Go Big or Go Home: Scaling NEIs to the Multifamily Sector

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ABSTRACT

This paper reports interim findings of the first phase of a regional study that will determine if health- and household-related NEIs attributable to energy efficiency (EE) improvements evidenced in low-income single-family (LISF) homes are also found in low-income multifamily (LIMF) buildings, and whether those identifiable NEIs can be quantified. We hypothesize that there are differences between demographic characteristics and health status of LIMF versus LISF residents that could influence the type and magnitude of NEIs. The study builds on two recent studies that monetized multiple NEIs attributable to low-income SF weatherization and other EE improvements, one at a national level and one in Massachusetts. The study follows a classical quasi-experimental research design with three research groups: comparison, treatment and control. The sample consists of 361 LIMF buildings (5+ units) across the Northeast and Midwest representing 1,660 apartment units and 2,448 persons total. The cornerstone of the study is a Resident Survey that asks respondents a series of questions about health, wellbeing, affordability, dwelling quality, and demographics. In-field staff distributed survey packets to residents, interviewed property managers, and documented building characteristics and conditions of systems that could provide insights into NEIs. NEIs explored include but are not limited to avoided medical costs from reduced asthma flare-ups and arthritis symptoms, avoided medical costs and deaths due to exposure to extreme indoor temperatures, reduced injuries and property damage from fires, and reduced losses in work income due to poor health. Findings presented are compiled from the first phase of the study capturing baseline conditions.

Introduction

This paper presents results from the first phase of a two-phase, regional study conducted by Three[3], Inc., Slipstream, and NMR Group funded by The JPB Foundation (JPB) and the Massachusetts (MA) energy efficiency Program Administrators (PA).[1] Three[3] and NMR Group were contracted by the MA PAs to evaluate the health and safety-related non-energy impacts (NEIs) attributable to improvements in the energy efficiency (EE) of income-eligible multifamily (MF) buildings served through the Mass Save® program. Three[3] and Slipstream were awarded funds by JPB to estimate not only the NEIs of weatherizing low-income MF (LIMF) buildings but to evaluate potential resilience benefits. More specifically, exploring the impacts of weatherization on social/community resilience and building systems resilience in the face of external factors, referred to in this context as press and pulse disturbances.[2] Both JPB and the MA PAs understand that additional quality research-based evidence is needed on the health and resilience benefits of MF weatherization to improve policy decision-making in this area.

The two studies are being conducted simultaneously, using similar research designs and the same survey instruments. Data collection in Massachusetts is being supported by the MA PAs, while funding

[1] JPB awarded this grant in an effort to support its national initiatives, such as its Energy Efficiency for All (EEFA) program and the Network for Energy, Water and Health for Affordable Buildings (NEWHAB). These initiatives encourage increased funding for the weatherization of affordable MF buildings at a national level.

[2] Disturbances that range across a risk-continuum from infrequent but high-consequence “pulse” disturbances (e.g., flood or fire) to more frequent, lower-consequence “press” disturbances (e.g., pests and vandalism).

from the JPB study supports data collection in other cold climate states, including Illinois, New Hampshire, New York, Pennsylvania, Rhode Island, Vermont, and Wisconsin. The primary data collection instrument is the Resident Survey (RS), which asks households a series of health, wellbeing, affordability, dwelling quality, household characteristics, and social/community resilience questions. In addition to the RS, an additional survey was administered to property managers to capture resilience benefits from a building systems perspective.[3]

In order to develop the research approach we organized and conducted three regional workshops to engage Energy Efficiency for All (EEFA) and other stakeholders, and subject matter experts, to gain their insights and inputs. A total of over 100 individuals participated in the workshops. Listening sessions were conducted with a combination of occupants and property managers of MF buildings in four cities—NYC, Chicago, Knoxville, and Madison. Numerous insights were gleaned and new "to-be-explored" NEIs were identified through these efforts. The specific research objectives include the following:

- Estimate the value of impacts of weatherization services on LIMF households by calculating money saved, or the dollar value of costs avoided, due to changes in health issues, energy affordability, and household financial situations.
- Gain insights into how health and safety impacts may differ across:
    - Building types (e.g., low-rise, high-rise)
    - Building functions (e.g., family, senior, supportive housing)
    - Demographics

To date, relatively little quantitative research has been conducted on the NEIs of MF households. There are substantial differences between building characteristics and performance of MF and SF homes, the demographics and health status of households who live in them, and the communities in which they are located (Bensch et al. 2014; Blasnick et al. 2014; Carroll et al. 2014). Due to these differences, we hypothesize that research on the health and household-related NEIs for households residing in SF homes should not be generalized to households residing in MF homes.

Non-Energy Impacts Overview

An extraordinarily important NEI of low-income weatherization, aside from energy and water cost savings, is the potential for overall improvement in human health and well-being simply through improving the physical condition of the home (NCHH 2009; Liddell and Guiney 2014; Wilson et al. 2014; Francisco et al. 2016; Tohn et al. 2016). Improvements in dwelling quality reduce exposure to evidence-based asthma triggers from a collective reduction in home-based environmental triggers including mold, dust, pests, and psychosocial stress (Breysse et al. 2004; Tonn et al. 2014; Rose, Hawkins, and Tonn 2015). Weatherization can directly reduce risks of thermal stress on occupants. For example, air sealing and insulation decrease drafts and unsafe temperatures inside the home, thereby improving the resilience (e.g., performance) of homes during extreme weather events (Hawkins et al. 2016; Hawkins 2019).[4] Figure 1 shows the complex relationships between weatherization and impacts on human health. This framework recognizes that weatherization can provide many direct and indirect benefits to households,

[3] Findings from the property manager survey related to building systems resilience will not be presented within this paper.

[4] It should be noted that asthma rates are higher than national averages amongst low-income individuals (Rose, Hawkins, and Tonn 2015) in contrast to the general population. Thermal stress is another example of a national health inequity (Madrigano 2013) and is expected to worsen over time due to the observed increase in frequency and duration of heat waves attributable to climate change (Wu et al. 2014).

and that increases in income as a result of household cost savings can result in expenditures that yield societal benefits (Tonn et al. 2014).

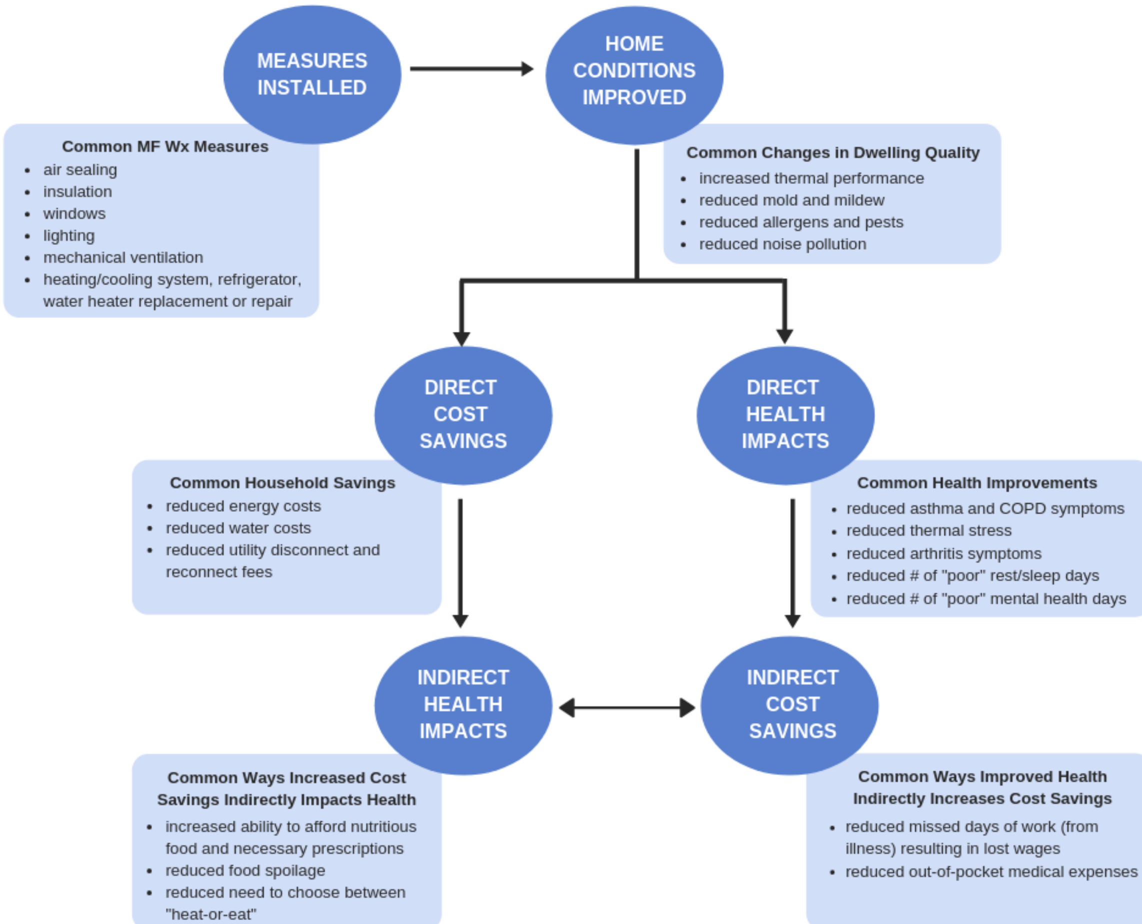


Figure 1. Conceptualizing the Connection Between Weatherization and NEIs

As Figure 1 illustrates, improvements in household members' health and financial situations can result in a cycle of positive feedback effects that reinforce and amplify each other. Improved health of those employed and of school-aged children can result in reduced missed days of work and school, directly and positively impacting household budgets. Improved budget situations allow households to better afford food, pregnant women to avoid "heat-or-eat" predicaments, individuals to better comply with prescription drug recommendations, and households to afford other healthcare expenses. These, in turn, have additional positive impacts on household members' health (Hawkins et al. 2016; Tonn et al. 2014).

In most cases, comprehensive weatherization is required to produce the most impactful health outcomes. For example, air sealing, insulation, heating/cooling system replacements, and mechanical ventilation are a few weatherization measures that can reduce the frequency of exposure to asthma triggers. Most of the health impacts accrue from the installation of standard weatherization measures intended to save energy, and not from energy-related health and safety measures, such as repairing unsafe combustion appliances or damaged light fixtures.[5]

[5] Non-energy-related health and safety measures include but are not limited to: grab bars in the bathrooms; installation/repair of railings; repair of steps, carpet, and linoleum; provision of dust mite mitigation measures (pillow and mattress covers), and mold remediation.

There are certain measures that can unilaterally impact health. For example, installing CO monitors can reduce CO poisoning, and installing smoke detectors can reduce injuries and deaths from home fires. Installing energy-efficient and superior lighting technologies can lead to reductions in trips and falls both inside and outside of MF buildings. Finally, replacing inefficient refrigerators that also work poorly can reduce instances of food poisoning and food loss. All these NEIs have been extensively studied in the LISF arena, but the question remains as to if LIMF residents experience the same type and magnitude of NEIs.

Expansion of NEI Research

Through the ideation sessions with stakeholders and subject matter experts, and the listening sessions with residents, we learned about additional NEIs that warranted exploration. It is widely known that IAQ improvements through weatherization can reduce asthma flares (Wilson et al. ; however, interim analysis suggests that weatherization has a positive secondary impact on chronic obstructive pulmonary disease (COPD). Evidence shows that improvements in household budgets can lead to improvements in nutrition, as fewer households report trading-off buying food to pay their utility bills (Tonn et al. 2014, Hawkins et al. 2019). Improved nutrition can lead to a tertiary NEI, reduced obesity. Furthermore improved thermal performance can reduce indoor thermal stress, which can reduce arthritis symptoms and associated pain which could then spur individuals to increase their physical activity.[6] These impacts can, in turn, synergistically and positively impact cholesterol levels.

The RS contains questions to help capture the NEIs described above that extend beyond our core health NEIs (e.g., asthma, thermal stress), and to explore these new secondary and tertiary NEIs. Several questions address the overlap between health issues and building systems resilience. For example, a prolonged power outage without any backup systems (e.g., generators, solar panels) could degrade life-sustaining refrigerated medicines, render electrical medical equipment inoperative, and limit accessibility to medical care. Table 2 lists 10 NEIs not previously assessed that we explored for monetization. Figures 5 and 6 present descriptive statistics for a select set of these exploratory NEIs.

Table 2. Additional NEIs considered for monetization

Additional NEIs Considered for Monetization	
Spoiled food	Refrigerated medicines
Energy assistance	COPD
Odors	CVD
Noise pollution	Diabetes
Mental health and well-being	Headaches

Monetization of NEIs

For Phase 1, we monetized 13 NEIs that have been identified, through previous research to have defensible, monetizable impacts (Table 1). Multiple factors were considered in the selection of this set of NEIs: (1) strong theoretical basis for applicability to the MF sector; (2) well-established peer reviewed monetization approaches; and (3) resources and availability of data to analyze the change in conditions rigorously and to attribute observed changes to the weatherization programs or measures. These NEIs, captured in the above framework, were prioritized for Phase 1 analysis and monetization. Table 1 includes one newly explored and monetized NEI for consideration – reductions in arthritis symptoms.

[6] Arthritis is evidenced to be exacerbated by cold temperatures (NCBI 2013).

Table 1. Monetized NEIs

Monetized NEIs		
Thermal stress – cold	Home productivity	CO poisoning
Thermal stress – hot	Short-term loans	Prescription medicine
Asthma	Low-birth-weight infants	Work productivity
Missed days of work	Food assistance	Arthritis
Reduced fire risk	Trips and falls (inside)	

Methodology

The cornerstone of the project is the resident survey (RS), a modified version of the national occupant survey administered as part of the two U.S. Department of Energy's Weatherization Assistance Program (WAP) evaluations.[7] For this study the RS was expanded to contain several new questions that explored additional health and safety issues. Wherever possible, the additional questions were drawn from existing reputable surveys pre-tested through implementation in the field. Questions that did not pertain to the MF context were dropped.

In Summer/Fall of 2019, approximately one-year after the Phase 1 survey period, respondents in the T and C group buildings will be asked to complete a follow-up survey (i.e., Phase 2). The T group will have been weatherized, providing the opportunity to compare survey findings both pre- and post-weatherization from the same household—a matched pairs analysis—to estimate changes in health attributable to weatherization.[8]

Study Groups and Sampling

A classical quasi-experimental research design was implemented. The sample consisted of existing MF buildings with five or more units that fell into one of three research groups:

- Comparison, with Treatment (CwT) – already weatherized;
- Treatment (T) – have not been weatherized, but will be; and
- Control (C) – will not be weatherized during the data collection period.

For the MA LIMF portion of the study, sample frames were derived from data provided by the participating MA utilities and their weatherization implementers. The JPB sample frame included seven other states from the Northeast and Midwest and was obtained from numerous lists of eligible buildings provided by state and local agencies, owners of affordable MF buildings, and utility companies.

A power analysis was conducted in order to set targets for the ideal survey sample size. The power analysis relied on two variables: asthma-related emergency department (ED) visits and missed days of work. Estimates of these variables were based on results from the WAP national evaluation occupant survey, using an alpha of 0.1. We set sample size targets to achieve a confidence interval of 90% or higher, with the assumption that our analysis would combine MA and JPB results.

[7] Three[3] principals designed the WAP survey, managed the national WAP evaluations, and conducted the health and household-related WAP NEI study while employed as research staff with Oak Ridge National Laboratory.

[8] Being able to successfully conduct a matched pairs analysis, rather than a cross-sectional, will be entirely dependent on final sample sizes.

Fielding

From January through June 2018, the team visited 67 sites in MA, and from January through November 2018, the team visited 123 sites in the other states. In-field staff distributed 2,629 survey packets to MA residents and 4,585 survey packets to residents outside of MA, interviewed the sites' property managers, sketched building floor plans, recorded building orientation, and conditions of building systems that can be used to provide insights into NEIs.

Recruitment and site visits. Property managers were contacted to gain permission to enter buildings and distribute survey packets. In-field staff was equipped with digital data collection tools uploaded with software (FileMaker Go) programmed for these purposes, in order to successfully link surveys to specific apartments. Staff distributed survey packets to residents by hanging a bag containing a paper survey, cover letter, project description, informed consent form, and a postage-paid return envelope on residents' doors. This participant recruitment approach was deemed to be the most effective option given that household contact information was unavailable. The survey packet cover letter invited occupants to respond to the survey via one of three modes: the paper version we distributed, an online format, or by phoning a call center. We distributed paper surveys in other languages (Mandarin, Russian and Spanish) where appropriate.

Challenges. The completed study sample sizes were not as large as planned. Based on previous research a survey response rate of 33% was estimated but the survey response rate was 6% after four weeks of fielding. The major obstacle was property managers were often unresponsive to recruitment efforts. As a result, the following steps were implemented in order to increase survey response rates, especially in the Treatment group.

- Increased the incentive to property managers from $20 to $100 (to gain access to property);
- Increased the incentive for residents to complete the survey from $20 to $25;
- Distributed flyers to common spaces notifying residents about the survey packets they received;
- Knocked on doors during site visits to "personalize" the effort and answer residents' questions;
- Offered an "instant" gift card for same-day survey completion (versus being mailed a gift card after completing the survey at a later date); and
- Re-visited sites to deliver postcard reminders and distribute reminder flyers.

The average MA survey response rate across all groups rose to 17%. By comparison, using the same steps, the average response rate across the other states was 23%. The study design set targets of over 3,000 completed surveys across all states to reach the sample size goal identified through the power analysis. Given the challenges with recruitment and completion rates we were unable to meet this target.

Existing systems and installed measures data. The research efforts have yielded three sets of data: (1) RS results, (2) building characteristics and conditions observed on site, and (3) existing (i.e., pre-weatherization) mechanical systems and weatherization measures installed. The installed measures data reported by participating partners will inform NEI estimates and allow us to correlate specific NEIs with specific measures or combinations of measures installed. The Installed (and existing) Measures Data

Collection Form (IM-DCF) was programmed as a fillable PDF data form. Weatherization agencies were asked to complete it for every participating T and CwT building in our sample.

Data Analysis

A cross-sectional analytical approach was employed to measure outcomes comparing weatherized and not weatherized buildings using Equation 1 below. For the final phase of the study (Phase 2) a matched pairs approach will be employed for appropriate NEIs, contingent upon sample sizes of sub-samples. For NEIs that will be analyzed via a cross-sectional approach in Phase 2, we will use Equation 2, the classic difference of differences.

- Equation 1. (Phase 1) Change in occurrence = Comparison - ($Treatment_{pre}$ + Control)
- Equation 2. (Phase 2) Change in occurrence = [($Treatment_{pre}$ – $Treatment_{post}$) – ($Control_{pre}$ - $Control_{post}$)

We attempted to control for statistically significant demographic imbalances between sample groups (discussed further in the following section). In order to explore such comparability issues between samples regression analyses were used to model the relationship between select outcome variables and one or more predictor variables. We modeled a combination of these relationships, predicted any statistically significant impacts of predictor variables on several outcome variables (e.g., number of times someone in the household went to the hospital for thermal stress) to control for the influences of the following predictor variables: region, age, gender, race, ethnicity, employment status, and level of education. A dummy variable was used for the main effect of interest; weatherization (Wx=1). The regression coefficient (β) of this 'Wx effect' variable was established as the estimate of change attributable to weatherization while attempting to control for confounding factors. The β coefficient was used as the main monetization input rather than the differences of means or the reported change (Δ) in pre/post frequencies used in the past for NEI monetization.

We conducted bootstrapping resampling tests to increase the rigor of analysis. This technique identified the uncertainty intervals surrounding the point estimates of the differences between the study groups and the resulting NEI values. Respondent resampling was done by household in order to account for potential clustering effects in analyses conducted at the level of individual household members.

The RS poses some questions that are related to the household (e.g. dwelling quality) while others are related to individual household members (e.g. asthma, thermal stress). Results presented, and the associated sample size (n), are drawn from a combination of household-level responses (n=1,660) and responses for each person in the household (n=2,448). The sample size was insufficient to draw final conclusions about the statistical significance of the results for those NEIs that will continue to be measured using a cross-sectional approach for analysis. For NEIs, such as asthma, that rely upon a matched-pairs analysis, Phase II survey data is critical for determining measured differences between the pre- and post-weatherization environments.

Sample Characterization

The section briefly characterizes the buildings represented by survey respondents and the respondents themselves. Participating agencies have provided data for the CwT buildings on existing (i.e. pre-weatherization) building systems and weatherization measures installed.[9] Pre-weatherization, 33% of the CwT units did not have a working cooling system and 30% did not have a working mechanical

[9] Results presented are based on data for 46% of the CwT buildings represented by this sample–data collection on existing and installed measures is ongoing.

ventilation system. In-unit lighting improvements were the most common reported set of measures installed (75%), followed by building level insulation (65%) and air sealing (61%). Cooling equipment installation/replacement was least often reported at 10%. Phase 1 data indicate the following about the buildings and households visited thus far:

- Approximately 90% of buildings in the sample are described as low-rise (less than five stories), with the majority of those having less than 79 units;
- Almost all buildings are heated with conventional technologies (e.g. central hot water boiler), with a very small percentage reported to be heated by air source heat pumps;
- The majority of the buildings are identified as family housing; however, the mean age of respondents for all groups exceed 55 years of age and close to one-half of primary wage earners are retired (58% of the CwT group and 41% of the T+C group); and
- Three-quarters of respondents live alone.

It is evidenced that two primary differences exist between the pre-weatherization (i.e., T+C groups combined) and the post-weatherization (CwT) group. First, the CwT group is spread more evenly between family and senior housing than the T+C sample, which has a much higher concentration of family housing than senior housing. Second, statistically significant differences between the CwT and T+C groups in age, gender, and race. The CwT group had main respondents who are older, more likely to be retired, and more likely to be female than the T+C groups. More than half (53%) of the C group identifies as Black or African American, compared to less than one-quarter (23%) of the CwT group and 24% of the T group. Because race correlates strongly with certain health outcomes (e.g., asthma) and treatment type researchers attempted to monitor racial composition and differences between surveyed groups to sample accordingly. However, due to the dependence on convenience sampling due to recruitment challenges the racial and ethnic imbalance between groups persisted.

Impacts and Outcomes

On balance, for this LIMF sample, most of the "usual suspects" NEIs improved post-weatherization. Evidence indicate that CwT homes had safer indoor temperatures and were less breezy than homes on the T+C group. This is based on CwT respondents reporting lower rates of the following indicators by 11%, 5%, 7% and 12%, respectively: (1) "almost every/some months living in unsafe indoor temperatures"; (2) "all/almost all the time home was too drafty/breezy"; the temperature of the apartment was (3) hot or very hot in the summer and (4) cold or very cold in winter. All these differences were statistically significant. Figure 3 presents descriptive statistics for select health and budget-related NEIs; such as, decreased frequency in ED visits and non-urgent care due to extreme cold (at statistically significant levels), use of oven to heat home, and struggling to pay energy bills.

MF results indicate that several common asthma triggers were lower for the CwT group, providing evidence supporting the decline in asthma-related outcomes. For example, reports of "presence of visible mold," "extremely/very infested with rodents," and "all/almost all the time home was too dusty" were 7%, 4%, and 8% lower, respectively, for the CwT group. All these differences were statistically significant. A common SF NEI found in previous research, reduction in cockroaches and other insects, was reported much less frequently by MF respondents (~5%).

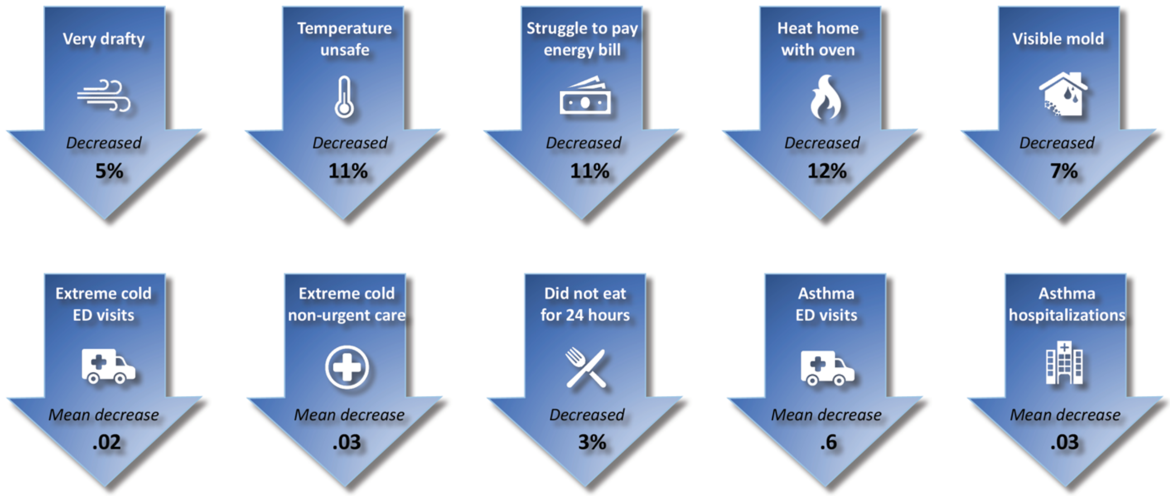


Figure 3. Health and budget-related MF NEIs – select resident survey results

Table 3 presents results indicating that asthma-related hospitalizations and ED visits were lower among CwT respondents than T and C respondents, and the differences were statistically significant.

Table 3. Asthma-related hospitalizations and ED visits

RS Question (All Persons in Household)	CwT	T + C	(+/-)
During the past 12 months, how many times did you have to stay overnight in the hospital because of asthma? (mean)	0.2 (n=76)	0.5 (n=170)	-0.3*
During the past 12 months, how many times did you visit the ED because of asthma? (mean)	0.4 (n=70)	1.0 (n=172)	-0.6***

* Difference is statistically significant at the p<.05 level. *** Difference is statistically significant at the p<.001 level.

Additional dwelling quality improvements are revealed in Figure 4 that not only have the potential to improve health but an individual's sense of wellbeing, such as; increased sense of safety, reduced rodent infestation, infiltration of odors and noise, and frequency of sleep disturbances due to noise.

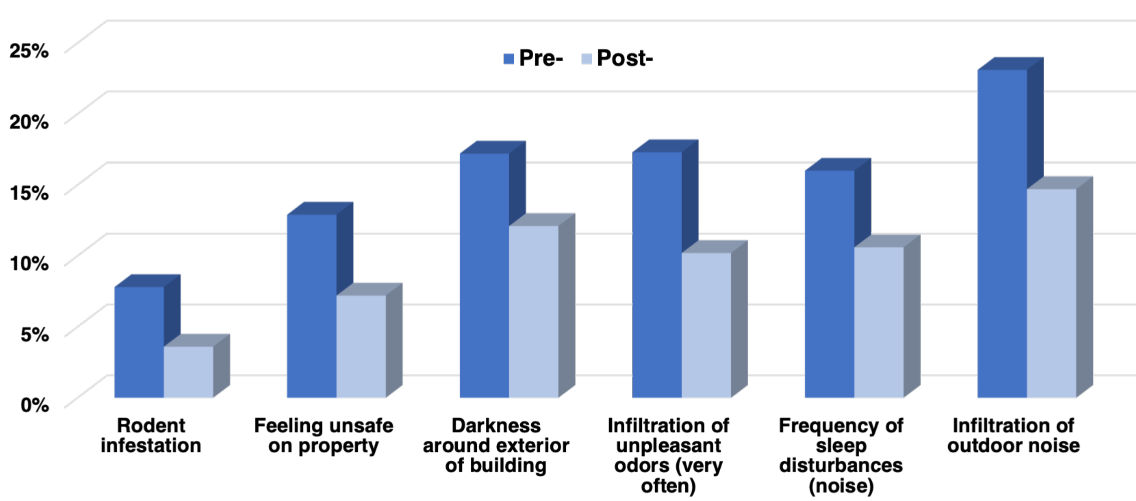


Figure 4. LIMF dwelling quality improvements

Figure 5 presents descriptive statistics for a select set of the exploratory NEIs. For example, arthritis symptoms have the potential to limit mobility, daily activities, influence intake of pain medication, ability to work, and quality of sleep, all of which can contribute greatly to overall quality of life (NCBI 2013). The survey results presented in the figure immediately below suggest that weatherization may have a measurable impact on all four of these exploratory NEIs.

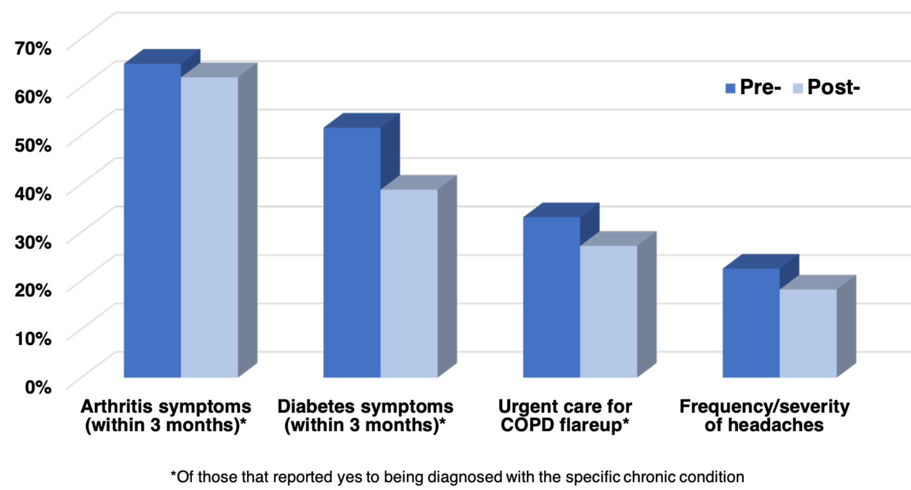
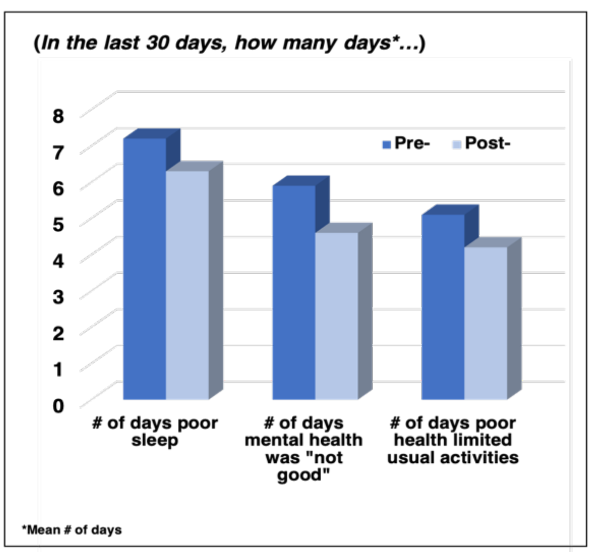


Figure 5. Exploratory MF NEIs

CwT respondents (post) report better general health than T and C respondents (pre) having fewer bad days of rest/sleep and fewer poor physical and mental health days (Figure 6, left side). Figure 6 (right-side) presents select questions that have the potential to influence community resilience outcomes, specifically, social cohesion.[10] Social cohesion is a predicting factor for community preparedness through a willingness to help neighbors during times of crisis.



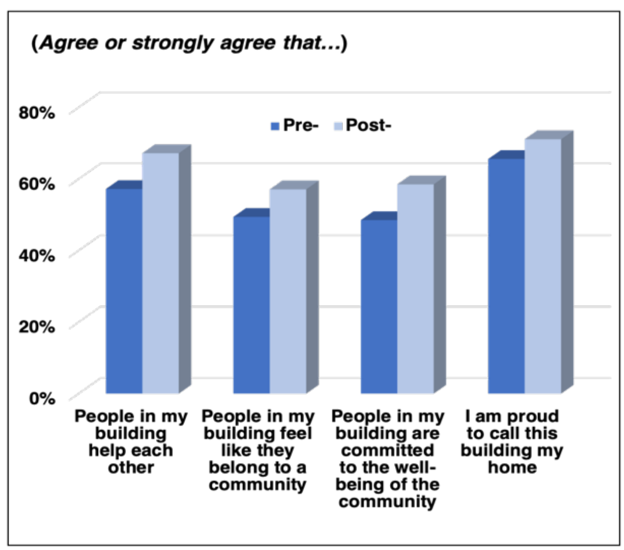


Figure 6. Additional health, well-being and quality of life indicators

[10] We are exploring NEIs associated with both social/community resilience, and building systems resilience, in the face of extreme events. Findings related to building systems resilience are not presented in this paper.

Monetization

We developed preliminary Phase 1 estimates for all NEIs listed in Table 1 and tested each for statistical significance using tests appropriate for the type of NEI being measured. Table 4 present estimated interim values for all NEIs *without taking statistical precision into account.* These are presented on a per-weatherized-unit basis, broken out by their societal and household benefit components.

Each NEI estimate was calculated using individualized monetization algorithms and inputs based on rates of change (+/-) indicated by the Phase 1 RS results and applicable secondary scientific and cost data sources. The regression β coefficient was chosen as the main monetization input for select NEIs and the differences of means or the reported change (Δ) in pre/post frequencies for the remaining. NEIs that include the benefit of avoided deaths (e.g., reduced thermal stress hospitalizations and home fires), are presented with and without the value of a statistical life (VSL). The main contributors to the bottom-line NEI estimates are: avoided hospitalizations and ED visits for thermal stress and asthma- and arthritis-related symptoms; avoided thermal stress deaths, especially thermal stress – cold.

Table 4. Estimated impact for MF residents – annual per weatherized unit (with and without value of statistical life [VSL])

	Per HH[1]	Per HH w/o VSL	Societal	Total	Total w/o VSL
Thermal stress – cold	$2,251.13	$18.54	$171.33	$2,422.46	$189.87
Thermal stress – hot	$959.00	$0.00	$53.05	$1,012.05	$53.05
Asthma	$36.22	$36.22	$1,167.24	$1,203.46	$1,203.46
Missed days of work	$14.03	$14.03	$4.19	$18.22	$18.22
Reduced fire risk	$12.96	$2.07	$4.12	$17.08	$6.19
Home productivity	$4.25	$4.25	$0.00	$4.25	$4.25
Short-term loans	$3.18	$3.18	$0.00	$3.18	$3.18
Low-birth-weight infants	$0.17	$0.17	$3.69	$3.86	$3.86
Food assistance	$0.00	$0.00	$147.09	$147.09	$147.09
Trips and falls (inside)	$0.00	$0.00	$0.00	$0.00	$0.00
CO poisoning	$0.00	$0.00	$0.00	$0.00	$0.00
Prescription medicine	$0.00	$0.00	$63.14	$63.14	$63.14
Work productivity	$0.00	$0.00	$1.93	$1.93	$1.93
Arthritis	$28.82	$28.82	$675.56	$704.38	$704.38
Annual Total per unit	$3,309.76	$107.28	$2,291.34	$5,601.10	$2,398.62

[1] Per HH = Per household (i.e., apartment unit)

The preliminary monetary value for both the household and societal benefit categories for the Carbon Monoxide (CO) poisoning and Trips and Falls (within the unit) NEIs are equal to $0. Preliminary data did not indicate the installation of any CO monitors.[11] As for the Trips and Falls NEI, the monetization method is still under development. Survey results indicate that trips and falls are more frequent in the CwT buildings, which runs counter to our theory of change. However, based on the WAP evaluation, MF homes were reported to receive less in-unit weatherization measures (that could result in reductions in trips and falls) compared to SF homes (~30% of MF buildings received in-unit measures). Also, CwT demographics

[11] The CO NEI valuation is not based on RS results but on measures installed, as reported by weatherization agencies.

suggest a much older population (mean age 67, compared to 60 years of age for both C and T), who are more prone to trips and falls. Absent any reasons for why weatherization could lead to increases in trips and falls, we decided to exclude a value for this NEI at the present time.

Overall, preliminary results support the hypotheses that: 1) improving the energy efficiency of LIMF buildings results in positive monetary valuation of NEIs; and 2) NEIs, as well as their values, for residents of SF homes would be different than those experienced in MF housing. Comparing the monetary values between the MA LISF study (Hawkins et al. 2016) and the preliminary results of the LIMF study we see some substantial differences. Table 5 present a side-by-side comparison of estimated NEI values – for household benefits only – between the two studies.

Table 5. Comparison of LISF and LIMF estimated household NEI values

	MA LISF (final results)	LIMF (preliminary results)
Thermal stress - cold		
Household WITH VSL	$463.21	$2,251.13
Household w/o VSL	$4.67	$18.54
Thermal stress - hot		
Household WITH VSL	$145.93	$959.00
Household w/o VSL	$8.28	$0.00
Asthma		
Household	$9.99	$36.22
Missed days of work		
Household	$149.45	$14.03
Fire risk		
Household WITH VSL	$93.84	$12.96
Household w/o VSL	$9.77	$2.07
Home productivity		
Household	$37.75	$4.25
CO poisoning		
Household WITH VSL	$36.98	$0.00
Household w/o VSL	$0.25	$0.00

The estimated monetary value for Thermal Stress NEIs (both hot and cold) in LIMF is much higher in magnitude compared to LISF. The monetary value of asthma is higher among the LIMF population, in part because the prevalence and incidence of asthma flares in the sample of MF households is higher than was found in the previous survey of SF households. The remaining NEIs: Missed Days of Work, Home Productivity, and reductions in CO Poisoning are considerably lower for LIMF residents, with CO being a $0 value for this interim analysis. Finally, the preliminary monetary value for reduction of Home Fire Risk is less for the LIMF population. According to secondary data, the baseline rate of fires in MF units is much lower than the baseline rate of fires in SF homes.

Conclusion

A cross-sectional analysis comparing weatherized and not weatherized buildings suggests that MF weatherization may reduce exposure to mold and dust, odors, noise, and thermal stress all the while having positive impacts on resident comfort, health and well-being. Residents of weatherized buildings report fewer issues with paying their energy bills, affording prescription drugs, food insecurity, or using their ovens for home heating than those that have not been weatherized.

Overall, the interim results support the hypotheses that (1) improving the EE of LIMF buildings results in positive monetary valuation of NEIs and (2) both NEIs and NEI values are different for residents of MF housing than for residents of SF homes. The demographic characteristics of the MF survey respondents and their self-reported health conditions differ enough from those SF residents to support the assertion that SF NEI values should not be generalized to the MF sector. The data show that the LIMF household NEIs that are directly related to specific health conditions (i.e., asthma and thermal stress) are potentially greater than those observed in the LISF population. Conversely, NEIs related to financial stability or general health (i.e., short-term loans, missed days of work, and home productivity) for the LIMF population appear to be lower than for the LISF population.

The final results of this research will be valuable to numerous stakeholders, including: EE program evaluators, organizations that advocate for increased funding to weatherize affordable MF buildings; local and state weatherization programs; healthy homes programs; public health and health care organizations; property owners/managers; and the residents themselves. These results can also be used to influence Public Utility Commissions to incorporate health-related NEI values into their cost-effectiveness calculations.

Furthermore, the RS asked questions whose results could provide the foundation for the estimation of additional NEIs. Based on interim results, expectations about the magnitude, and whether the observed change appears to be policy relevant, close to a dozen additional NEIs could be the focus of new monetization research. These include: arthritis, diabetes, headaches, utility disconnections, odors, noise, food loss, refrigerated medicines, and electrical medical equipment.

Key limitations and sources of uncertainty. There are three limitations and potential sources of uncertainty in this study: (1) the possibility of systematic error due to respondents' inaccurate or incomplete recall of past events or experiences (recall bias); (2) a lack of random assignment to Treatment and Control groups; and (3) bias due to the characteristics of sampled buildings not perfectly representing the population of buildings of interest.

Another source of uncertainty in this study is inherent to cross-sectional analysis, which involves identifying one or more comparison groups from which we collect the same data as the treatment group. Comparisons were drawn between the CwT group and T and C groups combined (T+C) to measure changes in pre- to post-weatherization outcomes based on the RS results. The comparison group served as the baseline against which the treatment group was compared. This study design assumes that differences between the treatment group and comparison group(s) are due to the "treatment" of weatherization.

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