NON-ENERGY IMPACT (NEI) ANALYSIS FOR XCEL ENERGY'S LOW-INCOME PROGRAMS

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List of Acronyms

AHRQ	Agency for Healthcare Research and Quality
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BLS	Bureau of Labor Statistics
C	Cold (climate zone)
CO	Carbon Monoxide
COPD	Chronic obstructive pulmonary disease
DOE	Department of Energy
DOT	Department of Transportation
ED	Emergency Department
EE	Energy Efficiency
EPA	U.S. Environmental Protection Agency
FY	Fiscal Year
HCUP	Healthcare Cost and Utilization Project
HHS	U.S. Department of Health and Human Services
IAQ	Indoor Air Quality
IECC	International Energy Conservation Code
LI	Low-Income
LIMF	Low-Income Multifamily
MEPS	Medical Expenditure Panel Survey
NEI	Non-Energy Impact
NFIRS	National Fire Incident Reporting System
OMB	Office of Management and Budget
OOP	Out-of-Pocket
PCT	Participant Cost Test
PV	Present Value
SCT	Societal Cost Test
SDOH	Social Determinants Of Health
SF	Single-Family
TRC	Total Resource Costs
VC	Very Cold (climate zone)
VEIC	Vermont Energy Investment Corporation
VSL	Value of a Statistical Life
WAP	Weatherization Assistance Program
WX	Weatherization

Executive Summary

This report estimates the non-energy impacts (NEIs) attributable to Xcel Energy's low-income energy efficiency program. The study was initiated as part of a pilot program to deliver comprehensive energy solutions to a predominantly low-income neighborhood in St. Paul, Minnesota. The pilot was delivered in partnership with EnergyCENTS Coalition (ECC), an implementer of Xcel Energy's low-income programs in that area. These programs offer energy related weatherization services free-of-charge to single-family, income-qualified households; services include measures such as air sealing, insulation, and heating system replacement services.

The energy efficiency sector is increasingly recognizing the health and social determinants of health (SDOH) benefits of weatherization. As a result, interest in measuring and monetizing the health and SDOH non-energy impacts (NEIs) of ~~its~~ low-income residential energy efficiency programs (i.e., weatherization programs) has increased in recent years. Monetizing NEIs allows these benefits to be included in total resource costs (TRC), societal cost test (SCT), participant cost test (PCT), and other energy efficiency program tests.

By changing the physical condition of homes, weatherization can produce direct health-related NEIs. Improving the thermal performance of the building envelope increases comfort for residents and reduces thermal stress, which can require serious medical intervention. Additionally, installation of a comprehensive set of weatherization measures can synergistically reduce evidence-based indoor asthma triggers and increase occupants' asthma control. People with controlled asthma require less high-cost medical treatment (i.e. hospitalizations and emergency department visits) from asthma flare-ups than those with poorly controlled asthma. Through testing for carbon monoxide (CO), repairing or replacing gas furnaces, and installing CO monitors and smoke detectors, weatherization also increases household safety. Improved health, in turn, can reduce missed days of work and lead to household economic benefits beyond the energy cost savings from the energy efficiency improvements. These financial benefits, along with energy cost savings, can then be used by households to produce additional household and societal benefits (e.g., better able to afford prescriptions, food and utility bills).

The first national study of health and SDOH NEIs was conducted as part of the evaluation of the U.S. Department of Energy's Weatherization Assistance Program (WAP).[1,2] The first survey of weatherization recipients, referred to herein as the WAP Occupant Survey, was designed through the WAP evaluation. Over 1,400 randomly selected weatherization recipients living in single-family and mobile homes were surveyed pre- and post-weatherization. Many of the questions addressed health and SDOH issues. Secondary data, such as medical encounter costs, were mined from publicly available sources. These data were paired with the survey results to calculate an estimated monetary value for observed NEIs.

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[1] A complete description of the methodology is found in: Tonn, B., Rose, E., Hawkins, B., and Conlon, B. 2014. Health and Household-Related Benefits Attributable to the Weatherization Assistance Program. ORNL/TM-2014/345, Oak Ridge National Laboratory, Oak Ridge, Tennessee, September.

[2] A complete report presenting findings from this component of the WAP evaluation was published in 2014 and can be found at weatherization.ornl.gov.

In 2019, Xcel Energy and Energy CENTS Coalition contracted Three[3] to assess and monetize select NEIs experienced by recipients of Xcel Energy's low-income (LI) energy-efficiency (EE) programs in Minnesota. The national WAP NEI evaluation research served as the foundation for the Xcel Energy LI EE NEI Study. Results for Xcel Energy's NEI study are based on primary data collected in the national WAP Occupant Survey from relevant climate regions (cold and very cold) and on previously developed algorithms. Updated and Minnesota-specific secondary data were selected as inputs to the algorithms. Regional Price Parities from the Bureau of Labor Statistics (BLS) are used to account for cost of living in the state of Minnesota. For NEIs realized through avoided medical encounters, data was mined from publicly available databases such as the Minnesota Department of Health; these data include medical encounter costs, health insurance coverage rates, and rates of uninsured households. Because medical expenditure data based on medical condition and care setting were not available for Minnesota at the necessary granularity, national costs were adjusted to reflect Minnesota medical treatment costs in 2019. Section 3.0 presents in detail survey results, algorithms, and Minnesota-centric secondary data.

The WAP NEI study monetized twelve NEIs. For this cohort study, a subset of seven of the twelve NEIs monetized in the national WAP evaluation was selected based on their estimable, direct impact on the household; the remaining five NEIs produced societal impacts only. Two NEIs that were not explored in the national WAP evaluation are also included in this study (see "Additional NEIs" in the table below). Table E.1 presents the nine NEIs monetized for the Xcel Energy LI EE NEI Study and Table E.2 presents the annual per household NEI estimated values.

Table E.1. Select NEIs Monetized for the Xcel Energy LI EE NEI Study

NEIs	Household Benefit	Societal Benefit
Previously monetized for National WAP Evaluation		
Asthma	X	X
Heat Stress	X	X
Cold Stress	X	X
Missed Days of Work	X	X
Predatory Loans	X	
Reduced Fire Risk	X	X
CO Poisoning	X	X
Additional NEIs		
Reduced Utility Disconnects	X	
Increased Food Security	X	X

In Table E.2, and throughout this report, estimated NEI values are presented as dollars per weatherized unit. Total NEI values are apportioned between households and society and do not overlap. Benefits attributed to households are directly related to increased income (e.g., through fewer missed days of work) and avoided household costs (e.g., fewer utility disconnect fees). Household benefits also include avoided out-of-pocket costs for reduced medical encounters, for example, and the value of avoided deaths (cold stress, fires, CO poisoning). Benefits to an insurer (private/commercial or public) are counted as societal benefits. For this study, we do not consider environmental benefits.

Cost benefit categories are influenced by health care coverage, as follows:

- For occupants covered by private or public insurance, the portion of the avoided medical costs payable by the insurer are categorized as a societal benefit and the remaining out-of-pocket (OOP) costs (i.e., copayments, deductibles) are categorized as a household benefit; and
- For occupants that are uninsured, all avoided medical costs are categorized as a household benefit.

In some circumstances an uninsured individual may not pay the full costs of medical treatment. In these cases, costs are generally covered by the medical institution, government, or philanthropic donations. Identifying an average percent of OOP across all institutions and care settings for Minnesota to apportion a percent of these costs to society was not achieved through this study and is a key limitation to this apportionment calculation. For future studies, this limitation will be addressed.

For three NEIs – asthma, CO poisoning, and food security – researchers estimated that 24% of the low-income population in Minnesota had private/commercial insurance, 64% had public insurance, and 11% were uninsured.[3] It was estimated that those with private insurance paid 12.5% of medical costs OOP and those with public insurance paid 8% OOP.[4,5] The household benefit was then calculated by applying the proportion of each insurance type and its associated OOPS rate to the estimated NEI value.

For the thermal stress NEI, the percentage of medical costs paid by each source (i.e., private/public/uninsured) and rate of OOP expenses were specific to patients treated for exposure to extreme temperatures in each of three care settings: Office-based events, Emergency room visits, and Hospital inpatient stays. The costs to each payer for treatment for cold and heat-related illnesses were retrieved from online databases provided by the Department of Health and Human Services (DHHS) and sponsored by the Agency for Healthcare Research and Quality (AHRQ). The databases included results from the 2015 Medical Expenditure Panel Survey (MEPS)[6] as well as a collection

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[3] The proportion of households at or below 200% Federal Poverty Level in Minnesotans with public (64.8%) and private (23.9%) insurance, as well as the percent uninsured (11.3%) were retrieved from the Minnesota Department of Health, Minnesota Health Access Survey. The most recent data available was from 2017. https://mnha.web.health.state.mn.us/PublicQuery.action

[4] Average percentage of annual OOP expenses for fully, commercially insured individuals in Minnesota were retrieved from a report from the MN Department of Health to the MN Legislature (2019) for 2015-2016 health care spending: https://www.health.state.mn.us/data/economics/docs/costs/healthspending2019.pdf

[5] Average percentage of annual OOP expenses for both non-elderly and 65+, for publicly insured individuals, were retrieved from Statistical Brief #500: *Out-of-Pocket Health Care Expenses by Insurance Coverage, 2000–2014* published by the Agency for Healthcare Research and Quality. Data retrieved is at a national level as Minnesota state data was unavailable. https://meps.ahrq.gov/data_files/publications/st500/stat500.shtml

[6] These databases are derived from administrative data and contain encounter-level, clinical and nonclinical information including all-listed diagnoses and procedures, discharge status, patient demographics, and charges for all patients, regardless of payer (e.g., Medicare, Medicaid, private insurance, uninsured). HCUP is the largest collection of nationwide and state-specific longitudinal hospital care data in the United States and can be accessed at: http://www.ahrq.gov/research/index.html.

of databases referred to as the Healthcare Cost and Utilization Project (HCUP).[7,8,9] Rates of thermal stress treatment by care setting and the number of deaths following hospitalizations were mined from MEPS and HCUP using the International Classification of Diseases diagnostic codes.[10]

Three NEIs – thermal stress, reduced fire risk, and CO poisoning – include estimates of avoided deaths attributable to the installation of weatherization measures. To monetize the value of avoided deaths, this study uses the Value of Statistical Life (VSL) published by the U.S. Department of Transportation.[11] VSL associated with avoided deaths (except for firefighters) is applied as a household benefit rather than a societal benefit.[12] The monetization results below are presented both with and without VSL.

Present values (PV), or the social discount rate, of each NEI are calculated over a ten-year time horizon to reflect the persistence of weatherization measures.[13] A 3.02% discount rate is used to estimate the PVs, following guidance published by the Minnesota Department of Commerce.[14]

Lastly, due to some of the monetization estimates having less certainty than others, NEIs were categorized and presented in three tiers.[15] Tier 1 included estimates based on observed monetizable outcomes attributable to weatherization and highly reliable cost data. Tier 2 and 3 estimates were established to have sound methodologies but may have lacked direct observations. For example, if the 'phenomenon' was not directly measured as reported by program recipients through the Occupant Survey the NEI was moved down to either Tier 2 or 3 (e.g. secondary data was relied upon to calculate estimates for NEIs attributable to the installation of CO monitors; therefore was

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[7] (Hawkins et al. 2014)
[8] (Tonn et al. 2014)
[9] Data generated from MEPS can be found on the following website: http://meps.ahrq.gov/mepsweb/
[10] "Effects of reduced temperature" (ICD-9-CM 991.0-991.9) and "Effects of heat and light" (ICD-9-CM 992.0-992.9)
[11] Value of human life, or as economists refer to it as, the Value of Statistical Life (VSL), is a measure used to compare regulatory costs to benefits. The VSL of $7.5M used in the national WAP evaluation was updated to $9.6M, a 2016 VSL recommended by the U.S. Department of Transportation (DOT). The DOT's Office of General Council updates this VSL annually and releases an annually revised memo entitled: *Guidance on Treatment of the Economic Value of a Statistical Life (VSL) in U.S. Department of Transportation Analyses.* In an effort to use a state level (rather than federal) VSL, we conducted a thorough scan of Minnesota government agencies' use of VSLs for cost-benefit analysis. In 2016, Minnesota's Department of Transportation (DOT) adopted the U.S. Department of Transportation (DOT) recommended VSL of $9.6M. There was no evidence found that this value has been updated since 2016.
[12] See Section 2.8 for a detailed discussion on avoided death benefits and VSL.
[13] With the exception of the non-energy impact of installing CO monitors, where present value was calculated over a more conservative 5-year period as the lifespan of CO monitors generally remains effective for an average of five years.
[14] The selection of a 3.02% discount rate was driven by guidance provided by the Minnesota Department of Commerce on February 11, 2020 to use a 3.02% societal discount rate (SDR) for present value calculations. https://www.edockets.state.mn.us/EFiling/edockets/searchDocuments.do?method=showPoup&documentId={F0943570-0000-CD1F-8C8C-9A3C836481A8}&documentTitle=20202-160294-01
[15] A peer review panel convened to assess the quality of the research methods employed by the WAP evaluation noted that the approaches to monetizing the set of NEIs explored in the WAP evaluation, and many of the NEI presented in this report, had varying degrees of rigor. For detailed information on the framework for assessing the accuracy of the estimates of non-energy benefits refer to Appendix B in the WAP evaluation's health and household-related NEI report (Tonn et al. 2014).

designated to be a Tier 2 NEI). Reduced risk of home fires is considered a Tier 3 NEI. The Occupant Survey was not adequate for describing fire risk among the WAP population, as its size and scope inhibited a proper representation of frequency and severity. Consequently, the degree of fire risk was inferred from installation of measures.

Results

Table E.2 presents annual per unit NEI values, apportioned by household and society, for Xcel Energy's LI EE NEI Study by tier. The annual household NEI value as estimated is $549.95. The total NEI value, including both household and societal benefits, is $1,156.97. The overall valuation results are driven in large part by the assertion that the program is saving lives, especially through the reduction of cold stress and reduced home fires; however, given the uncertainty surrounding the estimate of the number of deaths avoided, the household cost savings are presented both with and without the avoided death benefit.

The other main contributors to estimates presented in Table E.2 are avoided hospitalizations and emergency department (ED) visits related to asthma flare-ups and heat stress, as well as reduced healthcare costs from increased food security.

Table E.3 provides the PV for estimates presented in Table E.2. The household NEI value at PV as estimated is $4,890. Compared to installed measure costs of $3,262 (Table 12.2), one can see that the household benefits outweigh the costs by $1,628.

The total NEI value, including both household and societal benefits, at PV is $10,460.78. Comparing the installed measure costs of $3,262 (Table 12.2), and the total estimated NEI value, including both societal and household benefits, shows benefits outweigh the costs by $7,198.78. The results of this study do not capture environmental, economic, and employment benefits attributable to weatherization.

Table E.2. Annual Per Unit NEI Values for Xcel Energy's Low-Income Energy-Efficiency Program

NEI Value	Annual Per Unit Benefit				
	Household	Household W/O Avoided Death Benefit	Societal	Total	Total W/O Avoided Death Benefit
Tier 1					
Reduced asthma symptoms	$73.54	$73.54	$309.46	**$383.00**	$383.00
Reduced cold stress	$216.70	$1.64	$11.82	**$228.52**	$13.46
Reduced heat stress	$63.33	$2.72	$8.88	**$72.21**	$11.60
Fewer missed days at work	$33.41	$33.41	$11.64	**$45.05**	$45.05
Reduced utility disconnections	$0.05	$0.05	$0.00	**$0.05**	$0.05
Increased food security	$61.22	$61.22	$253.20	**$314.42**	$314.42
Tier 2					
Reduced use of predatory loans	$10.41	$10.41	$0.00	**$10.41**	$10.41
Reduced CO poisoning	$0.85	$0.04	$0.22	**$1.07**	$0.25
Tier 3					
Reduced home fires	$90.44	$6.20	$11.80**	**$102.24**	$17.72**
Annual Total—per weatherized home	**$549.95**	**$189.23**	**$607.02**	**$1,156.97**	**$795.96**

* For home fires, the avoided injuries and deaths to firefighters are categorized as a societal benefit ($0.28).

Table E.3. Per Unit NEI Values for Xcel Energy's Low-Income Energy-Efficiency Program at Present Value[16]

NEI Value	PV (10 years) Per Unit Benefit				
	Household	Household W/O Avoided Death Benefit	Societal	Total	Total W/O Avoided Death Benefit
Tier 1					
Reduced asthma symptoms	$717.87	$717.87	$3,021.05	**$3,738.92**	$3,738.92
Reduced cold-related thermal stress	$1,846.62	$13.96	$100.74	**$1,947.36**	$114.70
Reduced heat-related thermal stress	$539.68	$23.22	$75.70	**$615.38**	$98.92
Fewer missed days at work	$284.71	$284.71	$99.22	**$383.93**	$383.93
Reduced Utility Disconnections	$4.17	$4.17	$0.00	**$4.17**	$4.17
Increased Food Security	$521.70	$521.70	$2,157.61	**$2,679.32**	$2,679.32
Tier 2					
Reduced use of short-term, high-interest loans	$88.73	$88.73	$0	**$88.73**	$88.73
Reduced CO poisoning (5-year life)*	$3.88	$0.17	$1.00	**$4.87**	$1.16
Tier 3					
Reduced home fires	$882.92	$52.37	$115.18**	**$998.10**	$149.63**
Annual Total—per weatherized home	**$4,890.28**	**$1,706.90**	**$5,570.50**	**$10,460.78**	**$7,259.48**

*For CO poisoning, the PV was calculated using a 5-year life for the CO monitor. The remaining PVs are based on an estimated 10-year lifespan for weatherization measures.
** For home fires, the avoided injuries and deaths to firefighters are categorized as a societal benefit.

The results presented in Table E.2 and E.3 are conservative. As discussed throughout this report, NEI estimates are subject to the following assumptions integrated into the NEI algorithms:

- Except for asthma, reduced CO poisoning, and food insecurity only one (1) occupant per household is assumed to be affected for each NEI.
- The asthma analysis does not account for multiple re-admittances.
- For thermal stress, the calculation does not account for extreme winter and summer weather events that could occur in any given year. This analysis assumes an average year for climate. In addition, national (not specific to Xcel Energy's region) rates for treatment by care setting and rates of death following hospitalizations from thermal stress are applied.
- Only one (1) short-term, high-interest loan per year per household is assumed to be avoided.

[16] PV at ten years and 3.02% discount rate.

- It is assumed that weatherization only reduces the probability of a fire to the average homes in the U.S.

Furthermore, results presented in Table E.2 and E.3 do not encompass the full range of NEIs that have been reported. For example, NEI research conducted subsequent to the WAP evaluation suggests that weatherization could also have positive benefits for the following health conditions and issues: arthritis, chronic obstructive pulmonary disease (COPD), headaches, physical and mental health, and rest/sleep. This research also suggests that weatherization can reduce the intrusion of outdoor noise and odors and reduce needs for energy assistance.

1.0 Introduction

This report estimates the non-energy impacts (NEIs) attributable to Xcel Energy's low-income (LI) energy efficiency (EE) program. The study was initiated as part of a pilot program to deliver comprehensive energy solutions to a predominantly low-income neighborhood in St. Paul, Minnesota. The pilot was delivered in partnership with EnergyCENTS Coalition (ECC), an implementer of Xcel Energy's low-income programs in that area. These programs offer energy related weatherization services free-of-charge to single-family income-qualified households; services include measures such as air sealing, insulation, and heating system replacement services.

The energy efficiency sector's interest in measuring and monetizing the health and social determinants of health (SDOH) non-energy impacts (NEIs) of its low-income residential weatherization programs has increased in recent years. For example, the American Council for an Energy Efficient Economy (ACEEE) has organized two major conferences on energy and health and published a major report on the topic.[17] The Vermont Energy Investment Corporation (VEIC) published a playbook providing utilities and others with advice on how to measure and monetize health-related NEIs.[18]

There are several major reasons motivating this interest. First, monetizing health and SDOH NEIs supports energy efficiency investments that target economically disadvantaged households and their homes. Income-qualified programs have become less cost-effective due in part to major improvements in lighting energy efficiency; NEIs can help by supplementing energy savings. Second, measuring and assessing all benefits attributable to these programs and then communicating these findings to regulators is good practice. Third, monetizing NEIs allows these benefits to be included in total resource costs (TRC) and other energy efficiency program tests. For example, Three[3]'s NEI research in 2016 for the Energy Efficiency Program Administrators in the Commonwealth of Massachusetts has been used in TRC proceedings in that state and was also adopted in the states of Rhode Island and Delaware.[19,20]

The fourth major reason is to begin to build collaborative and financial relationships with the public health and healthcare sectors. From a public health perspective, investments in weatherization can be seen as an up-stream population health investment.[21] As discussed more in Section 2.1, weatherization measures can reduce thermal stress, trips and falls, CO poisoning, dangerous disruptions in utility services, and home fires, in addition to reducing

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17 Hayes, S. and Denson, R., (2019). Protecting the Health of Vulnerable Populations with In-Home Energy Efficiency: A Survey of Methods for Demonstrating Health Outcomes, Report H1901, ACEEE, Washington, DC, October.

18 Capps, L., Curry, L., and Leven, E. (2019). Energy-Plus-Health Playbook, VEIC, Winooksi, Vermont, July.

19 The Massachusetts PAs tasked NMR Group to review the health and household-related benefits study conducted through the national WAP evaluation as well as serve as reviewers for the 2015 cohort study. The purpose of NMR's review was to determine to what extent the health and safety NEIs quantified in the 2015 WAP-based evaluation overlapped with, augmented, or superseded the health- and safety-related NEIs previously examined in 2011 by NMR and/or were already being claimed by the Massachusetts PAs, and to develop recommendations for integrating the results.

20 See Hawkins et al. 2016 for a complete description of the Massachusetts Low-Income Single-family NEI study.

21 Kravatz M, Belliveau E, Tonn B, Clendenning G. (2018). *Co-funded health-focused housing intervention measure benefits: establishing a co-funded low-income residential program model.* Asilomar, CA: ACEEE. Published August 2018.

symptoms of individuals who suffer chronic respiratory issues. Washington's Weatherization Plus Health Program goes a step farther by installing healthy homes measures on top of its traditional comprehensive whole house weatherization program; this further improves the health of occupants who have asthma, COPD and other respiratory diseases.

From a healthcare perspective, weatherization reduces costs and could become a treatment reimbursable by medical insurance plans, which would increase funding for weatherization. For example, the Tennessee Valley Authority (TVA) is working with Three³ and Tennessee's Medicaid program, TennCare, on a data sharing agreement to evaluate TVA's income-eligible Home Uplift Program (HUP). This groundbreaking partnership aims to demonstrate how weatherization may lead to reductions in Medicaid and Medicare cross-over claim costs. It is possible that these cost reductions could be large enough for Medicaid programs such as TennCare to justify co-funding low-income weatherization.

Healthcare is interested not only in reducing its systemic costs but also in weatherization as a treatment for diagnosed health issues. For example, Children's Mercy Hospitals and Clinics in Kansas City has a process where children with severe respiratory issues can be referred to its residential environmental health program, which provides healthy homes and weatherization measures. Lastly, Three³ is working with two hospitals in Knoxville, Tennessee to refer children with uncontrolled asthma and adults with chronic obstructive pulmonary disease (COPD) to the local weatherization program to have patients' homes weatherized, thereby improving patients' health.

Indoor environmental quality, which is influenced by allergens and asthma triggers evidenced to impact respiratory and general health, has most recently become an even more important concern nationally. Due to the COVID-19 global pandemic causing people to spend more time at home, housing quality can greatly impact those with a compromised immune or respiratory system. Individuals with asthma and persons of elderly status have been reported to be at higher risk for contracting COVID-19. A high percentage of the weatherization income eligible population are seniors and low-income populations are disproportionately burdened with respiratory issues. It conceivable that weatherization is also providing measurable benefits to households sheltering-in-place during the epidemic, as well as any future need to shelter-in-place.

A national evaluation of U.S. Department of Energy's (DOE) low-income Weatherization Assistance Program (WAP) was conducted between 2009 and 2015. The evaluation included the assessment and monetization of twelve health and household-related NEIs.[22,23] In 2019, Xcel Energy and Energy CENTS Coalition contracted Three³ to use data from the WAP study to evaluate their low-income energy efficiency program in Minnesota.[24] Specifically, Three³ estimated the monetized value of nine health and NEIs experienced by recipients of the program. Data used to monetize the NEIs in the Minnesota included:

[22] Three³ (pronounced three cubed) research staff, under the auspices of Oak Ridge National Laboratory, managed the national WAP evaluation. A complete report presenting findings from this component of the WAP evaluation was published in 2014 and can be found at https://weatherization.ornl.gov.
[23] A complete description of the methodology is found in: Tonn, B., Rose, E., Hawkins, B., and Conlon, B. 2014. Health and Household-Related Benefits Attributable to the Weatherization Assistance Program. ORNL/TM-2014/345, Oak Ridge National Laboratory, Oak Ridge, Tennessee, September.
[24] Three³ managed the WAP evaluation and were the key authors of the health benefits report under the auspices of Oak Ridge National Laboratory.

- Weatherization recipient data from the Occupant Survey,
- Algorithms developed to monetize NEIs during the WAP evaluation; and
- Updated and Minnesota-specific secondary medical cost data

Sections 2.0 and 2.1 discuss how weatherization can yield health and SDOH benefits to households and society. A brief description of WAP and the evaluation upon which this report is based follows in Section 2.2. Section 2.3 introduces the NEIs assessed and monetized in the current study. Section 2.4 discusses how the decision was made to use primary survey data from the cold and very cold climate regions. Section 2.5 presents statistics that describe the research survey sample. Section 2.6 presents the general approach and specific assumptions used to monetize the nine NEIs. Section 2.7 addresses how avoided deaths were treated in our monetization. Finally, the monetization results, both annual and present value (PV), are presented in Section 2.9.

Technical details on the monetization approach for each of the nine are presented in Sections 3.0 through 10.0.[25] Each NEI section presents: an overview of how the NEI relates to weatherization; results from the Occupant Survey pertaining to the NEI; the monetization approach; tests of statistical significance; and the estimated NEI values. Section 11.0 presents a summary of Three^3's recent and ongoing research. Section 12.0 provides a simple cost-effective analysis for Xcel Energy Minnesota's program in 2019 based on: the number and cost of installed measures (reported by Xcel Energy); the estimated 'aggregate' NEI value calculated for this study; and energy savings costs for homes located in the cold and very cold climate regions (from the WAP evaluation).

[25] Section 4.0, Reduced Thermal Stress on Occupants, combines two NEIs, cold and heat-related thermal stress.

2.0 Non-Energy Impacts (NEI) Analysis For Xcel Energy's LI EE Program

2.1. Weatherization's Impacts on Health and Social Determinants of Health

Overview of Weatherization in the U.S.

The prototypical and largest weatherization program in the U.S. is the Weatherization Assistance Program (WAP) administered by the U.S. Department of Energy (DOE). This program provides grants to states, which then provide grants to local weatherization agencies to perform weatherization services. Homes receive energy audits, and based on the audit results, weatherization measures are selected to optimize both efficiency and cost-effectiveness. Common measures installed include: air sealing, insulation, furnace repair and replacement, and duct sealing. WAP and other programs also allow funds to be spent on health and safety measures. All homes are inspected post-weatherization. WAP funds the weatherization of single-family and mobile homes as well as multifamily buildings. Over 30 million homes in the U.S. are eligible for weatherization services annually.[26]

Many utilities offer low-income programs as part of their regulatory social contract[27], such as Xcel Energy's program under study in this project. Other funding comes from states, systems benefit charge programs, and re-programmed federal funds from the Low-Income Home Energy Assistance Program (LIHEAP). Combined, the sources fund the weatherization of approximately one-million units per year, and yet waiting lists can be long.[28]

Theory of Change

It is hypothesized that reductions in energy burden and material hardships and improvements in occupant health are all co-benefits of low-income weatherization. Figure 2.1 is illustrative of the relationships between weatherization and components of poverty. To begin, weatherization directly changes the physical condition of the home resulting in two major impacts. First, these changes have direct impacts on resident health and safety. For example, improvements in dwelling quality reduce exposure to evidence-based asthma triggers (e.g., air sealing measures reduce pest infestations), thereby reducing asthma symptoms. Weatherization directly reduces risks of thermal stress on occupants (e.g., air sealing and insulation decrease drafts and unsafe temperatures inside the home), and also reduce health risks associated with home fires and CO poisoning (e.g., through the installation of CO monitors and ensuring that combustion appliances vent properly).[29] Improved indoor environmental quality, including reduced intrusion of outdoor noise from adding insulation, can improve general physical and mental health.[30]

Second, these changes result in energy cost savings that reduce energy burdens, as well as cost savings in other areas (e.g., reduced utility disconnect and reconnect fees). Improvements in household members' health and financial situations result in positive feedback responses to

[26] (Carroll et al. 2014b)
[27] (Oppenheim 2016)
[28] (Tonn et al. 2015)
[29] It should be noted that asthma rates are higher than the national averages amongst low-income individuals (Rose et al. 2015). Additionally, thermal stress is another example of a national health inequity and is expected to worsen over time due to climate change (Wu et al. 2015).
[30] (De Souza et al. 2019)

each other. Improved health of those employed and of children can result in reduced missed days of work and school, directly and positively impacting household finances. Increased budget flexibility allows households to better afford food, avoid the decision to "heat or eat"[31], afford and comply with prescription drug recommendations, and pay for other healthcare expenses, which then have additional positive impacts on household members' health.

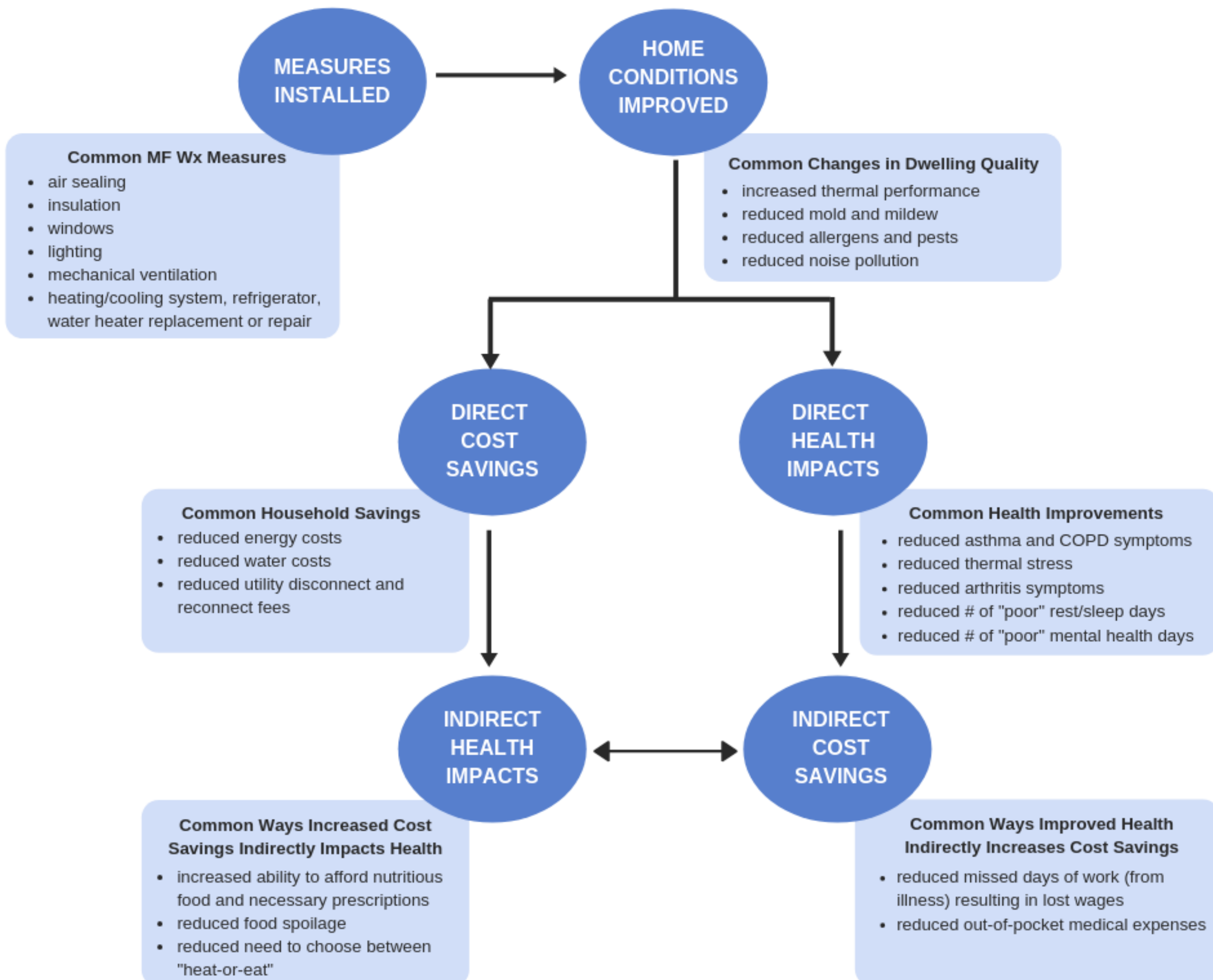

Figure 2.1. Weatherization's Impact Upon Poverty: Theory of Change

In many cases, comprehensive weatherization of homes is required to produce the most impactful health benefits. For example, air sealing, insulation, and cleaning of furnace and dryer filters are among many weatherization measures that can reduce the frequency of asthma triggers. Comprehensive weatherization is also needed to reduce thermal stress, flus and colds, and headaches. Most of the aforementioned health benefits result from standard weatherization measures rather than additional health and safety measures.

[31] (Frank et al. 2006)

On the other hand, some measures can independently impact health. For example, installation of CO monitors can reduce CO poisoning. Replacing an energy inefficient refrigerator that is unable to consistently keep food cool can potentially reduce food poisoning. Lowering the temperature on water heaters to save energy can also potentially reduce scalding.

Weatherization's Impacts on Energy Poverty

Evaluations find that energy consumption and energy cost burdens of low-income households are significantly reduced by weatherization programs.[32] For example, a comprehensive and rigorous evaluation of the energy savings attributable to WAP found that weatherization reduced natural gas consumption in single family homes by 17.8% with an annual energy cost savings of $239.[33] Using the present value of the energy costs savings taken over 19 years, the ratio of energy cost savings to the costs of the installed measures was 1.72. These results are reflective of the results of other evaluations of the energy savings and energy cost savings attributable to weatherization programs in the U.S.

Weatherization's Impacts on Health

Weatherization can also be a nexus point between housing, health, and energy consumption. Poor indoor air quality and extreme outdoor air temperatures can cause or exacerbate health problems for economically disadvantaged individuals and families living in substandard housing in America[34,35,36] and elsewhere in the world. [37,38,39,40,41,42,43] From an energy efficiency perspective, many vulnerable people are essentially living in tents.[44] It is not surprising that this has adverse health effects.

Research shows that weatherization has significant health benefits[45,46,47,48,49,50,51] and improves overall quality of life[52]. Weatherization can reduce asthma symptoms (e.g., air sealing keeps out

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32 (Tonn et al. 2018)
33 (Blasnik et al. 2014)
34 (Hood 2005)
35 (Bashir 2002)
36 (Gibson et al. 2011)
37 (Chard & Walker 2016)
38 (You & Kim 2019)
39 (Nicholls & Strengers 2018)
40 (Bouzarovski & Petrova 2015)
41 (Brunner et al. 2012)
42 (Burholt & Windle 2006)
43 (Jabre et al. 2020)
44 (Chard & Walker 2016)
45 (Breysse et al. 2014)
46 (De Souza et al. 2019)
47 (Rose et al. 2015)
48 (Howden-Chapman et al. 2007)
49 (Somerville et al. 2000)
50 (Haverinen-Shaughnessy et al. 2008)
51 (Liddell et al. 2010)
52 (Hernández & Phillips 2015)

allergens), thermal stress (e.g., insulation keeps indoor temperatures safe)[53,54,55] and scalding (e.g., by reducing water heater temperatures) (16). Current research in the multifamily sector suggests that the benefits may also extend to decreasing symptoms of COPD and certain types of arthritis.[56] Weatherization also improves indoor environmental quality.[57,58,59,60] For example, reduced intrusion of outdoor noise from air sealing and insulation can improve mental health and quality of sleep.[61] In summary, there are complex and indirect relationships linking energy efficiency measures to outcomes on all dimensions of health which contribute to significant material and psychosocial benefits.[62]

Weatherization's Impacts on Social Determinants of Health

NEI research finds that a household's financial well-being can improve post-weatherization, which leads to SDOH benefits. Households are less likely to forego buying food to pay utility bills, thereby reducing food insecurity.[63] Households are also more able to afford prescriptions. Improved health of all household members leads to reduced missed days of work for primary wage earners. This translates to a direct increase in income for many because three-fourths of low-income workers in the US do not have paid sick days.[64] Occasionally households also take out fewer short-term predatory loans after weatherization.[65]

The nature and extent of NEIs are dependent not only upon the type and number of weatherization measures installed but also upon the characteristics of the recipients and their homes. For example, the thermal comfort benefits of weatherization, which then might reduce thermal-stress related medical encounters, might be higher for programs that serve an older demographic or children.[66] Conversely, weatherization might benefit asthma sufferers who live in single-family homes more than those in large multifamily buildings because multifamily weatherization often does not include in-unit air sealing.

2.2. Overview of National WAP Evaluation

To estimate overall program cost effectiveness, it is important to not only calculate the program costs, energy savings, and the energy costs savings but also the NEIs attributable to the program. A component of the national WAP evaluation, the Occupant Survey, was administered to a random and representative sample of weatherized single-family[67] homes both pre- and

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[53] (Ahrentzen et al. 2016)
[54] (Alam et al. 2018)
[55] (Poortinga et al. 2018)
[56] (Three[3] & NMR Group 2019)
[57] (Doll et al. 2016)
[58] (Pigg et al. 2014)
[59] (Noris et al. 2013)
[60] (Francisco et al. 2017)
[61] (Tonn et al. 2014)
[62] (Gilbertson et al. 2012)
[63] (Cook et al. 2008)
[64] (Farrell & Venator 2012)
[65] (Tonn et al. 2014)
[66] (Nicholls & Strengers 2018)
[67] Single-family homes surveyed included mobile homes and small multifamily buildings consisting of between two and four units.

post-weatherization.[68] The phase 1 survey was administered just prior to a home receiving weatherization services – referred to as the Pre-Weatherization (Wx) Treatment group. The phase 2 survey was administered approximately eighteen months after the home was weatherized – the Post-Wx Treatment group. A comparison of these results provides direct insights into the impacts of weatherization because they involved the same group of households surveyed at different points in time.[69]

For comparison purposes, a group of homes that had been weatherized one year before the treatment group was also surveyed during phase 1 – this group is referred to as the Post-Wx Comparison, or simply, the Comparison group. Comparisons between the Pre-Wx Treatment and Post-Wx Comparison groups also provide useful insights since the data for both groups were collected in the same time period.[70]

For many of the NEIs evaluated through the national WAP evaluation, the differences between the treatment groups pre- to post-weatherization were statistically significant. Differences between the Pre-Wx Treatment group and the Post-Wx Comparison group were also statistically significant for many of the NEIs. Additionally, human stories shared by the weatherization agencies and recipients of the programs themselves supported the quantitative data collected. The combination of qualitative and quantitative data allowed researchers to engage in triangulation (i.e., arriving at conclusions by using multiple sources of information), a common research method in social sciences. In cases where quantitative data did not achieve statistical significance, qualitative data allowed the researchers to confidently monetize changes in the household. A national panel of experts reviewed all methodologies and assumptions and did not question the validity of any of the NEIs, nor were the findings dismissed as inconsiderable as there was a clear indication of health improvements.[71]

Survey results, data on weatherization measures installed (CO monitors), secondary databases containing national estimates of healthcare costs, and other secondary data and literature were used to monetize the twelve health and household related co-benefits of DOE's WAP:

- Reduced Carbon Monoxide Poisonings
- Reduced Home Fires
- Reduced Heat Stress-Related Healthcare and Costs
- Reduced Cold Stress- Related Healthcare and Costs
- Reduced Asthma-Related Healthcare and Costs
- Increased Productivity at Work Due to Improvements in Sleep
- Increased Productivity at Home Due to Improvements in Sleep
- Fewer Missed Days at Work Due to Improved Health
- Reduced Use of Predatory Loans
- Increased Ability to Afford Prescriptions
- Reduced Heat or Eat Choice Dilemma Faced by Pregnant Women
- Reduced Need for Food Assistance

[68] (Carroll et al. 2014)
[69] (Hawkins et al. 2016)
[70] Ibid.
[71] The monetization approach for the two additional NEIs explored in this study – reduced utility disconnects and increased food security – were not reviewed by the national panel of experts.

These NEIs were chosen for monetization because the evaluation collected data on the direct outcomes and/or monetizable outcomes related to each NEI. For example, the national Occupant Survey asked respondents about healthcare encounters for thermal stress, asthma symptoms and medical treatment, improvements in sleep, and missed days at work, to name a few. The evaluation also collected information on measures installed by WAP in a representative sample of homes that was used to estimate reduced carbon monoxide poisonings and home fires.

For NEIs based on rare events such as fires or CO poisoning, the research team relied on a combination of Occupant Survey responses, information about the weatherization measures installed in homes, and secondary data. Responses from the survey indicated that fires and CO poisoning were very rare, and national data for the general U.S. population validated this finding. However infrequent, preventing fires and CO poisoning are relevant policy issues, especially given that deaths could be avoided. For fire, monetization inputs included data on weatherization measures installed (e.g., various measures that map specifically to fire ignition risks or serve as fire suppressors). The CO poisoning monetization relied on national Occupant Survey responses regarding CO monitor installation. Both estimates incorporated secondary data to anchor the methodologies.

Descriptive statistics generated from these surveys suggest the following post-weatherization benefits, which are consistent with research cited above:[72,73]

- The physical condition of homes is improved, making the homes more livable;
- Weatherization recipients experience fewer 'bad' physical, mental health, and sleep/rest days;
- Weatherization recipients suffer fewer persistent colds and headaches;
- There are fewer instances of doctor and emergency department (ED) visits related to asthma and thermal stress;
- Households are better able to pay energy and medical bills;
- Households are better able to pay for food; and
- Household use of two kinds of short-term, high-interest loans (tax refunds and pawn shops) decreases.

In general, homes need to receive a full complement of major weatherization measures (e.g., air sealing, insulation, HVAC replacement/repair) to generate the types of NEIs described. Findings from the national WAP evaluation showed that enough homes received a sufficient level of measures to yield significant non-energy benefits. It should also be noted that while every household is expected to receive energy cost reduction benefits from weatherization, not every household is expected to receive the health and household-income related benefits identified through the national WAP evaluation. For example, only a subset of households will experience thermal stress events in the absence of home weatherization – it is logical that fewer households will experience this benefit than those that will experience energy cost reductions.[74]

[72] (Hawkins et al. 2016)
[73] (Tonn et al. 2014)
[74] (Hawkins et al. 2016)

2.3. Xcel Energy's LI EE NEI Study

For the Xcel Energy LI EE NEI Study a subset of seven of the twelve NEIs monetized in the national WAP evaluation was selected based on their estimable, direct impact on the household, which was of most interest to the utilities; the remaining five NEIs produced only societal impacts (i.e., reduced need for food assistance, improvement in prescription adherence, increased productivity at work due to improved sleep, reduction in low-birth weight babies from heat or eat dilemma). Two new NEIs that were not explored in the national WAP evaluation are also included. The nine NEIs monetized for the Xcel Energy LI EE NEI Study are as follows:

Previously monetized for National WAP Evaluation

- Asthma
- Heat Stress
- Cold Stress
- Missed Days of Work
- Predatory Loans
- Reduced Fire Risk
- CO Poisoning

Additional NEIs

- Reduced Utility Disconnects
- Increased Food Security

2.4. Comparison of Data between Cold and Very Cold Regions

As noted, the WAP evaluation was conducted nationally. Five climate regions were delineated for the evaluation, as shown in the U.S. map in Figure 1.[75] Figure 2.2 indicates that the whole of Minnesota state was classified as being in the very cold climate region; however, other sources classified the southern portion of Minnesota as part of the cold climate. Complicating the decision to use data from the cold or very cold climate zones was the fact that more survey data could be used if both climate regions were included.

Sample sizes for the 'very cold' sample were small, which posed challenges to capturing rare medical events (see Table 2.1). By combining survey responses from both the 'very cold' and 'cold' climate states for this analysis, the researchers could expand the population around the sample and increase the statistical power of individual NEIs.

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[75] Three[3] research staff, under the auspices of Oak Ridge National Laboratory, managed the DOE funded evaluation and conducted the health and household-related NEIs component. Please see the following report for additional information on the WAP NEI study: Tonn, B., Rose, E., Hawkins, B., and Conlon, B. 2014. Health and Household-Related Benefits Attributable to the Weatherization Assistance Program. ORNL/TM-2014/345, Oak Ridge National Laboratory, Oak Ridge, Tennessee, September.

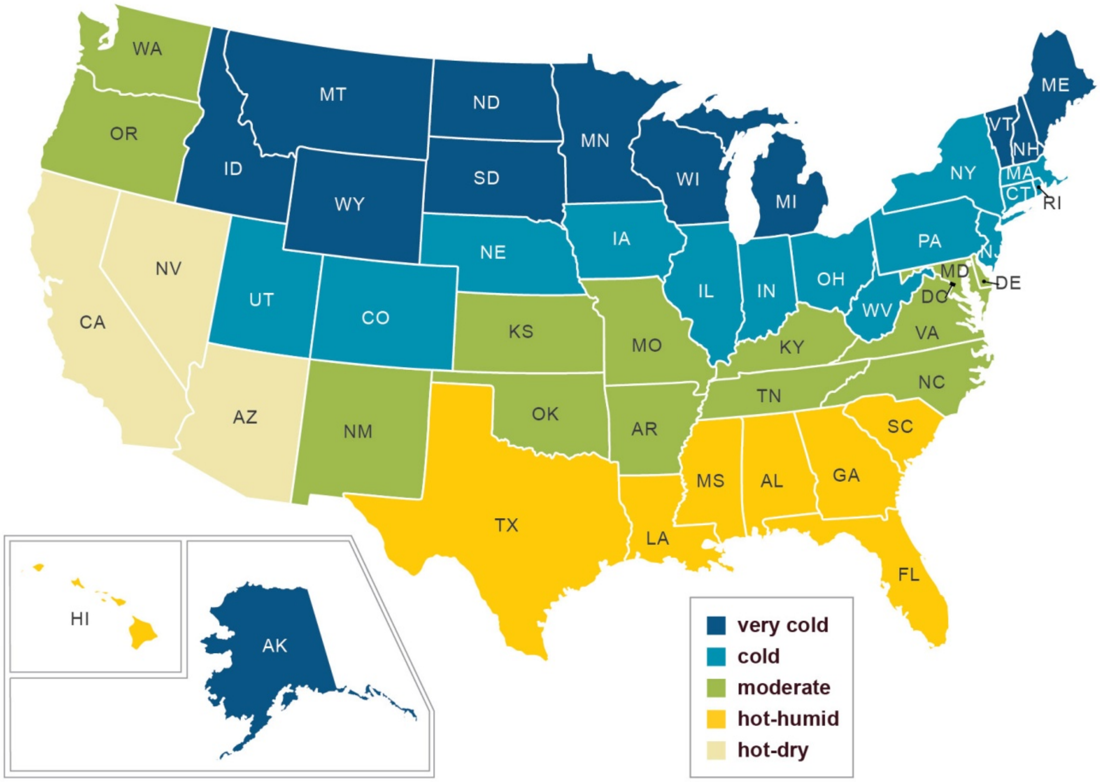

Figure 2.2. National WAP Evaluation Designated Climate Regions

The map presented in Figure 2.3 is based on climate designations used by the International Energy Conservation Code (IECC) and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) and shows Minnesota divided by zone 6 (cold) and zone 7 (very cold). Thus, this map also seems to suggest that it is appropriate to include data from both climate regions.

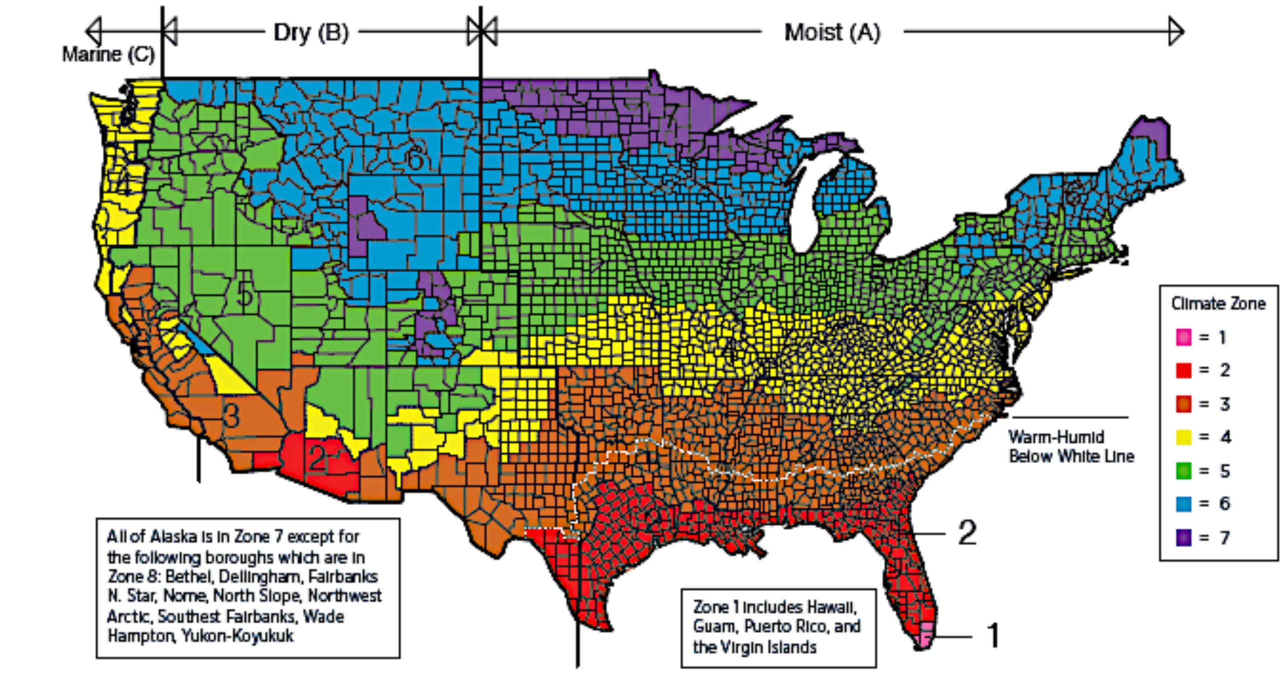

Figure 2. International Energy Conservation Code (IECC) climate regions

Figure 2.3. International Energy Conservation Code Designated Climate Regions

The primary consideration for the analyses presented in this section is to explore whether respondents and their health conditions are comparable between the cold and very cold climate states; if it was found that sample characteristics meaningfully diverged, then only the very cold climate data would be used in this study. For comparison purposes, data from the following three cohort subsamples are presented below: 1. Cold (C) climate region; 2. Very cold (VC) climate region; and 3. Cold + very cold (C + VC) combined (see Tables 2.1 – 2.4). Data include sample sizes by group (Table 2.1), asthma sub-sample size (respondents with current asthma) (Table 2.2), select housing and demographic variables (Table 2.3), and select health and SDOH variables (Table 2.4).

Table 2.1. Sample Sizes by Group and Climate Region

	Pre-Wx (Treatment Group–Survey Phase 1)	Post-Wx (Treatment Group–Survey Phase 2)	Post-Wx (Comparison Group–Survey Phase 1)
Cold (C)	318	190	331
Very Cold (VC)	176	105	209
C + VC	494	295	540
National – All	665	398	803

Table 2.2. Sample Sizes by Group and Climate Region for Respondents (only respondents that said yes to both: "have been told they have asthma" and "still have asthma")

	Pre-Wx (Treatment Group–Survey Phase 1)	Post-Wx (Treatment Group–Survey Phase 2)	Post-Wx (Comparison Group–Survey Phase 1)
Cold (C)	50	32	50
Very Cold (VC)	21	17	31
C + VC	71	49	81
National – All	94	61	123

Table 2.3. Select Housing and Demographic Variables by Climate Region per Sampled Group

		Pre-Wx (Treatment Group–Survey Phase 1)	Post-Wx (Comparison Group–Survey Phase 1)
% Single-Family Homes	Cold	75%	80%
	Very Cold	79%	80%
	C + VC	76%	80%
Heating Fuel - NG	Cold	61%	57%
	Very Cold	49%	55%
	C + VC	57%	56%
Heating Fuel - Electric	Cold	11%	10%
	Very Cold	11%	9%
	C + VC	11%	9%
Heating Fuel – Fuel Oil	Cold	12%	22%
	Very Cold	14%	17%
	C + VC	13%	20%
Age Respondent	Cold	56	68
	Very Cold	56	62
	C + VC	56	66
Household Size	Cold	2.6	2.2
	Very Cold	2.4	2.5
	C + VC	2.5	2.3
Respondent Employed	Cold	33%	34%
	Very Cold	44%	40%
	C + VC	37%	37%
Home in Rural Area	Cold	29%	29%
	Very Cold	30%	34%
	C + VC	29%	32%
Respondent Married	Cold	34%	34%
	Very Cold	34%	40%
	C + VC	34%	36%
Respondent - High School	Cold	41%	42%
	Very Cold	39%	43%
	C + VC	40%	43%

Table 2.4. Selected Health & Household Variables by Climate Region

		Sampled Groups		
		Pre-Wx (Treatment Group–Survey Phase 1)	Post-Wx (Comparison Group–Survey Phase 1)	Post-Wx (Treatment Group–Survey Phase 2)
Asthma Symptoms < 3 months ago (i.e. high-cost patient)	Cold	72.0% (n=50)	-	55.6% (n=27)
	Very Cold	61.9% (n=21)	-	53.8% (n=13)
	C + VC	69.0% (n=71)	-	55.0% (n=40)
Asthma Emergency Department	Cold	18.0% (n=50)	-	0% (n=28)
	Very Cold	15.0% (n=20)	-	7.7% (n=13)
	C + VC	17.1% (n=70)	-	2.4% (n=41)
Asthma Hospitalization	Cold	14.0% (n=50)	-	10.0% (n=28)
	Very Cold	15.0% (n=20)	-	7.7% (n=13)
	C + VC	14.3% (n=70)	-	9.8% (n=41)
Healthcare Encounter – too cold	Cold	4.1%	1.8%	2.6%
	Very Cold	0.6%	1.9%	1.0%
	C + VC	2.8%	1.9%	2.0%
Healthcare Encounter – too hot	Cold	3.8%	0.9%	1.1%
	Very Cold	0.6%	1.4%	2.9%
	C + VC	2.6%	1.1%	1.7%
Used Short Term Loan	Cold	18%	13%	9%**
	Very Cold	18%	8%	12%
	C + VC	18%	11%***	10%
Missed Days of Work	Cold	10.6	9.1	4.1**
	Very Cold	5.4	2.7	7.2
	C + VC	11.5	8.4*	10.8
Have Smoke Detector	Cold	94%	98%***	97%
	Very Cold	93%	98%	99%
	C + VC	94%	98%**	99%***
Have working CO Monitor	Cold	54%	90%***	81%***
	Very Cold	50%	78%	77%
	C + VC	56%	82%***	87%*

*p<.01, **p<.05, ***p<.001

Due to the comparability between the groups and the similarity to the demographics served by Xcel Energy Minnesota the team chose to base the study off data from the combined C + VC climate regions. As indicated in Table 2.1, this decision adds hundreds of more homes to our samples for data analysis. The results presented in Tables 2.3 and 2.4 indicate that the C and VC survey samples have similar percentages of residents live in single-family homes and heating their homes with electricity. There is a higher percentage heating with natural gas in the cold climate region. Given the reliance on NG as a heating fuel in Minnesota, this observation supports combining the C and VC climate region survey samples.

The demographic characteristics, such as age of main respondent and household size, are very similar between the two climate regions. Homes across the two samples have similar rates of smoke detectors and working CO monitors. There are some differences in health encounters for being too hot or too cold in one's home and missed days of work. However, in these instances, these issues are more prominent in the cold climate region and could be representative of the context in the southern part of Minnesota. Thus, combining the data for these variables across climate regions is preferable.

As a last point, it is recommended that the entire national sample be used with respect to the asthma variables. For the Massachusetts single-family NEI study, the asthma subsample for the cold climate cohort sample was too small to produce robust results (Table 2.2).[76] Therefore, it was decided to use the full national sample to capture impacts and outcomes.[77] This decision was supported by data that indicates that asthma prevalence does not vary significantly by climate region.

2.5. Descriptive Statistics

Due to the comparability between the C and the VC groups and their similarity to the demographics served by Xcel Energy Minnesota, the team chose to base this study on data from the combined C + VC climate regions.

The tables below present data for the pre- and post-weatherization treatment groups and the post-weatherization comparison group. For all NEIs, with the exception of asthma, data in the remaining sections of this report is presented for the combined C + VC climate regions. For the asthma NEI, national level data is presented. Table 2.5 characterizes the cohort sample with respect to housing and demographics, and Table 2.6 and 2.7 present frequencies from the Occupant Survey for health and household related variables.

[76] Those that said yes to both "have been told they have asthma" and "still have asthma".
[77] National occupant survey data was used for the asthma monetization effort but context-specific inputs were identified and used for the model (i.e., average state-level costs for asthma-related hospitalizations and ED visits).

Table 2.5. Housing and Demographic Characteristics

	Sampled Groups (C + VC only)	
	Pre-Wx Treatment (Survey Phase 1)	**Post Wx Comparison (Survey Phase 1)**
% Single-Family Homes*	76%	80%
Heating Fuel - Natural Gas**	57%	56%
Heating Fuel - Electric	11%	9%
Heating Fuel – Fuel Oil	13%	20%
Heating Fuel – Propane	3%	1%
Heating Fuel – Kerosene	1%	1%
Heating Fuel – Wood	5%	8%
Age Respondent (in yrs.)	56	66
Household Size	2.5	2.3
Respondent Employed	37%	37%
Home in Rural Area	29%	32%
Respondent Married	34%	36%
Respondent Education – High School	40%	43%

*Mobile homes and small multi-family (2-4 units) constituted the remaining percent.
**Percentages of heating fuel types might not total 100% due to rounding.

Statistical tests were conducted to assess the differences between the pre-weatherization treatment and post-weatherization treatment and comparison groups. Asterisks in the second column of Table 2.6 and second and third columns of Table 2.7 indicate whether a statistically significant difference existed between the pre-weatherization treatment and post-weatherization treatment groups and the pre-weatherization treatment and post-weatherization comparison groups, respectively.

Table 2.6. Health Variables Related to Asthma (National Sample)

	Sampled Groups	
	Pre-Wx Treatment (Survey Phase 1)	**Post-Wx Treatment (Survey Phase 2)**
Asthma Emergency Department	15.8%	4.3%*
Asthma Hospitalization	13.7%	10.6%
Asthma Symptoms < 3 months ago (i.e. high-cost patient)	70.5%	58.7%

**** p < .001, ** p <. 01 and *p <. 05*

Table 2.7. Health and Household Variables Related to Select NEIs (Cold + Very Cold Climate Regions)

	Sampled Groups		
	Pre-Wx Treatment (Survey Phase 1)	Post-Wx Treatment (Survey Phase 2)	Post-Wx Comparison (Survey Phase 1)
Medical Attention – too cold	2.8%	2.0%	1.9%
Medical Attention – too hot	2.6%	1.7%	1.1%
Missed Days of Work (ave. # days)	8.5	5.5	7.0**
Used Short Term Loan	17.6%	11.0%	10.3%**
Have working CO Monitor	53%	80%***	85%***
Have Smoke Detector	94%	99%***	98%**

**** p < .001, ** p <. 01 and *p <. 05*

2.6. Observations on Sample Sizes and Statistical Significance

There are a multitude of health studies conducted that consist of small sample sizes that represent respectable research. In developing our analyses, we have faced the issue of whether our sample sizes were large enough to capture rare events in relation to thermal stress and asthma. The occupant survey asked questions about fires and CO poisoning pre- and post-weatherization as well. The responses indicated that both were very rare given our sample size. National data supports these conclusions.[78] However, we believe that preventing fires and CO poisoning are important NEIs of weatherization. In the case of these four NEIs, had the sample sizes been larger one could argue that findings, and the level of significance, would be even higher than they were. Again, the magnitude of the change in healthcare needs from pre- to post-weatherization is enough to be policy relevant – there is a clear indication of health improvements.

Additionally, the quantitative findings are substantiated by anecdotal evidence put forth by the community action agencies, utility weatherization providers, and by recipients of the programs themselves.[79] Benefits are analyzed from multiple angles. Triangulation as a research method (i.e. arriving at conclusions by using multiple sources of information) is common within the social sciences. Because we approach the selected benefits for analysis in this way, we are able to confidently incorporate changes in occurrences into the larger monetized benefit even if they do not achieve statistical significance for the reasons explained above.

[78] (Tonn et al. 2014)
[79] (Tonn et. al 2014b)

2.7. Monetization Approach

Nine NEIs are addressed in this study. Two different approaches to monetization are used. The first approach makes use of the Occupant Survey results to establish household reported changes in health and SDOH conditions from pre- to post-weatherization. This approach is used for seven of the nine NEIs because a sufficient number of households provided answers to these questions to be able to conduct statistical analyses.

An engineering approach is used for two other NEIs: reducing home fires and CO poisoning. The Occupant Survey did include questions specific to instances of home fires; however, these events are relatively infrequent. Thus, the literature was consulted to provide estimates of the reduction in fires and CO poisoning that could be attributed to the installation of common weatherization measures. To substitute for the lack of survey data, data were collected from local weatherization agencies on the number of smoke detectors and measures installed that could reduce the probability of home fires. The survey was used to measure how many CO monitors were installed.

The decrease in occurrence for survey-based NEIs, with the exception of asthma, between pre- and post- treatment groups and between Pre-Wx Treatment and Post-Wx Comparison groups was calculated (i.e., an average of the differences) (see Equation 1 below). This approach was utilized to make the best use of the collected data.

Equation 1. *[(Pre-Wx Treatment – Post-Wx Treatment) + (Pre-Wx Treatment – Post-Wx Comparison)] / 2*

As mentioned previously, the equation (Equation 2) utilized for the monetization approach for the asthma NEI was different from the other survey-based NEIs due to the diverging sample characteristics between the treatment and comparison groups and is as follows:

Equation 2. *Pre-Wx Treatment – Post-Wx Treatment*

The tables in the following NEI sections (Section 3.0 - 10.0) contain the results of applying these equations. The Pre-Wx Treatment – Post-Wx Treatment values (decreased occurrence) are presented in column 1. Column 2 presents the Pre-Wx Treatment – Post-Wx Comparison values (decreased occurrence), and column 3 presents the change (+/-) (i.e., delta) resulting from the application of Equation 1 where applicable. Statistical significance (p-value) is presented within the each NEI section as well.

For the national WAP evaluation, the estimated NEI values were presented on a dollar per weatherized unit basis, broken down into societal and household benefit components as well as with and without the value of saved life. The present value (PV) of the benefits was estimated over a ten-year time horizon[80] using the discount rate of 0.1% published by the Office of Management and Budget for Fiscal Year (FY) 2013.

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[80] With the exception of the non-energy benefit of installing CO monitors, where present value was calculated over a more conservative 5-year period as the lifespan of CO monitors generally remains effective for an average of five years.

For the Xcel Energy LI EE NEI Study a variety of modifications were made to the methodology and inputs utilized for the national NEI monetization models. In order to conduct a state-level analysis, inputs needed to reflect the context. Each NEI section includes a listing of adjustments made, followed by the adjusted value of the input. Modifications that were applied to all NEIs are as follows:

- Only per unit/household impacts were monetized, and any values related to program-wide impacts from the national WAP evaluation were removed (i.e., number of homes treated by WAP in PY 2008).
- The discount rate was adjusted from an Office of Management and Budget (OMB) rate of 0.1% to a ten-year discount rate of 3.02%.[81]
- The Value of Statistical Life (VSL) was updated from $7.5M[82] to the U.S. Department of Transportation's (DOT) recommended value for 2016 of $9.6M (See Section 2.5.1).
- Lastly, the VSL associated with avoided deaths was applied as a household benefit rather than a societal benefit.[83]

To communicate differences in the robustness of the NEI estimates, the estimates were presented in three tiers. Tier 1 estimates were based on observed monetizable outcomes attributable to weatherization (i.e., observed through the national Occupant Survey, pre- and post-weatherization with a comparison group) and highly reliable cost data. Tier 2 and 3 estimates were established to have underlying sound methodologies, but may have lacked direct observations of improved health or well-being (e.g., based on counts of installed CO monitors rather than on survey reports of fewer CO poisonings post-weatherization) and/or required relatively more assumptions. These tiers are also used in this study.

2.8. Avoided Death Benefits

[81] The national WAP evaluation used the ten-year real treasury interest rate for 2013 (0.1%) from Office of Management and Budget (OMB) to calculate the present value (PV) of the total discounted savings for all NEIs. For this Xcel cohort study, the selection of a 3.02% discount rate was driven by guidance provided by Fresh Energy to Minnesota's Department of Commerce. The Department of Commerce requested input "regarding the appropriate discount rates to be used in Minnesota's Conservation Improvement Program cost-effectiveness tests." Fresh Energy recommends that the Department "make the Utility Discount Rate equal to the Societal Discount Rate in Minnesota's Conservation Improvement Program cost-effectiveness tests." The societal discount rate reported within the document is 3.02%.

[82] Value of human life, or as economists refer to it as, the Value of Statistical Life (VSL) is a measure used to compare regulatory costs to benefits. At the time of the WAP evaluations, the U.S. government agencies were using values ranging from $5-9 million in regulatory cost-benefit analysis. The WAP National Evaluation used a conservative VSL of $6 million (2000 dollars) adjusted for inflation to $7.5 million in 2008 dollars. See OMB Circular A-4 for more discussion on VSL.

[83] EPA does not explicitly state that the effect of the VSL costs and benefits should be applied as societal or household impacts; this lack of guidance has resulted in conflicting schools of thought on this matter. Based on consultation with health economists, the WAP National Evaluation chose to apply avoided costs as a societal benefit. However, based on additional research, it is clear that VSL estimates are based on the value that individuals' place on reducing their own mortality risk. Thus, for this study, it was decided to categorize VSL as a household benefit (See Section 2.5.1 for more detailed information on this decision).

It is assumed that weatherization can avoid deaths associated with four NEIs. To monetize the benefit of avoided deaths from thermal stress (heat and cold), CO poisoning, and fire, the VSL was updated from the $7.5M (2008 dollars) used in the national WAP evaluation to $9.6M, as published in the DOT guidance document for 2016.[84] Federal agencies including DOT and U.S. Environmental Protection Agency (EPA) use the VSL to assess the benefits of their regulations or policies intended to reduce deaths or fatalities (e.g., from traffic accidents or adverse environmental events/conditions).[85] An article published in *Risk Analysis* provides an overview of VSL application in federal regulatory analyses and states: 1) EPA's and DOT's estimates have become remarkably similar; both now use central VSL estimates somewhat above $9 million; 2) this increasing similarity results partly from reliance on the same type of research (wage risk studies); and 3) DOT has updated its guidance more frequently than EPA.[86]

The VSL does not refer to the "value of a life" but rather the value of a change in one's mortality risk. From the DOT guidance, the VSL is "defined as the additional cost that individuals would be willing to bear for improvements in safety (reductions in risks) that, in the aggregate, reduce the expected number of fatalities by one...what is involved is not the valuation of life as such, but valuation of reductions in risk."

The benefit of avoided deaths (except for firefighters) was applied in the current study as a household benefit. Cost benefit analyses conducted at the federal level do not typically distinguish benefits accrued to individuals/households apart from society as a whole.

In an effort to use a state-level (rather than federal) VSL, the project team explored whether a different VSL value has been used by regulatory agencies in Minnesota. We conducted a thorough scan of Minnesota state government agencies' use of VSLs for cost-benefit analyses. In 2016, Minnesota's Department of Transportation (DOT) adopted the U.S. Department of Transportation (DOT) recommended VSL of $9.6M. There was no evidence found that this value has been updated since 2016.[87]

2.9. Presentation of Findings

The presentation of estimated NEI values for Xcel Energy's LI EE NEI Study are similar to the national WAP evaluation in that:

- Values are presented on a per weatherized unit basis
- Values are broken down by their societal and household benefit components
- A PV estimate of the benefits is provided, and
- Estimates are presented in three tiers.

The main contributors to estimates presented in Table 2.8 are: avoided deaths from thermal stress, especially cold stress, and home fires; avoided hospitalizations and emergency department (ED) visits related to asthma flare-ups; and reduced healthcare

[84] DOT's annual VSL guidance for 2016 can be found in the Guidance on Treatment of the Economic Value of a Statistical Life (VSL) in U.S. Department of Transportation Analysis. The VSL was published in DOT's Benefit-Cost Analysis (BCA) Resource Guide, updated March 1, 2016, available at https://www.transportation.gov/sites/dot.gov/files/docs/BCA%20Resource%20Guide%202016.pdf.
[85] (Hawkins et al. 2016)
[86] (Robinson & Hammitt 2015)
[87] For more information: https://safety.fhwa.dot.gov/hsip/docs/fhwasa17071.pdf.

costs from increased food security. Table 2.9 provides the PV for the estimates presented in Table 2.8.

Table 2.8. Annual Per Unit NEI Values for Xcel Energy's Low-Income Energy-Efficiency Program

NEI Value	Annual Per Unit Benefit				
	Household	Household W/O Avoided Death Benefit	Societal	Total	Total W/O Avoided Death Benefit
Tier 1					
Reduced asthma symptoms	$73.54	$73.54	$309.46	**$383.00**	$383.00
Reduced cold stress	$216.70	$1.64	$11.82	**$228.52**	$13.46
Reduced heat stress	$63.33	$2.72	$8.88	**$72.21**	$11.60
Fewer missed days at work	$33.41	$33.41	$11.64	**$45.05**	$45.05
Reduced utility disconnections	$0.05	$0.05	$0.00	**$0.05**	$0.05
Increased food security	$61.22	$61.22	$253.20	**$314.42**	$314.42
Tier 2					
Reduced use of predatory loans	$10.41	$10.41	$0.00	**$10.41**	$10.41
Reduced CO poisoning*	$0.85	$0.04	$0.22	**$1.07**	$0.25
Tier 3					
Reduced home fires	$90.44	$6.20	$11.80**	**$102.24**	$17.72**
Annual Total—per weatherized home	**$549.95**	**$189.23**	**$607.02**	**$1,156.97**	**$795.96**

*For CO poisoning, the annual NEI is to be applied over the 5-year life of the CO monitor. The remaining NEIs are to be applied annually over the life of the relevant measure (10 years).
** For home fires, the avoided injuries and deaths to firefighters are categorized as a societal benefit ($0.28).

Table 2.9. Per Unit NEI Values for Xcel Energy's Low-Income Energy-Efficiency Program at Present Value[88]

NEI Value	PV (10 years) Per Unit Benefit				
	Household	Household W/O Avoided Death Benefit	Societal	Total	Total W/O Avoided Death Benefit
Tier 1					
Reduced asthma symptoms	$717.87	$717.87	$3,021.05	**$3,738.92**	$3,738.92
Reduced cold-related thermal stress	$1,846.62	$13.96	$100.74	**$1,947.36**	$114.70
Reduced heat-related thermal stress	$539.68	$23.22	$75.70	**$615.38**	$98.92
Fewer missed days at work	$284.71	$284.71	$99.22	**$383.93**	$383.93
Reduced Utility Disconnections	$4.17	$4.17	$0.00	**$4.17**	$4.17
Increased Food Security	$521.70	$521.70	$2,157.61	**$2,679.32**	$2,679.32
Tier 2					
Reduced use of short-term, high-interest loans	$88.73	$88.73	$0	**$88.73**	$88.73
Reduced CO poisoning (5-year life)*	$3.88	$0.17	$1.00	**$4.87**	$1.16
Tier 3					
Reduced home fires	$882.92	$52.37	$115.18**	**$998.10**	$149.63**
Annual Total—per weatherized home	**$4,890.28**	**$1,706.90**	**$5,570.50**	**$10,460.78**	**$7,259.48**

*For CO poisoning, the PV is calculated using a 5-year life of the CO monitor.
** For home fires, the avoided injuries and deaths to firefighters are categorized as a societal benefit.

[88] PV at ten years and 3.02% discount rate.

3.0 Reduced Asthma

Weatherization has the potential to act as a multi-component intervention mitigating the severity and incidence of asthma episodes by addressing evidence-based indoor environmental triggers. These triggers include mold, cockroaches, mice, dust, other particulate matter, and by-products of combustion from gas cooking stoves and portable unvented heaters. Comprehensive weatherization reduces exposure to home-based environmental asthma triggers, resulting in fewer asthma symptoms, direct medical costs, and indirect costs.

The treatment group included a limited number of respondents that had been diagnosed with asthma. As a result, the national level results were used instead of the climate-specific results (cold + very cold) to increase confidence in the conclusions drawn from this research. Although indoor environmental asthma triggers are often specific to geographic and climate regions, and diverse across housing types, differences in overall prevalence within the general population by region are negligible. Additionally, the WAP-eligible population is estimated to have a higher rate of asthma than the general population, so the higher, WAP-specific rate was chosen instead of Minnesota's state-wide asthma prevalence. We apply the higher WAP-based asthma prevalence rate because previous findings suggest that households applying for services are motivated in part by dwelling quality issues related to poor health status.

3.1. Inputs and Monetization Approach

Weatherization is hypothesized to reduce environmental asthma triggers in the home and thereby reduce the use of urgent care facilities, and other direct medical expenses associated with asthma. It was observed through the national Occupant Survey that reported incidences of seeking urgent healthcare through the ED and hospitals from asthma were reduced post-weatherization (Table 3.1).

Table 3.1. Occupant Survey Results – Asthma

Occupant Survey Question	Difference (+/-)
During the past 12 months did you have to stay overnight in the hospital because of asthma?	-3.1%
Not counting hospitalizations, during the past 12 months, did you go to an emergency room because of asthma?	-11.5%

Survey respondents were initially asked if they had "*ever* been told by a physician" that they have asthma. If the respondent answered in the affirmative, they were then asked if they *still* have asthma. The results from the survey indicate that 16.8% of adults in the WAP eligible population have current (i.e., active) asthma. Descriptive frequencies were generated for all respondents who reported current asthma in either phase of the survey, and for those who responded to both pre- and post-weatherization surveys.

Table 3.2 presents the observed rate of change in healthcare encounters by care setting and the level of statistical significance for the Treatment group only; the Comparison group asthma sub-sample was determined to not be comparable to the Treatment group. The improvement in asthma morbidity as measured by ED visits in the asthma sample was statistically significant. A reduction in hospitalizations for asthma was observed post-weatherization but was not statistically significant. Similar to thermal stress, we believe this to be a result of a small sample size and a rare event.

Table 3.2. Tests of Statistical Significance –Asthma

	ED Visit from Asthma Change (+/-)	Hospitalization from Asthma Change (+/-)	High Cost Asthma Patient Change (+/-)
Difference between Pre-Wx and Post-Wx Treatment (%)	11.5%	3.1%	11.8%
n[89]	47	47	46
Fisher's Exact Test (p-value)	.445	.154	.002
McNemar Test	1.000	.727	.388
Logistic Regression (n=130)	.035*	NA	NA

*The results from the logistic regression analysis indicate that weatherization is associated with fewer visits to the ED for asthma.

Due to the diverging sample characteristics between Treatment and Comparison groups, changes in responses pertaining to asthma control and associated urgent care utilization were monetized using responses from the Treatment group responses only pre- and post-weatherization. Tables 3.3 and 3.4 present the final descriptive frequencies for asthma-related hospitalizations and ED visits used for the monetization of benefits attributed to weatherization.

Table 3.3. Reduction in Asthma Related ED Visits for All Respondents Reporting Current Diagnosis of Asthma

% of Respondents Reporting Visit to ED due to asthma[90]	ED Visit	Difference
Whole Asthma Sample-Treatment Group (Pre-Wx; n=95)	15.8%	(-) 11.5%*
Whole Asthma Sample-Treatment Group (Post-Wx 1-year; n=47)	4.3%	

*** p<.001; ** p <.01; * p<.05

[89] The number of respondents who answered the survey questions referred to in Table 3.2 was less than the number of respondents who answered the questions referred to in Table 3.1.
[90] The number of respondents who answered this survey question is one more than the number in Table 3.2, One additional survey respondent answered this question, but was not on record for answering the survey questions in Table 3.2.

Table 3.4. Reduction in Asthma Related Hospitalizations for All Respondents Reporting Current Diagnosis of Asthma

% of Respondents Reporting Hospitalization due to asthma[91]	Hospitalization	Difference
Whole Asthma Sample-Treatment Group (Pre-Wx; n=95)	13.7%	(-) 3.1%
Whole Asthma Sample-Treatment Group (Post-Wx 1-year; n=47)	10.6%	

*** p<.001; ** p <.01; * p<.05

As stated, in addition to averted medical costs associated with hospitalization and ED visits due to asthma, there is sufficient evidence to suggest that weatherization acts in provides additional benefits beyond the changes in utilization of emergency care captured in the survey. These benefits are observed through other direct medical costs (i.e., reduced prescribed medicines, office and clinic visits, and hospital outpatient) and indirect costs (i.e., loss of work and school productivity, and restricted activity). Indirect costs were not used as inputs for this model due to the risk of double counting savings generated from other NEIs in this study (i.e. fewer missed days of work).

In order to monetize potential reductions in averted medical costs outside of ED visits and hospitalizations, a methodology was developed during the national evaluation of WAP to classify individuals as "high-cost" asthma patients pre-weatherization and "low-cost" asthma patients post-weatherization. A framework was developed based on respondents' reports of the last time they had asthma symptoms, compared to those who reported ED visits or hospitalizations due to asthma. Those who reported last having asthma symptoms less than three months ago were counted as high-cost asthma patients and those who reported last having asthma symptoms greater than three months ago were identified as low-cost asthma patients. Table 3.5 provides the reduction in high-cost patients in the treatment group whole asthma sample (11.8%). This reduction was used for the monetization of the benefit.

Table 3.5. Reduction in High-Cost Patients

% of Respondents Identified as High-Cost Asthma Patient by Group and by Sample[92]	High-Cost	Difference
Whole Asthma Sample-Treatment Group (Pre-Wx; n=93)	70.5%	(-) 11.8%
Whole Asthma Sample-Treatment Group (Post-Wx 1-year; n=46)	58.7%	

**** p<.001; ** p <.01; * p<.05*

Table 3.6 presents inputs used for monetization of the asthma NEI. Average state-level costs for asthma-related hospitalizations and ED visits were identified for 2014 and used

[91] The number of respondents who answered this survey question is one more than the number in Table 3.2, One additional survey respondent answered this question, but was not on record for answering the survey questions in Table 3.2.

[92] The number of respondents included in this analysis is fewer than the number referred to in Tables 3.2, 3.3 and 3.4 due to criteria filters used for high-cost patient analysis (i.e. still have asthma, answered survey questions related to asthma symptoms).

as inputs for the model after being adjusted for 2019 costs.[93] To estimate impacts from changes in other direct medical costs, the WAP 2008 estimate was adjusted to 2019 costs. The out-of-pocket (OOP) costs were estimated to determine the household benefit, with the remaining medical costs incurred by private and public insurers (e.g., Medicaid and Medicare) considered societal benefits.[94] A report (2019) published by the MN Department of Health suggests that, on average, commercially insured individuals spend approximately 12.5 % OOP of the total healthcare costs incurred.[95] This percentage was input as the household portion of the total asthma benefit calculated for the percentage of the population with commercial insurance (~24%) and those uninsured (~ 11%).[96,97]

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[93] Average asthma costs for inpatient and ED admissions across all age categories and payer types were retrieved from the joint report (2014), 'Asthma Among Minnesota Health Care Program Beneficiaries'; https://www.health.state.mn.us/diseases/asthma/data/documents/asthmamhcpreport.pdf

[94] The household benefit portion of the total estimated savings was calculated by applying the estimate that 24% of the low-income population in Minnesota have commercial (private) insurance or are uninsured (11%) and by then applying the estimate that of those meeting this criteria, 12.5% of medical costs are spent OOP. The estimated 8% OOP for those individuals covered by public insurances (e.g., Medicaid, Medicare) in MN accounting for 64% of the WAP-eligible population was also input for a total of $73.54 per household served benefit.

[95] OOP estimates for fully, commercially insured individuals in MN were retrieved from a report from the MN Department of Health to the MN Legislature (2019) for 2015-2016 health care spending: https://www.health.state.mn.us/data/economics/docs/costs/healthspending2019.pdf

[96] (Medical Expenditure Panel Survey 2014)

[97] https://meps.ahrq.gov/data_files/publications/st500/stat500.shtml

Table 3.6. Inputs and Sources for Asthma NEI Monetization

	Inputs/Sources
Occupant Survey	• Reported decreased rate of seeking medical care, by type of medical care sought: ○ Number of overnight hospital stays ○ Number of ED visits
Literature: Peer-Reviewed and State-level Resources	• 'Asthma Among Minnesota Health Care Program Beneficiaries' (2018) [98] ○ Average costs for specific health care encounters • MN Department of Health. Minnesota Health Care Spending: 2015 and 2016 Estimates and Ten-Year Projections: Report to the Minnesota Legislature February 2019.[99] ○ % OOPS for people with private insurance: 12.5%
Open-source Databases	• Bureau of Labor Statistics ○ Consumer Price Index to price-adjust medical costs for Minnesota 2019[100] • MN Department of Health; 2017.[101] ○ % Minnesota residents with public insurance: 64.8% ○ % Minnesota residents with private insurance: 23.9% ○ % Minnesota residents uninsured: 11.3% • Medical Expenditure Panel Survey: 2014.[102] ○ % OOPS for people with public insurance: 8%

The average cost for asthma-related hospitalization per individual was $2,908 resulting in an estimated savings of $40 per weatherized household. The average cost for an asthma-related ED visit per individual was $3,586 resulting in an estimated savings of $195 per household. After inflation, the average cost of all "other" medical costs was estimated to be $3,473 for 2019 resulting in an estimated cost savings of $148 per household. Table 3.7 presents the monetization approach in detail.

[98] (Minnesota Department of Health 2018)
[99] (Minnesota Department of Health 2019)
[100] (U.S. Bureau of Labor Statistics, "Consumer Price Index…")
[101] https://mnha.web.health.state.mn.us/PublicQuery.action
[102] https://meps.ahrq.gov/data_files/publications/st500/stat500.shtml

Table 3.7. Monetization Approach – Asthma

Monetization Approach
Key Variables
• Type of treatment/cost category: ○ *a = Value attributable to any Reductions in Hospitalizations Due to Asthma* ○ *b = Value attributable to any Reductions in ED visits Due to Asthma* ○ *c = Value of other direct medical costs excluding Hospitalizations and ED costs*
Equation 1. Reductions in Hospitalizations Due to Asthma
*a = ((Difference in number of hospitalizations for asthma-related symptoms between pre and post-weatherization groups) * (average cost of hospitalizations for asthma in MN))* • *a* = $40.00
Equation 2. Reductions in ED visits Due to Asthma
*b = (Difference in number of ED visits for asthma-related symptoms between pre and post-weatherization groups) * (average cost of ED visits for asthma in MN))* • *b* = $195.00
Equation 3. Reductions in Other Direct Medical Costs
*c = ((Difference in number of individuals classified as high-cost patients) * (average direct medical costs for high-cost asthma patients after deducting hospitalization and ED costs))* • *c* = $148.00
Equation 4. Asthma NEI Value (Household and Societal)
• *Total Annual Asthma Household NEI Value = household benefit for hospitalizations and ED visits (a+b) + household benefit (c) for all other direct medical costs* • *Total Annual Asthma Household NEI Value* = $45.12 + $28.42 = $73.54 • *Total Annual Asthma Societal NEI Value* = $383.00 – $73.54 = $309.46

3.2. Estimated Values

Table 3.8 presents the estimates of this NEI for the Xcel Energy LI EE NEI Study. This table includes the combined annual impacts per weatherized unit and PV of the impacts per unit, assuming a ten-year life span of the weatherization measures, for reductions in ED visits, hospitalizations, and other direct healthcare costs.

Table 3.8. Estimated Impacts of Reduced Asthma-related Costs

	Annual Per Unit Benefit	PV Per Unit Benefit
Households	$73.54	$717.87
Society	$309.46	$3,021.05
Total	**$383.00**	**$3,738.92**

The following conservative considerations and approaches were taken in devising the valuation of the asthma NEI for this study:

- The survey question asked if the head of household had asthma and did not ask if any other adult or child in the household had asthma. Asthma prevalence was estimated based on the head of household response only, which may be an underestimate of the percent of adults and children with asthma in WAP eligible homes. If the percentage is indeed higher, then additional savings would accrue.

- State-level current asthma prevalence for the general population in Minnesota was higher in 2018 than the national rate (8.3% compared to 7.7%[103]) and therefore may have a higher percentage of household members reporting asthma than the estimate used for this analysis: 16.8% across WAP homes nationally.
- The survey question asked those who reported current asthma if they have ever been to the ED or been hospitalized for asthma in the past 12 months, but did not ask the number of times. The cost savings estimate was calculated using only one urgent care event and readmittance rate for each affirmative response.
- According to national healthcare utilization sources used for monetizing this benefit, nearly 1/3 of those who visit the ED for asthma are readmitted within six months, with re-admittance to the hospital for adults (27.3%) and children (22.9%) also occurring. Frequency rates were only applied by calculating a savings benefit based on *one* re-admittance event despite the possibility that these events may have occurred multiple times.
- The total benefit related to indirect costs (12%) was extracted from the cost savings attributed to better asthma control post-weatherization. This decision was made to eliminate the chance for "double-counting" of duplicate benefits accounted for elsewhere in the analysis (e.g., fewer missed days of work).
- The Black/African American population accounts for 19% of the WAP population served nationally. It is possible that in Minnesota communities of color make up a larger percentage of the population served through utility weatherization. Since communities of color tend to have higher asthma prevalence, poor asthma control, and more frequent use of urgent care, the cost savings from this benefit would be higher than the proposed estimates if higher rates are observed.

[103] Sources: 2018 Behavioral Risk Factor Surveillance System (BRFSS) https://www.cdc.gov/asthma/most_recent_data_states.htm; and: https://www.cdc.gov/asthma/most_recent_national_asthma_data.htm

4.0 Thermal Stress

Extreme indoor thermal conditions caused by unsafe temperatures, excessive draftiness and humidity can cause adverse health effects and in some cases death. Heat exhaustion can occur after an individual is exposed to high temperatures for several days and has become dehydrated. Without proper intervention, heat exhaustion can progress to heat stroke, which can damage the brain and other vital organs, and even cause death.[104] Heat stroke is an extreme medical emergency requiring aggressive cooling measures and hospitalization for support.[105] The risk of heat-related illness dramatically increases when the heat stress index (relative humidity and air temperature combined) climbs to 90 degrees or more.

In contrast, exposure to extreme cold temperatures can eventually lead to heart and respiratory system failure and can also cause death. The more extreme cases can result in hypothermia in which the body's internal temperature falls too low. Even prolonged exposure to mild cold can cause hypothermia in older and more vulnerable populations.[106]

Some individuals are more at risk for heat and cold-related illnesses, such as: elderly persons, pregnant women and toddlers/infants; individuals with chronic medical conditions, mental disorders or mobility impairments; and any individual with inadequate food, clothing, or heating/cooling systems. WAP specifically targets this high risk population.

According to the State of Minnesota's Energy Sector Risk Profile, from 1996-2014, "the second-most common natural hazard in Minnesota is 'Winter Storm & Extreme Cold', which occurs once every 9 days on the average during the months of October to March."[107] Weatherization can decrease dangerously cold indoor temperatures by providing adequate heating and addressing excessive drafts in the home; alternatively, weatherization can address ventilation in the home to minimize heat-related illnesses.[108]

Additional risk factors for heat-related mortality include social isolation, low socioeconomic status, limited educational attainment, poor housing, lack of access to air conditioning, and less availability of health care services.[109,110] Several of these risk factors are present within the WAP population. Future drivers of heat-related mortality should also be recognized: an increase in housing density; more crowding from increased numbers of occupants within homes; increased population in warmer, inland

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[104] (National Institute of Health 2018)
[105] (CDC 2019)
[106] (Harvard Health Publishing 2014)
[107] (U.S. Department of Energy n.d.)
[108] In an appropriate climate region, such as the hot-humid, and when allowable under WAP regulations, WAP provides adequate cooling systems.
[109] (Huang 2011)
[110] (Tonn et al. 2014)

areas; an increase in energy prices; the urban heat island effect; and an aging population.[111,112,113]

Climate change is forecasted to increase the frequency and duration of extreme weather events. Death rates are projected to increase nonlinearly in the coming decades. One impact of this decades-long shift is record high temperatures in many places ranging from either hot or cold extremes.[114] From 1951 to 2012, the Twin Cities saw a 3.2° F increase in its annual average temperatures. Compared to the national and global rates, the Twin Cities metro area's temperature rate increase is faster–models project that the average annual temperature will rise between 3° and 5° F through 2050.[115]

4.1. Inputs and Monetization Approach

Findings from the Occupant Survey specific to respondents residing in the Cold (C) + Very Cold (VC) climate zones of the U.S. (see Figure 2.1 in Section 2.0) were used to estimate the thermal stress NEI for the Xcel Energy LI EE NEI study. The baseline and follow up national WAP Occupant Survey posed the following two questions to each respondent:

Table 4.1. Occupant Survey Results – Thermal Stress

Occupant Survey Question	(+/-)
In the past 12 months, has anyone in the household needed medical attention because your home was too cold?	-0.89%
In the past 12 months, has anyone in the household needed medical attention because your home was too hot?	-1.23%

Survey results revealed that the number of times occupants sought medical attention due to exposure to extreme temperatures inside their home was reduced post-weatherization. Taking an average of differences (discussed in Section 2.6, Equation 1) yielded a decreased rate of seeking medical attention for cold- and heat-related illnesses of 0.89% and 1.23%, respectively (see Tables 4.4 and 4.5). The monetized value of these benefits is presented in Section 4.2, Tables 4.6 and 4.7.

Equation 1. *Change = [(Pre-treatment – Post-treatment) + (Pre-treatment – Comparison group one year post- weatherization)] / 2*

The Occupant Survey did not provide a follow on question in order for the respondent to specify which care setting (i.e., hospitalization, ED visit, physician office visit) was needed. Nor were questions asked regarding the death of a household member that may have occurred within the past 12 months due to thermal stress. Therefore, in order to accurately estimate total cost savings associated with the reduction of medical

[111] (Phillips 2014)
[112] (Phillips 2019)
[113] (Tonn et al. 2014)
[114] (Gibbens 2019)
[115] (Minnesota Pollution Control Agency, "Effects of…")

encounters and avoided deaths due to thermal stress, the following steps were taken:[116,117]

- Secondary data sources were mined to establish the incidence rate, for the general U.S. population, of care settings utilized to treat these conditions.[118]
- A ratio based on care setting utilization, from weighted averages over a 5 year period, was applied to the percent reduction in seeking medical treatment (Occupant Survey), for both cold and heat-related thermal stress.
- Average cost for each type of medical treatment was mined from the same secondary data source, and multiplied by the ratio of care setting utilization.
- The percentage of deaths while hospitalized for both cold and heat-related thermal stress, for general U.S. population, was mined from a secondary data source.[119]
- Variables for "payer" (i.e., Medicare, Medicaid, Private/Other Insurance, Uninsured) were identified and isolated in order to group average yearly costs by payer. Average yearly out-of-pocket (OOP) costs were extracted from these costs.

The costs for treatment for cold and heat-related illnesses associated with thermal stress were retrieved from online databases provided by the Department of Health and Human Services (DHHS), sponsored by the Agency for Healthcare Research and Quality (AHRQ). The databases included the 2015 Medical Expenditure Panel Survey (MEPS)[120] as well as the Healthcare Cost and Utilization Project (HCUP).[121,122,123]

Data related to incidence rates of treatment by care setting and number of deaths following hospitalizations were mined from both MEPS and HCUP using International Classification of Diseases diagnostic codes.[124] Several medical conditions are associated with exposure to extreme temperatures, with hypo- and hyperthermia being the most extreme but least prevalent.[125,126]

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[116] (Hawkins et al. 2014)
[117] (Tonn et al. 2014)
[118] It was assumed that the same national incidence rate for type of treatment could be applied to the WAP population. We believe this assumption results in a conservative estimate as the WAP demographic consists of individuals that are more at risk for cold- and heat-related medical conditions. Therefore, one could argue the potential exists for the WAP population to require the higher-cost treatment (i.e., hospitalizations) (Hawkins et al. 2014; Tonn et al. 2014).
[119] Again, it was assumed, conservatively, that the same national rate of deaths following hospitalizations could be applied to the WAP population. We believe this is a conservative assumption as the WAP demographic consists of individuals that are more at risk for cold- and heat-related medical conditions.
[120] These databases are derived from administrative data and contain encounter-level, clinical and nonclinical information including all-listed diagnoses and procedures, discharge status, patient demographics, and charges for all patients, regardless of payer (e.g., Medicare, Medicaid, private insurance, uninsured). HCUP is the largest collection of nationwide and state-specific longitudinal hospital care data in the United States and can be accessed at: http://www.ahrq.gov/research/index.html.
[121] (Hawkins et al. 2014)
[122] (Tonn et al. 2014)
[123] Data generated from MEPS can be found on the following website: http://meps.ahrq.gov/mepsweb/
[124] Effects of reduced temperature" (ICD-9-CM 991.0-991.9) and "Effects of heat and light" (ICD-9-CM 992.0-992.9)
[125] (Hawkins et al. 2014)
[126] (Tonn et al. 2014)

The inputs discussed above allowed for the annual cost savings of weatherization for the thermal stress NEI to be estimated. This total cost savings was further broken down into either a societal benefit or a household benefit. For individuals/occupants covered by public health insurance (e.g. Medicare and Medicaid) or private/commercial insurance, the portion of the avoided medical costs payable by the insurer is categorized as a societal benefit and the remaining out-of-pocket (OOP) costs are categorized as a household benefit. For individuals/occupants that are "uninsured," the OOP costs (100% of total medical costs) are categorized as a household benefit.[127]

The NEI for reducing medical encounters due to both cold and hot temperature exposure was monetized using the inputs and equations presented in Table 4.2 and Table 4.3, respectively.

[127] It is worth noting that in some circumstances an uninsured individual may not pay the full or even a partial amount of the OOP costs of medical treatment. In these cases, costs are generally covered by the medical institution, government, or philanthropic donations. Identifying an average percent of OOP across all institutions and care settings for Minnesota to apportion a percent of these costs to society was not achieved through this study and is a key limitation to this calculation. For future studies, this limitation will be addressed.

Table 4.2. Inputs and Sources for Thermal Stress NEI Monetization

Inputs/Sources	
Resident Survey	• Reported change in rate of seeking medical care (2008): ○ Cold exposure, 0.89%; heat exposure, 1.23%
Literature: Peer-Reviewed and Other	• Minnesota Department of Transportation (DOT) (2016). Guidance on Treatment of the Economic VSL in U.S. DOT Analysis. ○ VSL of $9.6M [128,129]

Open-source Databases	• Bureau of Labor Statistics
	  ○ Consumer Price Index to price-adjust medical costs for Minnesota 2019[130]
	• Medical Expenditure Panel Survey (MEPS) - 2014
	  ○ Rate, for the general U.S. population, of types of medical treatment used to treat temperature related conditions
	  ○ Percent of medical cost that is OOP for Private/Other ONLY, per care setting, for both hot and cold
	    ▪ Hospital: 3.3%
	    ▪ ED: 8.9%
	    ▪ Office Visit (OV): 10.3%
	  ○ % of medical costs paid for by medical coverage type, per care setting for treatment of thermal stress - hot
	    ▪ Medicare: Hosp (66%); ED (25%); OV (21%)
	    ▪ Medicaid: Hosp (10%); ED (17%); OV (12%)
	    ▪ Private/Other: Hosp (18%); ED (26%); OV (56%)
	    ▪ Uninsured: Hosp (6%); ED (33%); OV (11%)
	  ○ % of medical costs paid for by medical coverage type, per care setting for treatment of thermal stress - cold
	    ▪ Medicare: Hosp (60%); ED (22%); OV (21%)
	    ▪ Medicaid: Hosp (23%); ED (20%); OV (12%)
	    ▪ Private/Other: Hosp (10%); ED (22%); OV (56%)
	    ▪ Uninsured: Hosp (7%); ED (37%); OV (11%)
	  ○ Average costs for medical treatment (Table 4.7 and 4.8)
	  ○ Percent of hospitalizations from thermal stress resulting in death (national rate, 2014): Hot (1.28%); Cold (2.51%)[131,132]

[128] In an effort to use a state level (rather than federal) VSL, we conducted a thorough scan of Minnesota government agencies' use of VSLs for cost-benefit analysis. For this study, the VSL of $9.6M was used which is the VSL recommended by the U.S. Department of Transportation (DOT) in 2016, which MN DOT adopted. For more information, see https://safety.fhwa.dot.gov/hsip/docs/fhwasa17071.pdf

[129] It should be noted that adjustments to inputs and refinements to the national WAP evaluation methods, related to estimating the benefits of avoided deaths from thermal stress, were made for this study: the VSL was increased from $7.5 M to $9.6M and value of avoided deaths were applied as a household benefit rather than a societal benefit.

[130] (U.S. Bureau of Labor Statistics, "Consumer Price Index…")

[131] This data was unavailable at Minnesota state level–sample sizes were too low to be reported. Assumptions were made that the same national rate of hospitalizations resulting in death could be applied to the Minnesota region.

[132] Due to insufficient data, all data related to deaths were from 2015. All national and state-level data related to hospitalizations and deaths following hospitalizations were mined from HCUP.

Table 4.3. Monetization Approach – Thermal Stress

Monetization Approach
Key Variables

• Care setting:
  ○ a = Hospital
  ○ b = ED
  ○ c = Physician office visit
• ΔM (a, b, c) = Change in rate of medical encounters (pre/post), by care setting (%)
• Medical coverage type (i.e. payer):
  ○ p_1 = Medicare
  ○ p_2 = Medicaid
  ○ p_3 = Private/Other
  ○ p_4 = Uninsured (i.e., OOP)
• C$ = Ave. cost for treatment, by care setting, by payer (p_1, p_2, p_3, p_4)
• D = Rate of reduction in thermal stress deaths

Equation 1. Change in number of healthcare encounters by care setting (pre/post)
• ΔM (a, b, c) = [(reported change in rate of seeking medical care) * (% of type of care setting utilized for cold and heat-related thermal stress (for a, b, and c)]
Equation 2. Household NEI (without avoided deaths), for each care setting (a, b, c)
• Household NEI (a, b, c) = (ΔM (a, b, c) * % of costs paid by p_3 * C$ paid by p_3 * % of OOP costs) + (% of costs paid by p_4 * C$ paid by p_4)
Equation 3. Rate of reduction in thermal stress deaths (R)
• R = % of hospitalizations resulting in deaths (U.S. population) * ΔM_a (hospitalizations)
Equation 4. Avoided death NEI
• Avoided death NEI = R * Value of Statistical Life (VSL)[133]
Equation 5. Societal NEI
• Societal NEI = [ΔM (a, b, c) * (((1 - % of OOP costs) * % of costs paid by p_3 * C$ paid by p_3) + (% of costs paid by p_1 * C$ paid by p_1) + (% of costs paid by p_2 * C$ paid by p_2))]
Equation 6. Total Household NEI (avoided deaths included)
• Total Household NEI = Household NEI (a + b + c) + Avoided death NEI

The following inputs and methodology used for the WAP evaluation were adjusted to produce an estimate of the thermal stress NEI for this study.

- Reported change in rate of seeking medical care for thermal stress is based on findings from C + VC climate zones only: 0.89% (cold); 1.23% (hot) (see Table 4.4 and 4.5).
- Average medical costs from 2008 (used in WAP evaluation) were adjusted to reflect 2008 medical costs for the state of Minnesota[134] then Minnesota 2008

[133] Value of human life, or as economists refer to it, the Value of Statistical Life (VSL), is a measure used to compare regulatory costs to benefits.
[134] More specifically, the Minneapolis-St. Paul-Bloomington metropolitan statistical area (MSA).

costs were price-inflated to reflect Minnesota 2019 medical costs (see Tables 4.7 and 4.8).[135]

- Percent of medical costs paid, by payer, for each care setting (a, b, and c)[136] was adjusted for the low-income population in Minnesota in 2019.[137]

Table 4.4. Need for Medical Care Due to Cold-Related Thermal Stress

	Pre-Wx Treatment	Post-Wx Treatment	Post-Wx Comparison	Change (+/-)
National	3.2%	1.5%	2.1%	-1.4%
C + VC Climate	**2.8% (n=494)**	**2.0% (n=295)**	**1.9% (n=540)**	**-0.89%**

*** p <.001, ** p<.01, *p < .05

Table 4.5. Need for Medical Care Due to Heat-Related Thermal Stress

	Pre-Wx Treatment	Post-Wx Treatment	Post-Wx Comparison	Change (+/-)
National	2.4%	1.5%	1.1%	-1.1%
C + VC Climate	**2.6% (n=494)**	**1.7% (n=295)**	**1.1% (n=540)**	**-1.23%**

*** p <.001, ** p<.01, *p < .05

Although a reduction in healthcare encounters due to indoor heat and cold exposure was observed post-weatherization, it was not statistically significant for either group. Both the Exact McNemar's test and Pearson Chi-Square test of independence determined that there was no statistically significant association in the proportion of respondents experiencing thermal stress (hot or cold) pre- and post-weatherization. We believe this to be a result of sample size and seeking medical care for these conditions being rare events. Healthcare encounters and mortalities for thermal stress are difficult to capture. Results from tests of statistical significance are presented in Table 4.6.

[135] These adjustments were based using medical care price indices provided by the U.S. Bureau of Labor Statistics, https://www.bls.gov/regions/midwest/data/consumerpriceindexhistorical_minneapolis_table.pdf
[136] This cost and payer data was exported from MEPS and specific to ICD-9 primary diagnostic codes, "Effects of reduced temperature" (ICD-9-CM 991.0-991.9) and "Effects of heat and light" (ICD-9-CM 992.0-992.9). http://meps.ahrq.gov/mepsweb/
[137] (Minnesota Department of Health 2017)

Table 4.6. Tests of Statistical Significance –Thermal Stress

C + VC Climate	Change (+/-)	Change (+/-)	Total Change (+/-)
	Pre-Wx (n=494) to Post-Wx Treatment (n=295)	Pre-Wx (n=494) to Post-Wx Comparison (n=540)	
Medical Attention – COLD Stress	**-0.80%**	**-0.98%**	**-0.89%**
***p*[1] =** Exact Sig. (2-tailed) [a] Asympt. Sig (2-sided) [b]	.774[a]	.295[b]	-
Medical Attention – Heat Stress	**-0.94%**	**-1.52%**	**-1.23%**
***p*[1] =** Exact Sig. (2-tailed) [a] Asympt. Sig (2-sided) [b]	.727[a]	.069[b]	-

[1] Statistically significant if $p < .05$; [a] McNemar Test; [b] Pearson Chi-Square

Table 4.7. Adjusted Medical Costs for Treatment of Cold-Related Thermal Stress

Average Costs: Cold-Related Thermal Stress		
Care Setting	**National 2008**	**Minnesota 2019**
Hospital Visit	$9,455	$11,247
Household Cost	$776	$677
Societal Cost	$8,679	$10,571
ED Visit	$552	$659
Household Cost	$120	$144
Societal Cost	$432	$516
Physician Visit	$136	$163
Household Cost	$22	$27
Societal Cost	$114	$136

Table 4.8. Adjusted Medical Costs for Treatment of Heat-Related Thermal Stress

Average Costs: Heat-Related Thermal Stress		
Care Setting	**National 2008**	**Minnesota 2019**
Hospital Visit	$5,802	$6,812
Household Cost	$451	$374
Societal Cost	$5,351	$6,438
ED Visit	$624	$745
Household Cost	$139	$167
Societal Cost	$485	$579
Physician Visit	$136	$163
Household Cost	$22	$27
Societal Cost	$114	$136

Table 4.9. Inputs for Estimating Avoided Deaths – Thermal Stress

	Cold-related	**Heat-related**
Rate of decreased medical care from thermal stress due to weatherization (based on occupant survey results for C + VC climate zones)	**0.89%**	**1.23%**
% of hospitalizations resulting in deaths from thermal stress (national rate, 2019)	2.51%	1.28%
Reduction in thermal stress deaths per 1,000 weatherized units (based on occupant survey results for C + VC climate zones)	0.022	0.006
VSL	$9.6M	$9.6M
Household avoided death NEB$, per weatherized unit, per year	**$215.06**	**$60.61**

4.2. Estimated Values

Tables 4.10 and 4.11 present annual and PV estimates of the thermal stress NEIs specifically for Xcel Energy's low-income weatherization program in the state of Minnesota. A conservative ten-year period is assumed for persistence of measures. Our analysis determined that, for cold-related medical conditions, 0.02 deaths, 0.9 hospitalizations, 3.6 ED visits, and 4.5 physician office visits are prevented annually per 1000 units weatherized. Because of Minnesota's cold and very cold climate, it is not surprising that the impacts of weatherization on hospitalizations and deaths due to cold temperatures are of a slightly higher magnitude than from exposure to hot temperatures. For heat-related medical conditions, 10.4 ED visits, 0.006 deaths, 0.5 hospitalizations, and 1.4 physician office visits are prevented per 1,000 units weatherized.

If a household responded yes to seeking medical treatment for thermal stress, it was conservatively assumed that only one person per household was affected (due to limitations of the survey tool). The WAP demographic consists of individuals that are more at risk for cold- and heat-related medical conditions; therefore, estimates derived from secondary data that include the general population are similarly conservative.

Table 4.10. Estimated Impact of Reduced Medical Treatment and Avoided Deaths Due to Exposure to Extreme Cold Temperatures

	Annual Per Unit Benefit	**Annual Per Unit Benefit W/O Avoided Death Benefit**	**PV Per Unit Benefit**	**PV per Unit Benefit W/O Avoided Death Benefit**
Households	$216.70	$1.64	$1,846.62	$13.96
Society	$11.82	$11.82	$100.74	$100.74
Total	**$228.52**	**$13.46**	**$1,947.36**	**$114.70**

Table 4.11. Estimated Impact of Reduced Medical Treatment and Avoided Deaths Due to Exposure to Extreme Hot Temperatures

	Annual Per Unit Benefit	Annual Per Unit Benefit W/O Avoided Death Benefit	PV Per Unit Benefit	PV per Unit Benefit W/O Avoided Death Benefit
Households	$63.33	$2.72	$539.68	$23.22
Society	$8.88	$8.88	$75.70	$75.70
Total	**$72.21**	**$11.60**	**$615.38**	**$98.92**

5.0 Fewer Missed Days of Work

Results from the WAP occupant survey indicated that, overall, occupants are healthier post-weatherization. Homes are safer, cleaner, and more comfortable. Reports of "bad" days of physical and / or mental health decreased by 3.3 and 1.5 days, respectively (Table 5.1).

Table 5.1. Occupant Survey Questions – Fewer Missed Days of Work

Occupant Survey Questions	Change (+/-)
Number of "bad" days of physical health in the last 30 days? (mean)	-3.3
Number of "bad" days of mental health in the last 30 days? (mean)	-1.5

Employed respondents[138] were asked how many days in the previous year they had missed work due to illness or injury of themselves and other household members both pre- and post-weatherization. Answers from this set of survey questions were used to estimate the Fewer Missed Days of Work NEI for Xcel Energy's low-income weatherization program (see Table 5.2). Results from the former set of questions are used to further substantiate the intersection between housing quality and health, which one could hypothesize would impact the number of missed days of work.

5.1. Inputs and Monetization Approach

The change in missed days of work attributable to weatherization (Table 5.2) was calculated using Equation 1 discussed in Section 2.6. Taking an average of differences yielded a decrease in missed days of work due to illness/injury of self by 0.4 days and by 1.4 days due to taking care of a household member that was ill or injured (Table 5.2), for a collective total of 1.8 fewer missed days of work (Table 5.2). The monetized value of these benefits is presented in Section 5.2, Table 5.6.

Table 5.2. Occupant Survey Questions – Fewer Missed Days of Work

Occupant Survey Question	Change (+/-)
How many days in the previous year have you missed work due to illness or injury? (mean)	-.41
How many days in the previous year have you missed work due to illness or injury of other household members? (mean)	-1.4

A one-way between groups analysis of variance (ANOVA) test was conducted to compare the effect of weatherization on the combined number of missed days of work due to illness and injury of self or others. It was determined that there was a statistically significant association at the $p<.05$ level between the pre-weatherization Treatment and Comparison groups, but no statistically significant association between the pre- and post-weatherization Treatment groups. Results from the tests of statistical significance are also presented in Table 5.3.

138 Percent of WAP households with an employed primary wage earner: 32%. The estimate may be under-valued because only one the head-of-household responded to this question.

Table 5.3. Tests of Statistical Significance – Total Number of Missed Days of Work

	Pre-Wx Treatment	Post-Wx Treatment	Post-Wx Comparison	Change (+/-)
National	7.7 (n=181)	6.9 (n=103)	7.3* (n=202)	-0.6
C + VC Climate Zone	**11.5 (n=119)**	**10.83 (n=61)**	**8.4* (n=155)**	**-1.8**

*** p <.001, ** p<.01, *p < .05

In addition to using the combined change in number of missed days of work, monetizing the estimated NEI included using inputs from secondary literature such as published average hourly income of low-income workers and the percent of low-income workers without sick leave, both for the state of Minnesota (Table 5.4).[139] Minnesota, in 2019, saw 66% of its low-income residents not being provided sick leave by their employer. While already financially burdened, facing a loss of any household income can be detrimental.

Table 5.4. Inputs and Sources for Missed Days of Work NEI Monetization

Inputs/Sources	

Occupant Survey	• Percent of WAP households (in C+VC climate) with an employed primary wage earner (2008):
	  ○ 32%
	• Reported change in number of missed days of work due to either illness/injury of self or other household member (2008):
	  ○ Total missed days of work: 1.8
	    ○ Self: 0.41 days
	    ○ Other: 1.4 days
	• Number of work hours per week (mean) (2008):
	  ○ 37.5 hours per week

Open-source Databases	• Institute for Women's Policy Research (2016) [140]
	  ○ Percent of low-income workers in Minnesota without sick leave: 66%
	• Bureau of Labor Statistics[141]
	  ○ Average hourly wage in Minnesota (10th percentile wage rate, across All Occupations - 2019): $11.41
	• Bureau of Labor Statistics[142]
	  ○ Consumer Price Index to price-adjust medical costs for Minnesota (2019)

The household benefit equation includes the percent of low-income workers in Minnesota without sick leave while the societal benefit is calculated by using the percent

[139] In Minnesota, in 2019, the average hourly 10th percentile wage rate, across All Occupations, was $11.41 and the 25 percentile wage is $14.48 per hour. We conservatively chose to use the lower wage rate. See: https://www.bls.gov/oes/current/oes_mn.htm#29-0000

[140] Low-income households are defined here at those with a household annual income of less than $15,000. https://iwpr.org/wp-content/uploads/wpallimport/files/iwpr-export/publications/B344-Minnesota%20Access%20Rates--.pdf

[141] In Minnesota, in 2019, the average hourly 10th percentile wage rate, across All Occupations, was $11.41 and the 25 percentile wage is $14.48 per hour. We conservatively chose to use the lower wage rate. https://www.bls.gov/oes/current/oes_mn.htm

[142] (U.S. Bureau of Labor Statistics, "Consumer Price Index…")

of low-income workers who do have sick leave. The complete equations are in Table 5.5.

Table 5.5. Monetization Approach – Missed Days of Work

Monetization Approach
Equation 1. Household NEI
Household NEI = ((% of WAP C+VC households with an employed primary wage earner) * (reduction in missed days work-due to self + reduction in missed days work-due to other) * (ave. hourly wage) * (7.5 hours/day)) * % low-income workers without sick leave in MN
Equation 2. Societal NEI
Societal NEI = [(% low-income workers WITH sick leave in MN) * ((% of WAP C+VC households with an employed primary wage earner) * (reduction in missed days of work-due to self + reduction in missed days of work-due to other) * (ave. hourly wage) * (7.5 hours/day))]

5.2. Estimated Values

Table 5.6 below presents the estimates of this impact for the Xcel Energy LI EE NEI Study. The table includes the annual per weatherized unit and the PV of the benefit per unit, assuming a ten-year life impact of weatherization on this benefit. The results in Table 5.6 can be considered conservative because only one worker per household was included in the benefit calculation.

Table 5.6. Estimated Impact of Fewer Missed Days of Work

	Annual Per Unit Benefit	**PV Per Unit Benefit**
Households	$33.41	$284.71
Society	$11.64	$99.22
Total	**$45.05**	**$383.93**

6.0 Reduced Use of Predatory Loans

Weatherization has the potential to decrease household financial stressors enough that some households that used 'predatory' loans (i.e., high-interest, short-term loans) prior to weatherization could stop using these loans post-weatherization. Energy and water cost savings, and other positive synergistic impacts on households' budgets[143] results in households being less frequently short on finances when utility and other bills are due. Results from the national occupant survey indicate that, overall, use of predatory loans decreased post-weatherization.

Once a household takes out a predatory loan, a vicious cycle can develop as unaffordable interest fees build up and require further loans to pay them off. For example, more than 2 million people in the US, approximately 1 percent of American adults, use high-interest automobile title loans annually, borrowing against their cars. Nationally, the most common APR charged on the typical one-month title loan is 300 percent, or 25 percent for each month that the loan is outstanding. The average lump-sum title loan payment consumes 50 percent of an average borrower's gross monthly income, far more than most borrowers can afford. By comparison, a typical payday loan payment takes 36 percent of the borrower's paycheck. [144]

The average pawn loan is much smaller than the average loan received from a payday lender. Pawn loans usually have a term of one month and an average fee of $20 for each $100 borrowed, which translates to an APR of about 250 percent (Avery and Samolyk 2011; Drysdale and Keest 2000). It was not reported on the survey, and therefore directly observed, how much households saved in fees and interest charges.

Savings from reduced energy costs can be put towards other household expenses, preventing the need for a payday loan to pay for recurring household expense (e.g., rent). Any dollars saved from avoided interest charges as well as the loan amount that becomes a new and additional debt represents an actual benefit to the household. Thus this positive monetary impact is not double counting saved energy costs spent on household expenditures (Tonn et al. 2014).

6.1. Inputs and Monetization Approach

Results from the national Occupant Survey indicate that post-weatherization, households experience fewer service disconnections, re-connection fees, and having to pay partial amounts owed on their utility bill. Survey respondents were also asked a question specific to dependence on predatory loans in order to cover monthly energy bills. Table 6.1 presents the percent change from pre- to post-weatherization per type of loan:

[143] E.g., fewer missed days at work; and less utility arrearages, disconnect and re-connection fees
[144] (Bourke et al. 2015)

Table 6.1. Percent Change (from pre- to post-) of Respondents Using Predatory Loans – by Loan Type

Survey Question	(+/-)
In the past year, have you used any of the following to assist with paying your energy bill?	
Payday loan	-1.6%
Tax Refund Anticipation Loan	-4.5%
Car Title Loan	-0.9%
Pawn shop	-4.3%
Other type of short term, high-interest loan	-1.0%

** Difference is statistically significant at the p<.01 level.

Households reported a small decrease in not having to resort to using predatory loans to make ends meet, with the largest drop seen in tax refund anticipation loans. Having more room in the household budget to pay any type of expense seems to have led respondents to make less use of these predatory loans; thereby, reducing the expense of exorbitant loan fees.[145,146,147]

Change in usage of loans was calculated using Equation 1 (presented in Section 2.6) and yielded an estimated percent difference of -6.9% (see last column of Table 6.2). Both the Exact McNemar's test and Pearson Chi-Square test of independence indicated a statistically significant association in frequency of loan use attributable to weatherization in the C+VC climate zones of the U.S. (Table 6.2).

Table 6.2. Tests of Statistical Significance – Used at Least One Predatory Loan in the Previous Year

	Pre-Wx Treatment	Post-Wx Treatment	Post-Wx Comparison	Change (+/-)
National	18.6% (n=660)	12.0% (n=392)	11.7%*** (n=797)	-6.75%
C + CV Climate Zones	**17.6% (n=490)**	**11.0%*** (n=290)**	**10.3%*** (n=536)**	**-6.9%**

*Statistically significant if: *** $p < .001$, ** $p < .01$ and * $p < .05$; [a.]McNemar Test; [b.]Fisher's Exact Test

The national Occupant Survey did not ask households to estimate total annual loan or interest amounts. Various references ranging in quality were used to estimate annual loan amounts and interest charges presented in Table 6.3.[148] Several important assumptions were made about the size and frequency of loans used by the responding households. Due to the level of operational uncertainty, this NEI was placed in Tier 2.

[145] (Pew Charitable Trust 2012)
[146] (Elliehausen 2009)
[147] (Karger 2004)
[148] (Wu & Fox 2011)
(Scinto 2011)
(Lusardi 2011)

Table 6.3. Estimated Average Magnitude of Annual Predatory Loan per Household

	Ave. Amount per Loan	Ave. Interest per loan (@ 25%)
Pay Day Loan	$400	$100
Tax Refund Anticipation Loan	$350	$87
Car Title Loan	$1,000	$250
Other types	$475	$118
Pawn Shop	$150	$37

For estimation purposes, it was assumed that loans were paid back in a one month time period and the loan terms for each type included a 25% monthly interest rate. It is a conservative assumption that households that do make use of one of these loan types only do so once a year. The household impact was calculated using the inputs presented in Table 6.4 and utilizing the formula presented in Table 6.5.

Table 6.4. Inputs and Sources for Predatory Loan NEI Monetization

Inputs/Sources	
Occupant Survey	• Percent reduction in households using short-term, high-interest loans: o Pay Day Loan: 1.6% o Tax Refund Anticipation Loan: 4.5% o Car Title Loan: 0.9% o Pawn Shop: 4.3% o Other types: 1.0%
Literature: Peer-Reviewed and Other	• Interest/Loan Fees (see Table 6.1) o Pew Charitable Trust[149] o National Consumer Law Center[150] o National Bureau of Economic Research[151] • Average loan amount (see Table 6.1) o https://www.nclc.org/images/pdf/high_cost_small_loans/ral/report-ral-2011.pdf o https://www.businessinsider.com/pawnshop-customers-statistics-2011-11?op=1 o https://www.nber.org/papers/w17103.pdf

The inputs used for the WAP evaluation were not revised to produce an estimate more tailored to the Minnesota context. There was insufficient data associated with typical loan amounts and interest/loans fees at a state level. However, data were updated to reflect loan and loan fee amounts in 2019.

Table 6.5. Monetization Approach – Reduced Need for Predatory Loans

Monetization Approach
Equation 1. Household NEI
*Household NEI = (average loan amount, by loan type) * (percent reduction in households using loans, by loan type) * (average monthly interest rate of 25%)*

[149] (Bourke et al. 2015)
[150] (Wu & Fox 2011)
[151] (Lusardi 2011)

6.2. Estimated Values

Table 6.6 presents the estimates of this benefit for the Xcel Energy LI EE NEI Study. This table includes the annual benefit per weatherized unit and its PV, assuming a ten-year impact of weatherization.

Table 6.6. Estimated Impact of Reduced Use of Short-Term, High Interest Loans

	Annual Per Unit Benefit	PV Per Unit Benefit
Households	$10.41	$88.73
Society	$0	$0
Total	**$10.41**	**$88.73**

7.0 Reduced Risk of Carbon Monoxide Poisoning

A combination of faulty combustion appliances and lack of a functional carbon monoxide (CO) monitor can contribute to an increased risk of CO poisoning. CO is a colorless and odorless gas emitted from burning carbon-based fuels, including many common household sources of heat and energy (e.g., natural gas, kerosene). These fuels are used in many household combustion appliances, such as furnaces, water heaters, ovens and cooking ranges. CO exposure can result in a range of symptoms from fatigue and nausea to death. Length of exposure, as well as general health and age of the victim, cause symptoms of CO poisoning to vary. While proper safety, maintenance, and monitoring can prevent nearly all Unintended, Non-Fire Related (UNFR) CO poisonings, the socio-economic status of the WAP eligible population can make such precautions unaffordable. As such, these characteristics could put the WAP population at significantly higher than average risk of UNFR CO poisoning.

Through WAP, CO monitors can be installed or replaced, if expired, in homes that use carbon-based fuels for heating. Combustion appliances are tested for CO levels during audits and again during final inspections. WAP standards state that all detected combustion safety issues be immediately addressed through appliance repairs or replacement.

As part of the Occupant Survey, respondents were asked if anyone in the household had been poisoned by CO and as a result had to seek medical attention. Equation 1 (presented in Section 2.2) yielded a decreased rate of seeking medical attention of 0.11% for treatment of CO poisoning (Table 7.1).

Table 7.1. Occupant Survey Question – Reduced Treatment for CO Poisoning

Occupant Survey Question	Change (+/-)
In the past 12 months, has anyone in the household been poisoned by breathing in carbon monoxide, and therefore went to see a medical professional?	**-0.11%**

Because of the small sample sizes relative to the incidence of CO poisonings, and because the research methodologies were not designed to capture the care setting for medical treatment or avoided deaths, these data were not used as inputs into the monetization algorithm. The methodology made heavy use of secondary data gleaned from literature to determine annual household and societal savings attributable to reduced medical treatment and avoided deaths from reduced occurrences of CO poisoning.

7.1. Inputs and Monetization

Occupant Survey respondents were asked if their homes were heated using fossil fuels and, if so, whether they had a CO monitor and whether the monitor was functional. A decision matrix was developed to how many homes used fossil fuels but did not have a functional CO monitor based on an analysis of pre-weatherization data (Table 7.2). These homes are theoretically at the highest risk of UNFR CO poisoning from their combustion appliances.

Table 7.2. Decision Matrix – Total Number of CO Monitors Needed

Pre-Weatherization Treatment – C + VC Climate Regions (n=494)					
Fossil Fuels as Heating Source?	No 11.5%				
	Yes 88.5%	**Have CO Monitor?**	No 41.0% (174)		
			Yes 59.0%	**Functional CO Monitor?**	No 7.0% (17)
					Yes 93.0%
CO Monitors Needing to be Installed or Replaced = 190					

The installation of CO monitors can contribute to fewer incidents of UNFR CO poisonings, which, in turn, reduces ED visits, hospitalizations, and fatalities. Therefore, the change in the number of homes with both combustion appliances and a working CO monitor (Table 7.3) were used to estimate the CO Poisoning NEI for this cohort study.[152] After selecting cases that use fossil fuels as main primary heat source, the Exact McNemar's test determined that there was a statistically significant association (p=.000) between weatherization and C + VC households reporting at least one CO monitor, between the Pre- and Post-Treatment groups (Table 7.3).

Table 7.3. Tests of Statistical Significance – Have CO Monitor

	Pre-Wx Treatment (n=424)	Post-Wx Treatment (n=260)	Difference (+/-)
Have CO Monitor	**59.0%**	**88.5%**	**27.7%***

*Statistically significant if p<.05

Although the Occupant Survey asked whether anyone in the home experienced CO poisoning, it did not provide a follow on question in order for the respondent to specify which care setting (i.e., hospitalization, ED visit) was needed for treatment of CO poisoning. Nor were questions asked regarding the death of a household member that may have occurred within the past 12 months due to CO poisoning. Therefore, in order to accurately estimate total cost savings associated with the reduction of medical encounters and avoided deaths due to CO poisoning it was required to rely on secondary data (Table 7.5) to achieve the necessary inputs:[153]

- An estimate of the proportion of treatment by care setting (ED and hospitalizations) and deaths due to UNFR CO poisoning.
- An estimate of the preventative performance of CO monitors.

[152] Based on primary data from the Occupant Survey indicating the number of CO monitor installed by WAP in the C + VC climate zones in 2008.
[153] (Tonn et al. 2014)

Values calculated in the bullet points above were then used to estimate the number of ED, hospitalizations, and deaths from UNFR CO poisoning potentially prevented by WAP nationally (Table 7.4).[154]

Table 7.4. Number of Avoided CO Poisonings due to Installation of CO Monitors – National (2008)[155]

Preventable? (WAP - National)	**ED Visits**	**Hospitalizations**	**Deaths**
Total	30.30	5.26	0.32
No	6.43	0.40	0.11
Yes	**23.87**	**4.85**	**0.21**
Preventable (per weatherized household)	9.9 E-05	9.9 E-05	9.9 E-05
Preventable (per household occupant)[156]	2.4 E-04	4.8 E-05	2.1 E-06

Table 7.5. Inputs and Sources for Reduced CO Poisoning

Inputs/Sources	
Occupant Survey	• Change in the number of homes with CO monitors, pre-/post- (%): 29.5% (Table 7.3) • Average household size (C + VC): 2.4 occupants

Literature: Peer-Reviewed and Other	• Tonn et al. (2014)
	  ○ Rate of reduced risk: Prevented ED and hospital visits, and prevented deaths per household occupant: ED (2.4 E-04); H (4.8 E-05); D (2.1 E-06) (Table 7.4)
	• MN Department of Health. Minnesota Health Care Spending: 2015 and 2016 Estimates and Ten-Year Projections: Report to the Minnesota Legislature February 2019.[157]
	  ○ % OOPS for people with private insurance: 12.5%

Open-source Databases	• Bureau of Labor Statistics
	  ○ Consumer Price Index to price-adjust medical costs for Minnesota 2019[158]
	• MN Department of Health; 2017[159]
	  ○ % Minnesota residents with public insurance: 64.8%
	  ○ % Minnesota residents with private insurance: 23.9%
	  ○ % Minnesota residents uninsured: 11.3%
	• Medical Expenditure Panel Survey: 2014[160]
	  ○ % OOPS for people with public insurance: 8%
	  ○ Average costs for medical treatment (Table 7.7 and 7.8)

[154] For a complete description of methodology refer to Tonn et al. 2014.
[155] (Tonn et al. 2014)
[156] Results from the Occupant Survey for the C + VC climate zones show that the average household size is 2.4 occupants; thus, CO poisoning preventions per weatherized household was multiplied by 2.4.
[157] (Minnesota Department of Health 2019)
[158] (U.S. Bureau of Labor Statistics, "Consumer Price Index…")
[159] https://mnha.web.health.state.mn.us/PublicQuery.action
[160] https://meps.ahrq.gov/data_files/publications/st500/stat500.shtml

The monetary values of avoided ED visits, hospitalizations, and deaths were calculated using medical costs for the treatment of CO poisoning. Benefits were then divided into household benefits and societal benefits by applying primary payor information from HCUP and MEPS Household Component Event Files.[161,162]

As with the asthma and thermal stress NEIs, for individuals/occupants covered by public health insurance (e.g. Medicare and Medicaid), the portion of the avoided medical costs payable by the insurer (92%) is categorized as a societal benefit and the remaining out-of-pocket (OOP) costs (8.0% as copayments or deductibles) are categorized as a household benefit. For individuals covered by private/commercial health insurance, the portion of the avoided medical costs payable by the insurer (87.5%) is categorized as a societal benefit and the remaining OOP costs (12.5% as copayments or deductibles) are categorized as a household benefit. For individuals/occupants that are "uninsured," the OOP costs (100% of total medical costs) are categorized as a household benefit.[163] Table 7.6 presents the monetization approach.

Table 7.6. Monetization Approach – Reduced Risk of CO Poisoning

Monetization Approach
Key Variables
• ED = # of prevented emergency department visits per weatherized unit • H = # of prevented hospitalizations per weatherized unit • D = # of prevented deaths per weatherized unit • C = change in the # of units with CO monitors (%) • ED$ = estimated cost of ED visit • H$ = estimated cost of hospitalization • VSL = value of avoided death • $I\%_h$ = percent of insurance costs covered by household • $I\%_s$ = percent of insurance costs covered by society
Equation 1. Annual Household Benefit
• $= ((C * ED * ED\$) + (C * H * H\$) * I\%_h) + (C * D * VSL)$
Equation 2. Annual Societal Benefit
• $= ((C * ED * ED\$) + (C * H * H\$)) * I\%_s$

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[161] Mean medical costs were based on the ICD-9-CM code 986 "Toxic effect of carbon monoxide". The hospitalization and ED costs were retrieved from an online database provided by the Department of Health and Human Services (DHHS) sponsored by the Agency for Healthcare Research and Quality (AHRQ). The data were collected through the Medical Expenditure Panel Survey (MEPS) (Tonn et al. 2014).

[162] MEPS Household Component Event Files http://meps.ahrq.gov/mepsweb/data_stats/download_data_files.jsp

[163] It is worth noting that in some circumstances an uninsured individual may not pay the full or even a partial amount of the OOP costs of medical treatment. In these cases, costs are generally covered by the medical institution, government, or philanthropic donations. Identifying an average percent of OOP across all institutions and care settings for Minnesota to apportion a percent of these costs to society was not achieved through this study and is a key limitation to this calculation. For future studies, this limitation will be addressed.

The methodology used for the national WAP evaluation was modified in several manners to produce an estimate of this benefit for the Xcel Energy LI EE NEI Study. The following bullets document the adjustments:

- The percentage of weatherized homes using fossil fuels for heating was adjusted to reflect percentages from the C + VC climates: 89%
- The average size of households being weatherized was adjusted to reflect the C + VC climate zone rates (Occupant Survey findings): 2.4[164]
- The average medical costs for ED visits and hospitalizations utilized for the WAP model were adjusted for the Minnesota context. National costs were adjusted to Minnesota costs for the year 2008, and then 2008 Minnesota costs were adjusted to 2019 costs (see Table 7.7).[165]

Table 7.7. Adjusted Medical Costs for Treatment of CO Poisoning

Coverage Type	2008 National ED Visits	2019 Minnesota ED Visits	2008 National Hospitalizations	2019 Minnesota Hospitalizations
Private Insurance	$1,337	$1,596	$5,929	$7,079
Public Insurance	$842	$1,005	$10,796	$12,891
Uninsured	$1,203	$1,436	$3,390	$4,048
Average of Costs	**$1,889**	**$2,255**	**$10,641**	**$12,705**

7.2. Estimated Values

CO detectors vary in lifespan according to the model, but they generally remain effective for an average of five years.[166,167,168] Therefore, a five-year time period was applied for this benefit rather than the ten-year time period applied to all other NEIs explored in this study for estimating PV.[169]

Table 7.8 presents the estimated NEI values of reducing the risk of CO poisoning. Given the above inputs and equations, we estimate the first-year total benefit of avoided costs associated with reduced risk of CO poisoning to be $1. Positing a five-year lifespan for the benefits, the present value would be $1.16.

Table 7.8. Estimated Impact of Reduced Risk of CO Poisoning

	Annual Per Unit Benefit (5-Year Life)	Annual Per Unit Benefit W/O Avoided Death Benefit	PV Per Unit Benefit (5 Years)	PV per Unit Benefit W/O Avoided Death Benefit
Households	$0.85	$0.04	$3.88	$0.17
Society	$0.22	$0.22	$1.00	$1.00
Total	**$1.07**	**$0.25**	**$4.87**	**$1.16**

[164] In contrast to the other NEIs estimated in this report, we were not limited by survey results to only focus on the respondent; therefore, we are assuming multiple occupants could be at risk in a single household.
[165] (U.S. Bureau of Labor Statistics, "Consumer Price Index…")
[166] (Rickert 2012)
[167] (North Shore Fire Department 2011)
[168] (BRK Brands, Inc. 2019)
[169] (Tonn et al. 2014)

8.0 Reduced Risk of Fire, and Fire-Related Property Damage

Housing quality and characteristics can influence the risk of unintentional residential structure fires. Persons who are elderly, persons of disability, or households that are of low socio-economic status have been linked with increased fire frequency, rate of injury, and fire intensity.[170,171,172] These characteristics are more common among the population served by low-income weatherization. As such, these households are particularly vulnerable and are exposed to higher than average home fire risks.

Features of the home and occupant behavior often correspond to indicators of risk associated with fire ignition and / or suppression of fire. Faulty wiring is more common among older homes. The dependence on unsafe methods of secondary space heating is quite prevalent among those who cannot afford to replace or repair primary heat sources.[173] WAP addresses many such causes and contributors of fires. It is hypothesized that weatherization has the potential to reduce fire risk and fire damage through the replacement or repair of heating equipment, cleaning and repair of dryer vents, and installation / replacement of smoke alarms.

The Occupant Survey posed three questions that directly relate to home fires Findings indicate that the frequency of home fires post-weatherization is reduced and the number of smoke detectors per household increased. However, the value of the Reduced Fire Risk NEI was estimated utilizing data from secondary data sources rather than primary data collected through the occupant survey as presented in Table 8.1. Table 8.4 in Section 8.2 presents the estimated NEI value of reduced fire risk.

Table 8.1. Occupant Survey Questions – Reduced Risk of Fire

Occupant Survey Questions	Change (+/-)
In the past 12 months how many times has the fire department been called to put out a fire in your home? (# of times)	**-3**
In the past 12 months did any fire start in your home as a result of using an alternate heating source, such as space heaters, electric blankets, your kitchen stove or oven, heating stove, furnace, or your fireplace? (% yes)	**-0.6%**
Do you have one or more smoke detectors in your house? (% yes)	**4.5%**

Both the Exact McNemar's test and Pearson Chi-Square test of independence determined that there was a statistically significant association between weatherization and households reporting at least one working smoke detector (Table 2.5). The change from pre-weatherization to post-weatherization treatment was statistically significant at the $p < .001$ level ($p = .000$). The change from pre-weatherization treatment to post-weatherization comparison group was statistically significant at the $p < .01$ level ($p = .002$).

170 (Tonn et al. 2014)
171 (Shai 2006)
172 (Istre et al. 2001)
173 (Tonn et a. 2014)

8.1. Inputs and Monetization Approach

While the occupant survey questions presented in Table 8.1 address key aspects of fire, several factors restricted their ability to properly gauge fire risk among the WAP population. First, the Occupant Survey's sample size was too small to accurately describe fire frequency and consequence.[174] Though WAP households face a decidedly larger likelihood of fire than the general population, these events occur relatively infrequently with less than four out of one thousand homes catching fire annually.[175] Second, the survey tool was not designed to capture extreme fire events. Major fire damage in these households could result in an occupant's death, relocation, or deferral of WAP services, which would prevent survey participation.

The process of identifying fire risk and prevention (see Figure 8.1) among WAP-eligible households in single-family buildings is complex and multi-faceted.[176] The bullet points below summarize the methods and sources used to estimate the Reduced Fire NEI:[177]

- National fire data, a subset of the National Fire Incident Reporting System (NFIRS) database, included primary fires in in one- and four-unit residential buildings.[178,179]
- General causes of these fires were determined and cases with unknown or invalid causes were removed from further consideration.
- Relevant fire incidents were identified by the presence of weatherization-preventable contributors to fire.
- Zip code-level housing and poverty data were matched with each fire to construct sample weights to estimate fire frequency among households under 200 percent of the poverty level.
- Fires and subsequent damages were weighted to estimate national totals.
- Probabilities of fire occurring in WAP homes were estimated using fire incidents and total homes among single-family households whose income was less than 200 percent of the poverty level.
- These probabilities were applied to the single-family and mobile homes that received WAP services in 2008.

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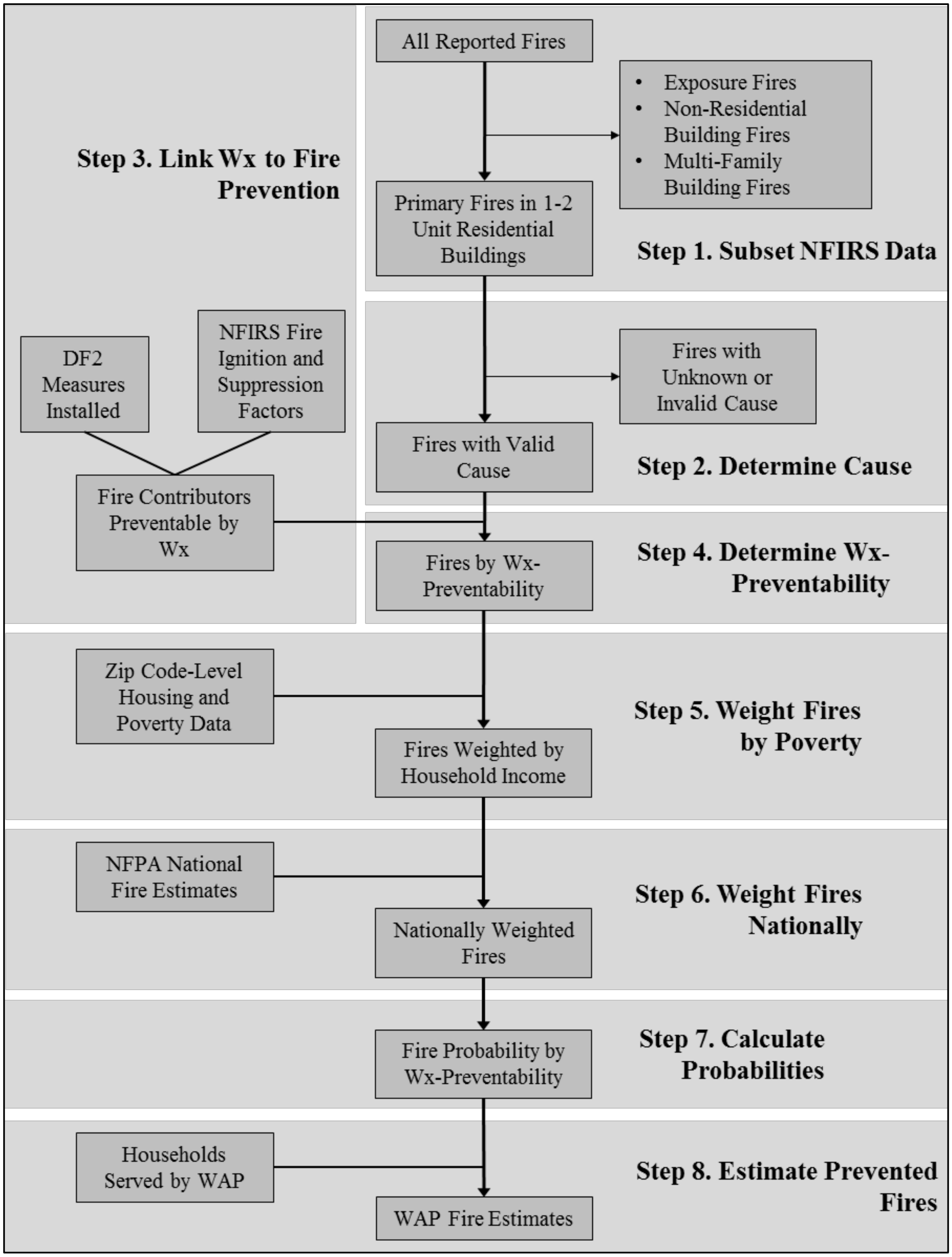
174 (Tonn et al. 2014)
175 Ibid.
176 For details on methodology and sources refer to: Tonn, B., Rose, E., Hawkins, B., and Conlon, B. 2014. Health and Household-Related Benefits Attributable to the Weatherization Assistance Program. ORNL/TM-2014/345, Oak Ridge National Laboratory, Oak Ridge, Tennessee, September.
177 (Tonn et al. 2014)
178 Fire frequency and fire damage estimates came from the,. NFIRS 5.0 compiled and standardized fire incident data voluntarily reported from approximately 23,000 fire departments in the United States (Tonn et al. 2014).
179 The values of interest came from six variables: fire service deaths, fire service injuries, other deaths, other injuries, property loss, and contents loss. "Fire service" refers to firefighters and "other" refers to civilians. Property loss and contents loss are rough dollar estimates made onsite by fire responders (Tonn et al. 2014).

Figure 8.1. Overview of WAP Fire Prevention Estimation Methodology



Xcel Energy's low-income energy efficiency program installs comparable measures as those installed by WAP as reported through the WAP evaluation in 2008. Many such measures can reduce fire risk thereby reducing property damage in homes, and cases of occupant injury and/or death. For this cohort study, the researchers were not able to collect all measures installed during 2019 through Xcel Energy's weatherization program. Therefore, a direct mapping to measures installed in the 2008 WAP program was not possible. The estimated value presented in this section captures a potential NEI if a comprehensive weatherization package was provided.

From the WAP evaluation, 17 measures or sets of measures were investigated that have been assumed to reduce fire risk and damage (see Table 8.2), and are categorized as either igniters or suppressors. Measures shown to have the most impact on fire risk reduction are: central space heating systems; electrical repair; clothes dryer vent repair/replacement; insulation; and installation/replacement of smoke detectors.[180]

Based on major measures reported to have been installed in 2019 from Xcel Energy, it appears that not all measures listed in Table 8.2 are part of its traditional program delivery, such as health and safety measures (e.g., electrical repairs and smoke detectors). Section 12.0, Table 12.2, presents the list of Xcel Energy's weatherization measures installed in 2019.

Table 8.2. Select Measures Proven to Reduce Fire Risk and Damage and Estimated Reduction in Risk [181]

Individual Measures	Benefit %
Igniters	
Electrical repair	16.55
Heating system	20.11
Cooling system	2.87
Clothes dryer vent repair/replacement	11.56
Refrigerator replacement	1.49
Water heater	4.73
Chimney repair	3.52
Fans repair/replacement	2.58
Lighting	2.84
Suppressors	
Smoke alarm installation/replacement	5.87
Windows, doors repair/replacement	2.41
Ventilation	3.68
Air sealing	2.39
Wall insulation	4.27
Roof, attic, ceiling insulation	12.20
Floor insulation	2.07
Gas	0.87

The average medical costs for ED visits and hospitalizations utilized for the WAP model were adjusted for the Minnesota context. National costs were adjusted to Minnesota costs for the year 2008, and then 2008 Minnesota costs were adjusted to 2019 costs (see Table 8.3). These adjustments used medical care price indices provided by the U.S. Bureau of Labor Statistics.[182]

180 (Tonn et al. 2014)
181 Ibid.
182 (U.S. Bureau of Labor Statistics, "Consumer Price Index…")

Table 8.3. Adjusted Medical Costs for Treatment of Fire-Related Injuries

2019	Burn Center	Other Hospital	Emergency Department	Doctor's Office/Clinic
Burns	$31,296	$16,988	$862	$299
Inhalation	$47,274	$9,922	$548	$421
Burn + Inhalation	$86,772	$27,456	$1,711	$0
Trauma	$32,016	$32,016	$1,142	$885
Other	$7,224	$7,224	$654	$401

8.2. Estimated Values

Table 8.4 below presents the estimates of this NEI specifically for recipients of low-income weatherization in Minnesota. This table includes benefits both per weatherized unit annually and the PV per unit, assuming persistence of measures for a ten-year period.

Table 8.4. Estimated Benefit for Reduced Home Fire Occurrences[183]

	Annual Per Unit Benefit	Annual Per Unit Benefit W/O Avoided Death Benefit	PV Per Unit Benefit	PV per Unit Benefit W/O Avoided Death Benefit
Households	$90.44	$6.20	$882.92	$52.37
Society[1]	$11.80	$11.52	$115.18	$97.25
Total	$102.24	$17.72	$998.10	$149.63

[1] Avoided injuries and deaths to firefighters ($0.28) were categorized as a societal benefit.

The estimated benefits presented in Table 8.4 are conservative for the following reasons:

- The probability of a fire post-weatherization is assumed to be the average probability of a home fire occurrence.
- The probabilities of secondary fires were not considered.

[183] For individuals/occupants covered by public health insurance (e.g. Medicare and Medicaid), the portion of the avoided medical costs payable by the insurer is categorized as a societal benefit and the remaining out-of-pocket (OOP) costs (8.0% as copayments or deductibles) are categorized as a household benefit. For individuals/occupants covered by private health insurance, the portion of the avoided medical costs payable by the insurer is categorized as a societal benefit and the remaining out-of-pocket (OOP) costs (12.5% as copayments or deductibles) are categorized as a household benefit. For individuals/occupants that are "uninsured," the OOP costs (100% of total medical costs) are categorized as a household benefit.

9.0 Reduced Utility Disconnects

When utility bills are not paid for extended periods of time, residents risk having their utilities disconnected. Disconnections are costly for both utility companies and their customers due to the extra administrative work and, in many cases, manual in-field labor required. This extra cost to the company is partially passed along to the customer as fees and penalties. Because weatherization reduces a home's energy consumption, it increases the likelihood that a household will be able to afford their utility bills and avoid disconnections.

9.1. Inputs and Monetization Approach

Findings from Occupant Survey questions (Table 9.1) and secondary data from Xcel Energy Minnesota publications (Table 9.2) were used to determine annual household savings attributable to reduced utility disconnections. Post-weatherization the percent of respondents reporting at least one utility disconnection in the past year decreased by 1.6% (Table 9.1).

Table 9.1. Occupant Survey Questions – Utility Disconnects

Occupant Survey Question	Pre-Wx Treatment	Post-Wx Treatment	Post-Wx Comparison	Change (+/-)
In the past 12 months was your electricity or natural gas ever disconnected because you were unable to pay your home energy bill? (% yes)	11.6% (n=198)	9.9% (n=91)	10.2% (n=176)	-1.6%

Both the Exact McNemar's test and Pearson Chi-Square test of independence determined that there was no statistically significant association in the proportion of reports of utility disconnections pre- and post-weatherization. Results from tests of statistical significance are presented in Table 9.2.

Table 9.2. Tests of Statistical Significance – Utility Disconnects

	Change (+/-)	Change (+/-)	Total Change (+/-)
	Pre-Wx (n=494) to Post-Wx Treatment (n=295)	**Pre-Wx Treatment (n=494) to Post-Wx Comparison (n=539)**	
% Decrease in Utility Disconnections	-1.7%	-1.4%	-1.6%
Exact Sig. (2-tailed)*	0.815[a]	0.668[b]	-

*Statistically significant if p<.05; [a]McNemar Test; [b]Fisher's Exact Test

Publications made available online by Xcel Energy provided disconnect-related fees specific to the company. Notably, Xcel Energy Minnesota does not charge a disconnect fee but does have reconnect and service fees. Because disconnections are often a result from unpaid bills, estimated late fees a resident may incur leading up to a disconnection were also estimated. Past due amounts over $10 are subject to a 1.5% late payment fee or $1, whichever is greater; the 1.5% rate was assumed for this study.

Table 9.3 presents monetization inputs and data sources. Table 9.4 presents the monetization approach for reduced utility disconnects.

Table 9.3. Inputs and Sources for Reduced Utility Disconnects

Inputs/Sources	
Occupant Survey	• Percent difference in rate of disconnections from pre to post: -1.6%
Open-source Databases	• Xcel Energy Minnesota Residential Electrical Prices. Xcel Energy, June 2019.[184] ○ Ave. reconnection fee: $22.50 ○ Ave. service processing charge: $7.00 ○ Late fee rate: 1.5% of utility bill • Keeping Costs Low. Xcel Energy, 2019.[185] ○ Average utility bill for a Xcel Energy Minnesota customer: $91.30

Table 9.4. Monetization Approach – Reduced Utility Disconnects

Monetization Approach
Key Variables
• D% = Percent difference in rate of disconnections pre-/post- (%) • L% = Late fee rate (1.5% of the total utility bill) • B$ = Avg. utility bill cost • R = Reconnection fee • S = Service processing charge
Equation 1. Late Fees Incurred Leading Up to Disconnection
• Late Fees = D% * L% * B$
Equation 2. Cost of Reconnections
• Reconnections = D% * (R + S)
Equation 3. Total NEI
• Total NEI = Late Fees + Reconnections

9.2. Estimated Values

Table 9.5 presents the estimates of this NEI specifically for recipients of WAP in the C + VC climate zones. This table includes benefits both per weatherized unit annually and the PV per unit, assuming persistence of measures for a ten-year period.

Given the above inputs and equations, the annual per unit household benefit of avoided costs associated with disconnections is estimated to be $0.49. For all fees, the entire cost falls on the household, so no adjustments were needed to account for societal costs. Positing a ten-year lifespan for the benefits, the present value would be $4.17.

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184 (Xcel Energy "Xcel Energy Minnesota…")
185 (Xcel Energy, "Keeping Costs Low")

Table 9.5. Estimated Benefit for Reduced Utility Disconnects

	Annual Per Unit Benefit	PV Per Unit Benefit
Households	$0.49	$4.17
Societal	-	-
Total	$0.49	$4.17

10.0 Food Security

The WAP Occupant Survey found that, prior to weatherization, one-third of respondents traded off buying food in order to afford their energy bill at least once in the previous year. Following weatherization, these households presumably had lower utility bills and more money to spend on things other than energy, and as a result, the percent of households reporting trade-offs between paying for food or energy dropped by nearly a quarter.

Food insecurity is a term that describes when households have to make decisions like foregoing food to afford energy, or have uncertain access to food for any reason. Among food insecurity's many ramifications, a study published by the CDC[186] notes, "Food insecurity is associated with numerous chronic health conditions, including diabetes mellitus, hypertension, coronary heart disease, chronic kidney disease, and depression."[187] Reasons for the connection may include "worse diet, food-medication trade-offs, and reduced 'bandwidth' to manage complex chronic conditions."[188] Based on the relationship between food insecurity and poor health, researchers have used secondary data to quantify the difference in average total health care costs for an adult experiencing food insecurity versus a food secure adult. Their research reports the excess health care costs associated with food insecurity for every county and state in the US.

10.1. Inputs and Monetization Approach

Responses to the Occupant Survey as well as information about Minnesota health insurance rates were used to determine annual household savings attributable to increased food security. The USDA's Food Insecurity Survey, considered the industry standard for measuring food security, relies on multiple questions. Questions from the Occupant Survey that were most closely aligned with questions posed in USDA's Food Insecurity Survey were selected for inputs into the monetization algorithm (Table 10.1). Findings indicate that respondents experience fewer instances of food insecurity post-weatherization.

Averaging the results of the three questions within each research group – Pre-Treatment, Post-Treatment, and Comparison – was explored. However, the decision of how to weight each question became an issue as the impact of one question might be *more* of an indicator of food insecurity than the other. Therefore, the decision was made to identify increased food security by capturing the change in reports of any one of the food insecurity indicators. Equation 1 was then used to calculate a 12.2% decrease in positive responses to any one of the situations that indicate experiencing instances of food insecurity (Table 10.1).

The Pearson Chi-Square test of independence determined that there was a statistically significant association in the proportion of respondents experiencing two of the three

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186 The CDC report includes the excess health care costs associated with food insecurity for every county and state in the US.
187 (Berkowitz et al. 2018)
188 Ibid.

food insecurity indicators between the pre-weatherization and comparison groups. Results from tests of statistical significance are also presented in Table 10.1.

Table 10.1. Occupant Survey Questions – Food Insecurity Indicators

Occupant Survey Questions	Pre-Wx Treatment	Post-Wx Treatment	Post-Wx Comparison	Change (+/-)
Over the past 12 months, how often has your household not purchased food in order to pay an energy bill? (%at least once)	33.1% (n=492)	28.1% (n=292)	22.3%*** (n=539)	-7.9%
In the past four weeks, did you or any household member go a whole day and night without eating anything because there was not enough food? (% yes)	7.5% (n=494)	5.4% (n=295)	5.6% (n=540)	-2.0%
In the past four weeks, did you worry that your household members would not have nutritious food? (% yes)	20.5% (n=493)	16.7% (n=294)	13.7%** (n=539)	-5.3%
% of respondents reporting "yes" to at least one of the above food insecurity indicators	**40.0%**	**29.8%**	**25.8%**	**-12.2%**

*** p <.001, ** p<.01, *p < .05

Secondary data was collected on health care costs of food insecurity to estimate the savings associated with improving food security. The most recent insurance coverage data available for low-income households in Minnesota was combined with research on the percent OOP costs based on a person's insurance status. The monetized value of these benefits is presented in Section 10.2, Table 10.4.

Table 10.2. Inputs and Sources for Increased Food Security Monetization

Inputs/Sources	
Resident Survey	• Percent difference in rate of food insecurity from pre to post: -12.2% • Avg. # of adults per weatherized home: 1.7

Literature: Peer-Reviewed and Other	• Medical Expenditure Panel Survey: 2014.[189]
	  ○ % OOPS for people with public insurance: 8%
	• MN Department of Health. Minnesota Health Care Spending: 2015 and 2016 Estimates and Ten-Year Projections: Report to the Minnesota Legislature February 2019.[190]
	  ○ % OOPS for people with private insurance: 12.5%

Open-source Databases	• *The Healthcare Costs of Food Insecurity.* Feeding America Research, Aug. 2019.[191]
	  ○ Excess health care costs associated with food insecurity, per adult: $1,516
	• MN Department of Health; 2017.[192]
	  ○ % Minnesota residents with public insurance: 64.8%
	  ○ % Minnesota residents with private insurance: 23.9%
	  ○ % Minnesota residents uninsured: 11.3%

Table 10.3. Monetization Approach – Increased Food Security

Monetization Approach
Key Variables

• D% = Percent difference in rate of food insecurity (%)
• C$ = Excess health care costs associated with food insecurity, per adult
• M = Mean # of adults per weatherized home
• Medical coverage type (i.e., payer):
  ○ a = Public insurance (e.g. Medicare, Medicaid)
  ○ b = Private insurance
  ○ c = Uninsured
• P% = Percent of Minnesotans with the given insurance type/payer
• O% = Percent OOPS for the given insurance type/payer

Equation 1. Total NEI
• *Total NEI = D% * C$ * M*
Equation 2. Household NEI Value
• *Household NEI = Total NEI * ($P\%_c$ + ($P\%_a$ * $O\%_a$) + ($P\%_b$ * $O\%_b$))*
Equation 3. Societal NEI Value
• *Societal NEI = Total NEI - Household NEI*

As with many of the NEIs, for respondents covered by public or private insurance, the portion of the avoided medical costs payable by the insurer was categorized as a societal benefit and the remaining OOP costs were categorized as a household benefit.

[189] https://meps.ahrq.gov/data_files/publications/st500/stat500.shtml
[190] https://www.health.state.mn.us/data/economics/docs/costs/healthspending2019.pdf
[191] https://www.feedingamerica.org/sites/default/files/2019-07/The%20Healthcare%20Costs%20of%20Food%20Insecurity%20Brief_July%202019.pdf
[192] https://mnha.web.health.state.mn.us/PublicQuery.action

For the uninsured all of the avoided medical costs was categorized as a household benefit.

10.2. Estimated Values

Table 10.4 presents the estimates of this NEI for recipients of WAP in the C + VC climate zones. This table includes benefits both per weatherized unit annually and the PV per unit, assuming persistence of measures for a ten-year period. Benefits are also divided into household or societal. Given the above inputs and equations, we estimate the first-year total benefit of avoided costs associated with increased food security to be $314. Positing a ten-year lifespan for the benefits, the present value would be $2,679.

Table 10.4. Estimated Benefit for Reduced Food Insecurity

	Annual Per Unit Benefit	PV Per Unit Benefit
Households	$61.22	$521.70
Societal	$253.20	$2,157.61
Total	**$314.42**	**$2,679.32**

11.0 Summary of Recent and On-Going Research Studies

Since the initial NEI research conducted as part of the WAP evaluation Three³ has continued to expand and refine its approach to the identification, assessment, and monetization of health and SDOH benefits that can be attributed to weatherization. Our current evaluation projects focusing on low-income weatherization include two studies of single-family homes and one study of multifamily housing.

Single-Family Studies

The Robert Wood Johnson Foundation (RWJF) is funding a study of the **Knoxville Extreme Energy Makeover (KEEM)** low-income, energy-efficiency retrofit program in Knoxville, TN. The data collection for both the baseline survey and one-year follow-up is complete and includes 99 Treatment homes that participated in KEEM, as well as 197 Comparison with Treatment (CwT) homes that were weatherized one year prior to the study, and 152 Control homes that did not receive weatherization. The KEEM resident survey was expanded to include questions about asthma for all members of the household, as well as respondent COPD, sinus infections, and bronchitis.

Results from the KEEM study indicate that some of the more general health indicators, such as worsening headaches and days of poor physical and mental health show improvements with statistical significance in the $p < .2$ range. Notably, the smaller sample sizes in this study limited the conclusions that could be drawn. Both the average number of days a resident experienced poor mental health and the rate of worsening headaches decreased by over a third.

The Tennessee Valley Authority (TVA) is funding Three³'s evaluation of the **TVA Home Uplift Initiative**, an income-qualified weatherization service. As the first round of surveys included 701 Treatment homes and 296 Control homes throughout the TVA service area, which includes all of Tennessee and parts of Georgia, Alabama, Mississippi and Kentucky. The TVA resident survey was expanded to include questions about asthma and thermal stress for all members of the household, as well as low birth weight infants and insurance status.

The TVA Home Uplift study has not completed the second round of surveys, so final pre/post comparisons are not possible at this time. However, two health conditions of interest, COPD and trips/falls inside the home, are worthy of mention to show the frequency and severity with which they affect the weatherization population prior to retrofits. Notably, over half of respondents with COPD in the Treatment group and three-quarters of those in the Control group had to see their doctor for worsening symptoms in the past year. Also of concern, of the 5% of Control homes where a household member suffered a trip or fall, over 12% of the trips/falls resulted in hospitalization.

Because of the geographic and programmatic similarities between KEEM and Home Uplift, Three³ merged the KEEM dataset with data from Knoxville residents in the Home Uplift study for more robust sample sizes. In addition to informing the asthma and thermal stress analysis, it provided a new opportunity to look at specific health conditions such as worsening headaches and COPD as well as our general health indicators.

Multifamily Study

The **Low-Income Multifamily (LIMF)** study in the Midwest and Northeast is jointly funded by the **JPB Foundation** and the **Energy Efficiency Program Administrators**

of Massachusetts. The study collected data on 2,964 residents from 1,921 households – 1,309 pre-weatherization (Treatment + Control) households and 612 Comparison with Treatment households. One year later, the study collected follow-on data, post-weatherization, from 940 residents. The LIMF Resident Survey, quite possibly the most expansive to date, includes questions related to the following NEIs: arthritis and diabetes.

During preliminary analyses of results two important observations were made. First, the incidences of diabetes and arthritis among the main respondents is comparatively high. Second, the results suggest that weatherization can positively impact these health issues. For example, for those living in weatherized multi-family buildings, symptoms related to diabetes were reported to have decreased. There were statistically significant associations between post-weatherization reductions in hospitalizations for both diabetes and arthritis, and urgent care treatment for arthritis.

We continue to work to improve our monetization estimates. We have now incorporated questions that capture data points for health issues experienced by all household members, as opposed to only asking questions about the main respondent, for certain conditions or illnesses, including asthma, thermal stress, and COPD.

We continue to expand partnerships and data sharing agreements with the healthcare sector to collect actual health claim and health claim cost data. Our goal is to reference medical records for home occupants and learn how many medical interventions were required for a health condition (e.g., asthma) pre- and post-weatherization, as well as to identify the costs of those specific interventions.

12.0 Cost-Effectiveness Analysis

This section describes the cost and health-related NEIs estimated to result from the Xcel Energy Minnesota low-income energy efficiency programs. To the extent that these benefits/impacts have been quantified, a dollar value has been determined for each one.[193] The total costs of weatherization measures for Program Year (PY) 2019 (Table 12.2) have been compared to the total estimated monetary benefits of the health-related NEIs (Table 12.3).

Forecasting long-term avoided costs, defined as costs that would have been spent if the energy efficiency savings measure had not been installed, is the typical approach for quantifying the benefits of energy efficiency. Within an avoided cost framework, the approach can be as basic as estimating the fixed and variable costs of weatherization measures and subsequent impacts, respectively. All such cost savings resulting from the installation of weatherization measures can be directly counted as avoided cost benefits. The value of avoided costs, for the purposes of this study, is the "aggregate" of household NEI values (excluding societal NEIs). Due to the scope of this project, the availability of time, resources, and data needed to complete a more sophisticated cost-effectiveness analysis were limiting factors. Through the collection of direct data in the future, the study team would be able to address limitations and assumptions required for this analysis. This analysis does not include the avoided energy supply benefits that are typically considered when performing benefit-cost analysis of Xcel Energy's Conservation Improvement Program energy efficiency portfolio.

For energy efficiency programs with long measure lives, cost-effectiveness can be profoundly affected by the discount rate assumption – comparing the PV of the annual costs and benefits over the life of an efficiency measure. Costs of programs most often require an upfront investment while benefits accrue over several years. For the purposes of this study, to calculate the PV, a 3.02% discount rate over a ten year life-time of the measure is used.[194]

Average costs by weatherization measure for Xcel Energy's low-income conservation program are provided in Table 12.1.

Table 12.1 Average Cost by Weatherization Measure – Xcel Energy Minnesota, 2019

Weatherization Measure	Cost
Air Sealing	$277
Attic Insulation	$1,573
Wall Insulation	$1,378
Furnace	$2,928
Boiler	$4,647

[193] In many cases a cost-effectiveness analysis is used when a cost-benefit analysis is not a viable analysis option because placing a set value on the outcome is difficult. In the health care sector this can be the case as patient success and outcomes differ widely. Simply, costs might be able to be directly calculated, but the outcomes/benefits can only be estimated; therefore a cost-effectiveness analysis may be more appropriate.
[194] The selection of a 3.02% discount rate was driven by guidance provided by the Minnesota Department of Commerce on February 11, 2020 to use a 3.02% societal discount rate (SDR) for present value calculations. https://www.edockets.state.mn.us/EFiling/edockets/searchDocuments.do?method=showPoup&documentId={F0943570-0000-CD1F-8C8C-9A3C836481A8}&documentTitle=20202-160294-01

In PY 2019, 167 single-family homes received weatherization services through Xcel Energy's low-income energy-efficiency program. Table 12.2 presents the number of homes that received a specific weatherization package or measure. Close to half of the homes received a furnace and 10% had a new boiler installed. Thirty-eight percent received insulation but did not require a heating system replacement.

The total costs for the 63 homes that received air sealing and/or insulation is about $135,000; total costs for the 85 homes that received a furnace and/or insulation is close to $300,000; and the total costs for the 19 homes that received a boiler and/or insulation is approximately $109,000. The grand total cost for weatherization measures installed through Xcel Energy's low-income energy-efficiency program in 2019 is calculated at $544,812. The average cost for single-family homes treated in 2019 is $3,262.

Table 12.2 displays the total average costs by measure or measure package, the grand total cost, and the average cost per single-family home treated in 2019. Data used for these calculations (i.e., measure costs, and installed measures) was provided directly by Xcel Energy Minnesota. Comparing the average WAP measure cost per home located in the cold and very cold climate regions combined, as reported through the national WAP evaluation for PY 2008 ($3,768) and price adjusted for inflation from 2008 to 2019, the values vary only by about $500.[195]

[195] The measure costs estimated through the national WAP evaluation for single-family site-built homes in PY 2008 (Blasnik et al. 2014), and adjusted to 2019 dollars, are as follows: the cold climate zone is $2,701, the very cold is $4,836 and the C + VC combined is $3,768.

Table 12.2. Total Costs by Weatherization Measures Installed – Xcel Energy's Low-Income Energy-Efficiency Program, 2019

Weatherization Measures	# of Homes	Total Average Costs
Air Sealing and Insulation		
Attic Insulation Only	1	$1,573
Attic + Air Sealing	47	$86,950
Attic + Air Sealing + Walls	14	$45,192
Wall Insulation Only	1	$1,378
Total – Air Sealing and Insulation	63	$ 135,093
Insulation and Furnace[1]		
Attic + Air Sealing + Wall + Furnace	2	$12,312
Attic + Air Sealing + Furnace	24	$114,672
Wall + Furnace	1	$4,306
Furnace Only	58	$ 169,824
Total – Insulation and Furnace	85	$301,114
Insulation and Boiler[1]		
Attic + Air Sealing + Wall + Boiler	4	$31,500
Attic + Air Sealing + Boiler	4	$25,988
Boiler Only	11	$51,117
Total – Insulation and Boiler	19	$108,605
Grand Total	**167**	**$544,812**
Average cost per SF home treated in 2019		**$3,262**

[1]The combination of air sealing, attic and wall insulation, and heating system (boiler or furnace) is considered a complete package of measures as installed by Xcel Energy.

The total household NEI value (i.e., benefit) at PV as estimated through the Xcel Energy LI EE NEI Study is $4,890.28 (Table 2.9). Comparing installed measure costs of $3,262 and the total estimated household NEI value, shows that the benefits outweigh the costs by $1,628. The total NEI value including both household and societal benefits is $10,460.78 (Table 2.9). Comparing installed measure costs of $3,262 and the total estimated NEI value, shows that the total benefits outweigh the costs by $7,198.78.

Table 12.3 provides installed measure costs (from Xcel Energy), the estimated NEI values, and the difference between the two.

Table 12.3. Installed Measures Costs, NEI Values, and Cost-Effectiveness

Costs & Cost-Effectiveness Household Benefits and Total (Household + Societal) Benefits				
Measure Costs	Household Benefits	Societal Benefits	Difference	Total Difference
$3,262	$4,890	-	**$1,628**	
$3,262	$4,890	$5,571	-	**$7,199**

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