization and weatherization plus home repair programs on the elderly. It also reports on the outcomes of some specific programs that integrate health and safety-focused measures with low-income weatherization. The scope of the review is international but with emphasis on the implications for integrated health and weatherization programs in the United States. The purpose is to provide evidence for how weatherization programs can have disproportionately greater health and safety benefits for the elderly compared to other demographic groups and to share how models for specific health and safety measures in weatherization programs, such as installing handrails, can greatly increase the non-energy benefits. Citing numerous studies and providing compelling statistical evidence, the author argues that weatherization of low-income elderly households can reduce energy burdens, reduce stress and mortality from extreme temperatures, improve elderly ability to age in their home (as opposed to more expensive long-term care facility), increase food and health-care security, reduce COPD symptoms, reduce financial stress, and overall significantly cut health care costs. When weatherization is coupled with targeted health and safety interventions like home repairs to reduce fall hazards and occupational therapy, health benefits can be much greater as seen in pilot programs in Connecticut and Vermont.

Tags: program character; NEIs

NEEP. 2017. "Non-Energy Impacts Approaches and Values: An Examination of the Northeast, Mid-Atlantic, and Beyond." Northeast Energy Efficiency Partnerships. https://neep.org/non-energy-impacts-approaches-and-values-examination-northeast-mid-atlantic-and-beyond.

The report reviews approaches, examples, and high-level considerations for including NEIs in utility program cost-effectiveness screening based on a review of relevant literature and case-studies. The primary purpose is to provide information and guidance to the New Hampshire Public Utility Commission to guide future policy. The authors outline the general best practices for incorporating NEIs in cost-effectiveness tests from the National Standard Practice Manual for Assessing Cost-Effectiveness of Energy Efficiency Resources (NSPM). These guidelines are high-level and appropriately take account of design and development considerations of cost-effectiveness tests for programs or portfolios, including considerations around policy alignment, scale of impacts, symmetry of impacts, timeframes for evaluating costs and discount rates. The remainder of the article reviews and compares how U.S. states are incorporating NEIs in cost-effectiveness tests. Methods are compared based upon the type of test used (Total Resource Cost test vs Society Cost Test) and ways NEIs are selected and valued (combinations of adders and specific values for NEIs typically that are easy to measure). The authors conclude noting the wide range of approaches used across state programs and the difficulty comparing specific numbers and methods. They encourage increased transparency and information sharing from experiences.

Tags: monetization; SIR

Nevin, Rick, David E. Jacobs, Michael Berg, and Jonathan Cohen. 2008. "Monetary Benefits of Preventing Childhood Lead Poisoning with Lead-Safe Window Replacement." Environmental Research 106 (3): 410–19. https://doi.org/10.1016/j.envres.2007.09.003.

This article identifies the benefits associated with lead-safe window replacement and quantifies several of these benefits to examine the cost effectiveness of replacement. The article identifies several benefits from window replacement, including lower energy use, increased property value, and avoided medical costs, crime, and behavioral and cognitive issues from lower lead exposure. The authors use historical data from the 1990's and early 2000's to estimate the average increase in blood level levels for homes that have certain windowsill dust levels and were built within a certain timeframe. Combining this data with data on energy savings and home values, the article then compares the benefits of window replacement to the cost of window replacement for homes built in certain time periods. It finds that the homes built before 1960 would see net economic benefits from lead-safe window replacement.

Tags: lead painted windows

NMR. 2011. "Massachusetts Special and Cross-Sector Studies Area, Residential and Low-Income Non-Energy Impacts (NEI) Evaluation." Report prepared for Massachusetts Program Administrators. https://ma-eeac.org/wp-content/uploads/Residential-and-Low-Income-Non-Energy-Impacts-Evaluation-1.pdf

Through a combination of a literature review and analysis of existing data, this evaluation sought to review the potential relevance and reliability of potential NEIs associated with the Massachusetts Program Administrators' (PAs) low-income residential programs. Classifying and assessing the reliability of the NEIs found in the literature allowed the authors to recommend NEI quantification methods that include deriving values from the literature, from engineering estimates and algorithms, and from data collection through surveys of program participants. The authors provide estimates for relevant NEIs that might be applied by program administrators to their low-income programs. When possible, NEI values were derived from the existing literature or by developing modified algorithms from the literature. For residential and low-income program participants, including owners of low-income rental housing, select NEI values were derived using surveys of program participants. In some cases, the authors propose apportioning the value of some NEIs to specific measures based on each measure's relative contribution to the overall mean bill saving for a weatherization job.

Tags: monetization; NEIs

Noris, Federico, Gary Adamkiewicz, William Delp, Toshifumi Hotchi, Marion Russell, Brett Singer, Michael Spears, Kimberly Vermeer, and William Fisk. 2013. "Indoor Environmental Quality Benefits of Apartment Energy Retrofits." Ernest Orlando Lawrence Berkeley National Laboratory. https://doi.org/10.1016/j.buildenv.2013.07.003.

This article evaluates the impacts of an energy retrofit program that selects measure combinations based on the impact on energy savings and indoor air quality. This measure protocol addresses how to include non-energy impacts in a weatherization program and the results illustrate the impact of including them. The program included 16 apartments in three cities in California that were retrofit between August 2011 and March 2012. The study measured indoor air quality parameters for two weeks prior to the retrofit and two weeks after the retrofit. The findings generally indicate an improvement in indoor air quality after retrofit, with most of the measured parameters improving in the post retrofit period. The authors did not have energy savings results at the time this paper was published.

Tags: program character; NEIs

Noris, Federico, William W. Delp, Kimberly Vermeer, Gary Adamkiewicz, Brett C. Singer, and William J. Fisk. 2013. "Protocol for Maximizing Energy Savings and Indoor Environmental Quality

Improvements When Retrofitting Apartments." Energy and Buildings 61 (June): 378–86. https://doi.org/10.1016/j.enbuild.2013.02.046.

This article provides an overview of a protocol used to consider both energy savings and non-energy impacts when selecting retrofit measures for a home. The method assigns points for expected impact on indoor air quality and energy savings for each potential retrofit. The authors tested the protocol on 17 apartments in two climate zones in California in 2012. The authors detail the baseline and post-retrofit conditions of the apartments, but do not present the measured results for IAQ and energy savings in this article.

Tags: program character; NEIs

Norton, Ruth Ann, Brendan Wade Brown, Kiki Malomo-Paris, and Elizabeth Stubblefield-Loucks. 2016. "Non-Energy Benefits of Energy Efficiency and Weatherization Programs in Multifamily Housing: the Clean Power Plan, and Policy Implications" https://www.greenandhealthyhomes.org/wp-content/uploads/ghhi.pdf.

This literature review identifies and explores how home-based energy efficiency and health interventions on multi-family housing can confer positive economic, health, and environmental non-energy benefits at the individual and community level. It reviewed literature from 2000-2015 and concluded with policy recommendations.

Tags: lead painted windows; NEIs

Oppenheim, Jerrold. 2018. "Assessing Low-Income Health Impacts of Energy Efficiency Supports Expansion of Energy Efficiency." International Energy Policy & Programme Evaluation Conference. https://energy-evaluation.org/wp-content/uploads/2019/06/2018-oppenheim-paper-vienna.pdf.

The report article discusses the results of recent program evaluations that apply different methods to monetize health and safety NEIs so that the cost accounting could be used in low-income program design. The first study is a survey-based evaluation of NEIs for the national Weatherization Assistance Program (Tonn et al, 2014). The second is a similar evaluation of the value of health and safety NEIs for a Massachusetts low-income weatherization program for single-family homes (Hawkins et al, 2016). The author of this article was not involved in these evaluations but discusses the methods used and the potential implications for low-income program design in Massachusetts and contextualizes the evaluation results within the history of including NEIs in weatherization program design, particularly in Massachusetts. Depending on the methods used, including NEIs can increase the monetary value of weatherization program up to 50-fold. Similarly, benefits of heat pump installations could be increased up to 8-fold with inclusion of health and safety benefits. The accounting of these benefits is sensitive to methods. For example, a high estimate statistical value of human life used for avoided deaths from rare events like fires and carbon monoxide poisoning can greatly increase the estimate value of NEIs. The author concludes with some discussion about some of the challenges and potential unintended consequences associated with incorporating the monetary value of health and safety NEIs in program design.

Tags: monetization; program character; NEIs

Pigg, S., D. Cautley, and P. W. Francisco. 2018. "Impacts of Weatherization on Indoor Air Quality: A Field Study of 514 Homes." Indoor Air 28 (2): 307–17. https://doi.org/10.1111/ina.12438.

This peer-reviewed article details a randomized control trial evaluation completed as part of the national evaluation of the Weatherization Assistance Program (WAP). The field study examined indoor air quality in 514 single-family homes treated under WAP. The goal of the research was to monitor five indoor environmental quality conditions to understand the impact of weatherization

on indoor air quality. The sample homes included both a treatment and control group. The fieldwork monitored homes for between one week and several months pre- and post-weatherization, depending on the parameter involved. The monitoring was completed between November 2010 and August 2011. It covered the continental United States, with a focus on high radon areas. The researchers found a small but statistically significant increase in radon and humidity, no statistically significant change in formaldehyde, and lower carbon monoxide levels post-weatherization.

Tags: program character; NEIs

Pigg, Scott, Dan Cautley, Paul Francisco, Beth Hawkins, and Terry Brennan. 2014. "Weatherization and Indoor Air Quality: Measured Impacts in Single-Family Homes under the Weatherization Assistance Program." Oak Ridge National Laboratory. https://doi.org/10.2172/1223066.

This report is a detailed overview of a randomized control trial evaluation of indoor air quality in 514 single-family homes treated under the Weatherization Assistance Program. The objective of the research was to test and monitor five indoor environmental quality conditions to understand the impact of weatherization on indoor air quality. The researchers utilized a treatment and control group to control for non-program effects and monitored the homes for between one week and several months pre and post-weatherization, depending on the parameter involved. The fieldwork was completed between November 2010 and August 2011 and covered the continental United States, with a heavy sampling of high radon areas. The researchers found a small but statistically significant increase in radon and humidity, no statistically significant change in formaldehyde, and lower carbon monoxide levels post-weatherization.

Tags: program character; NEIs

Poortinga, Wouter, Shiyu Jiang, Charlotte Grey, and Chris Tweed. 2018. "Impacts of Energy-Efficiency Investments on Internal Conditions in Low-Income Households." *Building Research & Information* 46, (6): 653-667. https://www.tandfonline.com/doi/full/10.1080/09613218.2017.1314641.

This article summarizes the methods and results of a field study demonstration that monitored internal temperature and humidity pre and post weatherization. The aim of the research was to identify how weatherization impacts indoor temperature and humidity overall as well as to compare the impact across rooms in the home and measures installed. The field study monitored conditions in 88 low-income homes in Wales for 28 days pre-weatherization and 28 days post-weatherization. It was completed in two waves between January 2014 and April 2015. The authors found that weatherization increased internal temperature to healthy levels and had no impact on relative humidity. The two measures with a significant impact on temperature were wall insulation and connecting a property to the gas main network.

Tags: NEIs

Riggert, Jeff, Nick Hall, John Reed, and Andrew Oh. 2000. "Non-Energy Benefits of Weatherization and Low-Income Residential Programs: The 1999 Mega-Meta-Study." ACEEE Summer Study on Buildings. https://www.aceee.org/files/proceedings/2000/data/papers/SS00_Panel8_Paper25.pdf.

This literature review summarizes the non-energy benefits from residential weatherization programs with an emphasis on low-income programs across the U.S. The goals of the review were to 1) provide a more comprehensive catalogue of non-energy benefits from prior studies, 2) document the range of metrics and associated estimates for the impacts and dollar value of those benefits, and 3) place the disparate benefits listed into larger categories. The authors reviewed, classified and summarized 91 relevant studies which were catalogued in a database shared with ORNL. Authors placed the studies into the following categories: general benefits which cross

multiple categories, economic benefits, environmental benefits, health and safety benefits, utility service benefits, and other benefits which did not fit into one of the other categories. In the narrative, the authors list the numerous specific sub-benefits and provide examples of estimated quantitative impacts and monetary values. They conclude that the dollar value of non-energy benefits may often exceed the value of energy benefits for weatherization programs but encourage more coordinated and careful study to get better estimates. It is worth noting that the impacts from studies were reported at the level of a home or program, not by specific measure.

Tags: monetization; NEIs

Rose, Erin, Beth Hawkins, Bruce Tonn, Debbie Paton, and Lorena Shah. 2015. "Exploring Potential Impacts of Weatherization and Healthy Homes Interventions on Asthma-Related Medicaid Claims and Costs in a Small Cohort in Washington State." Oak Ridge National Laboratory. https://weatherization.ornl.gov/wp-content/uploads/pdf/WAPRecoveryActEvalFinalReports/ORNL_TM-2015_213.pdf.

This report shares results from an exploratory analysis of the asthma-related health impacts of weatherization and healthy home interventions for 49 households in Northwestern Washington State. This evaluation as performed as part of the broader evaluation of the national WAP program that ORNL conducted for DOE. The study used three study groups: Medicaid-insured Healthy Homes Only, Weatherization Plus Health, and WAP Only and addressed the impact of delivering a combined weatherization and healthy housing program. Results suggest the benefits occur with the delivery of both weatherization and healthy housing interventions, which showed improved dwelling quality and reduced home-source asthma triggers with a statistically significant decrease of $421 in annualized asthma-related Medicaid costs.

Tags: program character

Sandel, Megan, Andrea Baeder, Asa Bradman, Jack Hughes, Clifford Mitchell, Richard Shaughnessy, Tim K. Takaro, and David E. Jacobs. 2010. "Housing Interventions and Control of Health-Related Chemical Agents: A Review of the Evidence." *Journal of Public Health Management and Practice* 16 (5): S24. https://doi.org/10.1097/PHH.0b013e3181e3cc2a.

This article summarizes the effectiveness of 14 housing interventions on reducing exposure to common indoor health contaminants. The article, published in 2010, reviewed past studies on interventions and categorized each into one of four categories: (1) ready for implementation, (2) need more field evaluation, (3) need more formative research, and (4) insufficient evidence. The interventions were addressing lead levels, pesticides, VOCs, secondhand smoke, or radon gas. Four of the fourteen interventions received a categorization as ready for implementation. The relevance to weatherization is that the interventions could be incorporated into existing programs to provide non-energy benefits.

Tags: NEIs

Schweitzer, Martin and Bruce Tonn. 2002. "Nonenergy Benefits from the Weatherization Assistance Program: A Summary of Findings from the Recent Literature." Oak Ridge National Laboratory. https://doi.org/10.2172/814309.

Summarizes the findings from a national literature review on ratepayer, household, and societal NEIs attributable to weatherizing low-income homes. The study is a follow-up to 1993 DOE WAP research. Monetary benefits are broken into these three main categories and multiple subcategories within each category. This study quantifies a broader array of benefits and the results show an increased monetary value in non-energy benefits.

Tags: monetization; NEIs

Simon, Jeff, Alan Levensohn, Barbara B. Metzger, Susan Hardman, and Susan J. Klein. 1993. "Burn Prevention Through Weatherization Assistance Programs." *American Journal of Public Health* 83 (12): 1787–88. https://europepmc.org/article/med/8259818.

This article provides an overview of a 3-year pilot program in New York that integrated burn prevention services into typical weatherization programs. It provides an example of how non-energy benefits were integrated in typical weatherization services. The pilot program ran in the late 1980s and gave funding to weatherization agencies to provide burn prevention during their home visits. This resulted in comprehensive home inspections for burn risks, installation of 9,000 smoke detectors, the lowering of 450 water heater set temperatures, and the distribution of 4,000 burn injury kits. The article states that the inclusion of burn prevention did not impact the program metrics, adding minimal costs (4.50 per smoke detector) and time spent per home visit.

Tags: program character

Skumatz, Lisa. 2014. "Non-Energy Benefits/Non-Energy Impacts (NEBs/NEIs) and Their Role & Values in Cost-Effectiveness Tests: State of Maryland." Energy Efficiency for All. Accessed June 29, 2020. https://www-new.energyefficiencyforall.org/resources/non-energy-benefits-non-energy-impacts-nebs-neis-and-their-role-and-values/.

This report gives a thorough overview of the history of non-energy impact research in the United States before recommending how Maryland should include non-energy impacts in cost-effectiveness tests. The report, published in 2014, identifies non-energy impacts as well as how they are typically estimated. For each of the identified NEIs, it also provides an estimated range of the dollar value per household and the percent adder per dollar of kWh savings. The authors recommend that Maryland use a constant dollar or percentage adder for NEIs that have less variability across programs in the short-term while conducting further research on more state specific NEI values in the medium to long term.

Tags: monetization; NEIs

Skumatz, Lisa. 2016. "Non-Energy Benefits/NEBs - Winning at Cost-Effectiveness Dominos: State Progress and TRMs." ACEEE Summer Study on Buildings. https://www.aceee.org/files/proceedings/2016/data/papers/6_1147.pdf.

The purpose of the paper is to present common approaches to including NEB in utility program benefit-cost (B/C) tests, present the most common monetary values used and make a general argument for including NEBs in these program B/C tests. The scale of these B/C tests presented are typically at the U.S. state and program portfolio level, but there is some mention of measure-specific valuation of NEBs. The author presents tables of the typical values of NEBs in common categories, (e.g. health, safety, comfort, water, reduced utility costs, economic and environmental benefits) from the utility, societal, and participant perspective based on a review of the literature. Values are presented in ranges both as a dollar value per participant and as a percent of the total job energy savings. The author notes some issues with transferring NEB values across regions and programs suggesting that calculating value as a fraction of energy savings might be a better method than flat dollar values. The author also notes the limited research on NEB values specific measures, different fuels (gas vs electric) and housing type (single vs multi-family). A range of approaches for including NEBs in program B/C tests are presenting with specific example programs and states. These methods are presented to fall on a scale from more conservative, i.e. only in marketing or as a flat program percent adder, to more aggressive, i.e. including more NEBs and measuring impacts. Lastly the authors make a case for

including NEBs in B/C tests on the basis that the uncertainty of their value is often equal to or less than that of other components of the test such as measure life or net-to-gross ratios.

Tags: SIR

Skumatz, Lisa A. 2015. "Efficiency Programs' Non-Energy Benefits: How States Are Finally Making Progress in Reducing Bias in Cost-Effectiveness Tests." *The Electricity Journal* 28 (8): 96–109. https://doi.org/10.1016/j.tej.2015.09.008.

Provides best practices for estimating NEBs, state treatments, discount rates, and other NEB considerations with a goal to include non-energy benefits in utility program cost-benefit analysis and calculate the NEB values in a way that reduces bias in the cost-benefit tests. The study referenced literature from the past 20 years across the U.S. and includes a breakdown for how states are incorporating NEBs in benefit cost tests, including providing specific examples in Massachusetts, California, New York, Colorado, Vermont, and the District of Columbia. It describes a domino effect in the adoption of NEBs in benefit cost tests as states adopt changes. The wide range of values on the participant and utility NEBs are because those values are dependent on the sector the program is offered to, measures included in the program, and climate zone. NEBS are perceived to be imprecise and other elements included in utility benefit cost ratios have inaccuracies as well.

Tags: monetization; NEIs; SIR

Smith-McClain, Lisa, Lisa A Skumatz, and John Gardner. 2006. "Attributing NEB Values to Specific Measures: Decomposition Results from Programs with Multiple Measures," ACEEE Summer Study on Buildings. https://www.aceee.org/files/proceedings/2006/data/papers/SS06_Panel2_Paper23.pdf.

The article, published in 2006, uses data from a weatherization program to detail a method that attributes non-energy benefits to specific measures. It quantifies the value of non-energy benefits and uses econometric methods to try to assign the monetary values to specific measures. The authors used data from phone surveys with 362 participants that asked the value of non-energy benefits relative to energy savings. Using demographic data and results from the phone survey, the researchers utilized regression analysis to attempt to discern measure-level impacts. The authors found that most measures did not have a discernible impact, but that households that received insulation valued the non-energy benefits, on average, at $288 greater than those who did not.

Tags: program character

Sutter, Mary, Jenn Mitchell-Jackson, Steven Schiller, Lisa Schwartz, and Ian Hoffman. 2020. "Applying Non-Energy Impacts from Other Jurisdictions in Cost-Benefit Analyses of Energy Efficiency Programs: Resources for States for Utility Customer-Funded Programs." 2020. https://emp.lbl.gov/publications/applying-non-energy-impacts-other.

Describes non-energy impacts (NEIs) and their importance, identifies NEIs used in energy efficiency programs in 30 states and considers the transferability of their values and the methods to calculate their values for inclusion in cost-benefit analyses of energy efficiency programs. A literature review was performed to provide information about 16 categories of NEIs to incorporate in cost-benefit analysis for utilities and for assessing energy efficiency in utility resource planning and acquisition. NEIs are divided into two groupings: utility and everything else, which includes participants and society. This report focuses on NEIs associated with general public energy efficiency programs, not low-income programs.

Tags: monetization; program character; NEIs

Takaro, Tim, James Krieger, Lin Song, Denise Sharify, and Nancy Beaudet. 2011. "The Breathe-Easy Home: The Impact of Asthma-Friendly Home Construction on Clinical Outcomes and Trigger Exposure." *American Journal of Public Health* 101 (1). 10.2105/AJPH.2010.300008.

This article explores the non-energy asthma-control benefit of moving into an asthma-friendly Breathe-Easy home in Seattle and King County, Washington. It used a quasi-experimental design to compare results of public housing residents with a child with asthma who moved into an asthma-friendly home with a matched historical comparison group. Study results suggest that moving low-income children with asthma into asthma-friendly housing reduces exposure to indoor asthma triggers and improves clinical outcomes over and above what is seen with in-home asthma education alone.

Tags: NEIs

Tetra Tech. 2018. "Program Administrators of Massachusetts: Non-Energy Impact Framework Study Report." Tetra Tech.

This report provides a framework for future research on non-energy impacts for the Massachusetts energy efficiency program. The goal of the research was to identify NEIs that are not being included, develop a strategy for conducting future research, and avoid double counting of NEIs across initiatives. The researchers completed this in three tasks: (1) inventory NEI values currently claimed, (2) conduct in-depth interviews with program staff, and (3) review literature on NEIs. They found eight NEIs that need future research and prioritized those eight based on the expected impact on cost effectiveness.

Tags: monetization

Three3 Inc., and NMR Group, Inc. 2018. "Low-Income Multifamily Health- and Safety-Related NEIs Study (TXC 50) Preliminary Findings Report." Massachusetts Program Administrators.

This article presents the initial results from an evaluation of the health and household non-energy impacts from weatherization of low-income multifamily homes. The objective of the research is to evaluate the impact of weatherization on health for households that reside in multifamily buildings and to discover how the impact differs across housing types. The researchers have completed Phase 1 of the research, which consisted of surveying Massachusetts residents between January and June of 2018 on household conditions. The method follows that of previous MA research on single-family health benefits from weatherization. It will utilize both a pre and post matched pair comparison as well as a treatment and comparison group. The initial findings show that the value from the non-energy benefits could be as high as $134 per unit and that the benefits are lower for multifamily residents than single-family residents.

Tags: monetization; program character; NEIs

"Title IV—Energy Conservation And Renewable Resource Assistance For Existing Buildings." n.d. U.S. Government.

This 1976 legislation established the weatherization assistance program. The act, Energy Conservation in Existing Buildings Act of 1976, highlights the main reasons for creating a weatherization program and sets the guidelines for what the program will provide and how it should be administered. The main reasons for establishing the act mention the impact on economic output, the potential to reduce the energy burden of low-income people, and the reduction in need for foreign energy imports. It directs the Federal Energy Administration to

create a program through the rulemaking process that provides states financial assistance to weatherize low-income residents' homes.

Tags: legislation

Tonn, Bruce, Erin Rose, Beth Hawkins, and Brian Conlon. 2014. "Health and Household-Related Benefits Attributable to the Weatherization Assistance Program." Oak Ridge National Laboratory. https://weatherization.ornl.gov/wp-content/uploads/pdf/WAPRetroEvalFinalReports/ORNL_TM-2014_345.pdf.

This report identifies and quantifies health and home-related non-energy benefits from the national Weatherization Assistance Program. The report is one of many summarizing the results from evaluations completed on program year 2008 and 2010 of WAP. The authors utilize responses from an occupant survey that was administered to a sample of participants pre and post weatherization to evaluate the impact on 11 health and home measures. They then monetize the NEIs by estimating the incidence of the benefit from the survey responses and the value of the reduction from secondary research. They find that the 10-year discounted monetary value of these 11 health benefits is $14,150 per unit.

Tags: monetization; NEIs

Vine, Ed. n.d. "Addressing Non-Energy Benefits in the Cost-Effectiveness Framework." California Public Utilities Commission. https://library.cee1.org/system/files/library/9734/CEE_EvalNEBCostEffect.pdf.

This paper from the California Public Utilities Commission (CPUC) describes how NEIs can be incorporated into cost benefit calculations for utility programs, projects and/or measures using four methods from the California Standard Practice Manual. The methods differ based on whose perspective the costs and benefits are apportioned, e.q. utility, rate payers, and/or society, and on the scope of costs and benefits included, e.g. energy only or NEIs plus energy. These are the Total Resource Cost (TRC) test which takes the perspective of both utilities and rate payers, Program Administrator Cost (PAC) or Utility Cost Test (UTC) which measures costs/benefits only from the perspective of the program administrator, Ratepayer Impact Measure (RIM) test which only considers impacts on rates and the Participant test which looks at the perspective of participating customers. In addition to the range of perspectives that can be included, there are also different methods of incorporating NEBs in cost-effectiveness tests. These include tallying the total costs and benefits of NEBs and energy savings in the TRC approach (includes utility and rate payer benefits), excluding NEB-related costs and benefits from the calculation, or tallying all NEB and energy costs and benefits but only for the utility with the PAC test. The paper describes the challenges associated with quantifying NEBs, explains how to carry out the methods and provides examples of NEB program adders in six states (these are mostly flat percentage adders for avoided emissions or low-income benefits). The authors then show an illustrative cost-benefit calculation for using four methods for a hypothetical home retrofit program showing how the net benefits differ based on the method used. The purpose of the paper is to provide practical information for utility program administrators in California.

Tags: SIR

Wilson, Jonathan, David Jacobs, Amanda Reddy, Ellen Tohn, Jonathan Cohen, and Ely Jacobsohn. 2016. "Home RX: The Health Benefits of Home Performance." U.S. Department of Energy, Energy Efficiency & Renewable Energy. https://www.energy.gov/sites/prod/files/2016/12/f34/Home%20Rx%20The%20Health%20Benefits%20of%20Home%20Performance%20-%20A%20Review%20of%20the%20Current%20Evidence.pdf.

The paper shares the results from a literature review performed as one part of DOE's Health and Home Performance Initiative with a focus on understanding the occupant health and indoor environmental outcomes resulting from energy home performance upgrades, and how indoor environmental conditions can affect health. The results showed base energy efficiency work including two of three measures: insulation, air sealing, and heating improvements can create healthier living environments and additional studies are needed to demonstrate improved indoor air quality and document reductions in healthcare utilization. The authors reviewed studies from the United States, Europe, Canada, and New Zealand.

Tags: NEIs

Wilson, Jonathan. n.d. "Is Window Replacement a More Effective Long-Term Lead Control Strategy than Repair?" National Center for Healthy Housing. Accessed June 17, 2020. http://nchharchive.org/Research/Window-Repair-LongTerm-Lead-Control-Strategy-.aspx.

This article summarizes the benefits and costs associated with replacing windows rather than performing friction work on windows to remove lead. With this focus, the article quantifies a non-energy benefit associated with a specific weatherization upgrade, window replacement. It summarizes the benefits of window replacement, including lower lead exposure and the associated increased lifetime earnings, improved home value, and increased energy efficiency. Utilizing published research from the late 1990's and early 2000's, it details the monetary value associated with each of these benefits as well as the incremental costs for a double pane or ENERGY STAR window compared to window lead work. It finds that the upgrade to a double pane or an ENERGY STAR window saves between $1,000 and $2,000 over its lifetime.

Tags: lead painted windows