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ABSTRACT

Ratepayer-funded programs spend millions of dollars on home energy retrofits each year in the United States. Measuring the impacts of such retrofits is critically important to determining whether the benefits justify the costs, and if the program should be expanded, shuttered, or adjusted. Current efforts to measure the impacts of energy retrofits - when carried out at all - are typically limited in their scope. Most focus on energy benefits alone, and in particular, the monetary value of energy savings. While some take a broader perspective, inclusive of non-energy impacts (NEIs), many of those efforts focus exclusively on positive impacts and neglect the potential for negative ones. This research describes the limitations of common methods used to evaluate occupant NEIs of energy retrofit projects and introduces a framework for better understanding and evaluating occupants' NEIs. We reviewed evaluation studies that measured occupant NEIs associated with energy retrofit projects. Based on this review, we developed a comprehensive typology of NEIs. We triangulated our NEI typology with an inventory of building retrofit measures from the National Residential Efficiency Measures Database to articulate the possible NEIs of specific retrofit measures, providing a framework to guide NEI assessments. The framework is a valuable resource because it can guide the assessment of NEIs generally as well as measure-specific NEIs, while capturing both positive and negative impacts. We also consider how our framework can be the foundation of a new assessment tool that addresses the limitations of common NEI evaluation methods.

Introduction

The impact of energy upgrades to occupied spaces can extend well beyond the utility bill, for example, to improve the health, safety, and comfort of occupants. Such additional impacts beyond energy savings gained from installing energy efficient measures are referred to as non-energy impacts (NEIs; Caputo et al. 2017). Efforts to quantify NEIs have been underway for decades; in the 1990s, NEIs gained broad research interest as a lens to increase the estimated market value of energy retrofit campaigns (Brown et al. 1993; Mills and Rosenfeld 1996).

Despite broad agreement on the value of considering NEIs and decades of attention to the subject, there remains a lack of consistency in conceptualizing and measuring occupant NEIs (TecMarket Works et al. 2001). There are three general types of NEIs: social impacts, utility impacts, and occupant impacts (Skumatz and Dickerson 1998). The focus of this paper is occupant impacts which we define as perceived impacts by the occupants of buildings that underwent energy efficient retrofits beyond energy or bill savings. Occupant NEIs are often discussed as intangible effects on occupants' subjective quality of life, also described as soft NEIs (NMR Group 2011), or hard-to-measure NEIs (Skumatz 2002). They are variously defined

in evaluations, rarely comprehensively assessed, and there is often an exclusive focus on measuring positive impacts (Freed and Felder 2017).

Most NEI evaluations have focused on capturing and comparing the monetary value of non-energy benefits (NMR Group 2011; Amann 2006; Schweitzer and Tonn 2002; L. Skumatz 2014). These values are typically assessed by asking participants to estimate a monetary value of NEIs such as comfort, and results can be extremely inconsistent (Myers and Skumatz, 2006; Skumatz and Dickerson 1998; Freed and Felder 2017). Nonetheless, these studies have provided some compelling support of the significance of NEIs, sometimes concluding that their collective net value exceeds that of the associated energy savings (Riggert et al. 2000, Schweitzer and Tonn 2002). For example, a study that was done on the New York Energy $mart program found that NEIs were valued slightly higher than energy savings (Barkett et al. 2006). Tonn et al. (2018) estimated that the energy savings of the weatherization assistance program in 2010 per household unit were $2872 while the value of occupant NEIs were $1816 for the same year.

Quantifying NEIs is helpful for developing cost-benefit analyses for programs and advocating for retrofit policies from a financial perspective. However, the sole focus on monetizing NEIs obscures the possibility of understanding occupants' qualitative experience with retrofits. Understanding how specific retrofit measures impact occupants can also play a role in informing future retrofit practices. There is a lack of research focused on developing techniques to identify and better measure quality of life impacts from the occupants' perspectives and to improve our understanding of relationships between specific retrofit measures and NEIs.

This research reviews occupant NEI evaluation studies and other relevant literature in order to synthesize best practices for conceptualizing and measuring occupant NEIs and to identify areas for improvement in common NEI evaluation methods. Our ultimate purpose is to create an NEI evaluation tool that will facilitate rigorous, standardized assessments of occupant NEIs and build out the body of knowledge regarding relationships between specific retrofit measures and NEIs. The analyses in this paper provide a foundational framework upon which to build such a tool.

Methodology

We conducted an integrative literature review (Torraco 2005). We first reviewed, critiqued, and synthesized representative literature on the topic of NEIs in the context of residential energy retrofits. Using the keywords "energy retrofit", "non-energy benefits", "non-energy impacts", and "co-benefits", we searched Google, Google Scholar, and Web of Science to identify relevant peer-reviewed journal articles, conference papers, and professional reports. Twenty relevant publications published between 1993 and 2018 were identified. We focused on studies that evaluated NEIs of energy retrofit projects using primary or secondary data and excluded review articles. Our review also excluded studies that focused on non-residential retrofits and studies that focused on only a single type of NEI (e.g., health). We reviewed the publications, recording which specific NEIs were considered, the valence of NEIs considered (i.e., positive, negative, or both), and how NEIs were defined, categorized, and measured.

Since our aim was to identify gaps in the NEI evaluation literature, we also drew on insights from other relevant literature. Specifically, we consulted research from the fields of architecture and environmental psychology regarding Post-Occupancy Evaluation, which focuses on obtaining feedback about the performance of the built environment, including energy performance and occupant satisfaction (Li et al. 2018). We also consulted research from

Experimental Psychology and Applied Psychology (Howard et al. 1979; 1981) to better understand the strengths and pitfalls of research designs used in NEI assessments (e.g., self-report and pre-post versus post-then designs). We compiled the knowledge gained from our review of NEI research and insights from other relevant fields to create a framework for a new NEI evaluation tool.

Analysis and Discussion

Toward Clarity in NEI Terminology

There are a variety of terms used interchangeably with NEIs, such as non-energy benefits (NEBs), co-benefits, and multiple benefits (Cluett and Amann 2015). The term "benefits" implies only positive outcomes and is sometimes explicitly defined that way (e.g., Cluett and Amann 2015, Philbrick et al. 2014), although sometimes the term is used in contexts where both positive and negative impacts are considered (Skumatz 2014). Focusing exclusively on positive impacts, or implying such a focus by using the term "benefits", is misleading because energy retrofits can also have negative impacts on occupants, e.g., if new, more efficient equipment is less user-friendly or has inferior performance compared to prior equipment. Thus, we assert that "non-energy *impacts*" is the most accurate and inclusive term for considering the full spectrum of the occupant impacts of energy retrofits.

Toward Consistency in Conceptualizing NEIs: A New Typology

Occupant NEI categorizations differ across the reviewed studies. Brown et al. (1993) identified comfort, health, safety, and indoor air quality as the main categories. Mills and Rosenfeld (1996) identified seven categories: improved indoor environment, comfort, health, and safety; reduced noise; labor and time savings; improved process control; increased amenity or convenience; water savings and waste minimization; and direct and indirect economic benefits. Specific impacts have been inconsistently assigned to these categories across different studies (e.g., reduction of contaminants might be categorized as an air quality, health, or safety NEI). The inconsistent and broad categories used throughout the literature inhibit the possibility of conducting meaningful comparisons across studies.

Future evaluations would benefit from standardization of well-defined and mutually-exclusive NEI categories. Table 1 presents a typology of occupant NEIs that we developed inductively by synthesizing NEI categorization schemes across the reviewed literature, with examples of each type of NEI from the papers reviewed.[1] This typology is thus more comprehensive than prior individual treatments of NEIs. We carefully operationalized each NEI category in order to enable standardized conceptualization of NEIs for greater consistency across future studies.

Table 1. Common NEI categories identified through the literature review. *Indicates negative impacts.

Impact category	Definition	Example NEIs from the publications reviewed

[1] The 20 papers reviewed to compile the examples are all listed in Figure 1.

Aesthetics	Impacts related to the aesthetic quality of the exterior and interior environment	Improved overall appearance of home Better physical condition of home Attractive appliances
Air quality	Impacts related to the air quality of the space	Reduction of contaminants and CO Eliminating back drafting and spillage of combustion products Improved ability to reduce airborne contaminants Reduced pollutant concentrations
Convenience	Conveniences and inconveniences of use related to effort and time savings, overall ease of use and reliability of new retrofit features	Easier cleaning (less dusting and vacuuming) More space Extended appliance lifetime More reliability and less maintenance Poor fit of new equipment, e.g., into many fixtures*
Economic	Direct and indirect economic impacts resulting from the retrofit added values and the energy savings	Impacts leading to changes in expenses or transaction costs: -Extended lifetime of the unit -Reduced service termination and reconnection fees -Reduced bill and operation costs -Higher replacement cost for new bulbs* Impacts leading to a decrease of economic hardships: -Decreased homelessness, evictions and residential mobilities -Reduced home mortgage failures -Increased non-energy expenditures -Reduced need for income assistance Impacts leading to long term economic gains: -Enhanced property and neighborhood value -Eased sale and lease of home -Buffered energy price increases
Education and awareness	Impacts relevant to the information gained through the retrofit process	Increased participant knowledge Greater awareness Ability to make informed decisions when buying new appliances or moving to a new home Ability to control bill and understand it Improved sense of environmental responsibility Greater understanding of home operation
Health	First and second degree health impacts resulting from retrofits	Better UV protection Fewer illnesses (cold, headache, and respiratory issues) Support general mental health and physical well-being Better sleep Fewer doctor visits, hospitalizations, and sick days Less mold and leaks
Noise	Impacts related to noise resulting from indoor equipment and outdoor activities	Low sound infiltration Inside and outside noise reduction Reduced outside noise and inside noise from appliances Quieter HVAC Increased noise from the new equipment*
Process control	Impacts related to occupant control over different home features	Centralized monitoring Optimal speed Better control for light, temperature, and air circulation More options and features Automatic thermostat controls Greater control over HVAC
Safety	Impacts that influence the sense of safety inside and outside the home	Fewer fires Better outdoor security resulting from light Fewer emergency calls Enhanced (sense of) safety
Thermal comfort	Impacts on the perceived temperature and relative humidity of the conditioned space.	Less drafty Reduced thermal stress on occupants Better air circulation Increased ambient temperature in summer*

Visual comfort	Impacts related to the light quality and its impact on visual comfort	Increased light quality Improved quality and quantity of lighting Dimmer or harsher light than incandescent bulbs*
Water and waste minimization	Impacts resulting from less water usage, sewage and waste production	Less solid waste Water savings Sewer savings Reduced water usage Reduced detergent use
Other benefits	Catch-all category for rarely mentioned impacts	Improved productivity Enhanced pride/prestige Enhanced responsibility for family well-being

Toward Balanced Assessments: NEI Valence

Related to the discussion of NEI terminology and the focus on "non-energy benefits", only 11 out of the 20 publications reviewed mentioned negative impacts, most commonly highlighting inconvenience as a drawback of energy retrofits (Figure 1). Inconveniences addressed included making the space smaller or harder to clean, or increasing technical complications. Most of these simply assigned a monetary value for the negative impacts generally, without specifying them. For example, some assigned a numeric value for the resulting decrease in comfort without clearly explaining what caused the decrease of comfort. In other cases, all the positive impacts were detailed and assigned a value, while the negative impacts were simply estimated as a whole and then subtracted from the positive values to present the net positive impacts. Only a few studies (Barkett et al. 2006, NMR group 2011, Skumatz 2002 and 2005), provided equitable focus on detailed examples of the positive and negative impacts. For example, Barkett et al. asked occupants to report whether they experience positive, negative, or no effect for each assessed NEI. Future evaluations would benefit from soliciting information on positive and negative impacts equitably, for the sake of objectivity and completeness.

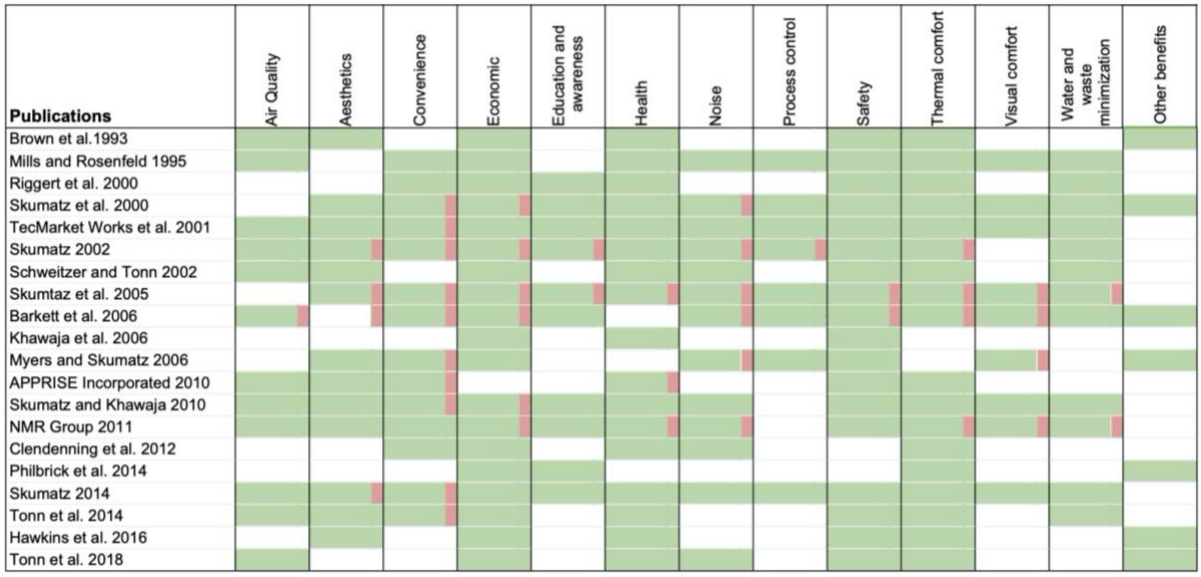

Figure 1. Matrix of publications reviewed and the positive and negative impacts addressed by each publication. The Red bar on the right of the cells indicate that the publication mentioned a negative impact.

Toward Richer Information about the Value of NEIs

As previously mentioned, the most common approach to measuring occupant NEIs has been to assign them a monetary value by asking occupants to characterize the value of NEIs relative to their energy cost savings. The list below summarizes the most widely used strategies to quantify the value of NEIs:

- Willingness to pay (contingent valuation): Asking users how much they are willing to pay for such benefits (Skumatz and Khawaja 2010).
- Direct query: Asking users to provide an estimated dollar value for the benefits (Barkett et al. 2006).
- Relative or comparative valuation: Asking users to compare the value of the benefits relative to the value of the energy savings (Cluett and Amann 2015).
    - Labeled Magnitude Scaling Approach (LMS): Asking users to locate the non-energy benefits gained from the upgrade on a worded scale from much more valuable than the energy savings to much less valuable than energy savings (Amann 2006).
    - Ranking: Asking residents to rank which benefits are the most important.
- Conjoint analysis: Focuses on capturing the attributes that are most important in the non-energy benefits. It develops hypothetical product offerings and asks occupants to choose their favorite group of attributes (NMR Group 2011). This approach focuses on specific technologies, and it is usually used to enhance features related to the technology under evaluation.

Results of these analyses have sometimes been shown to be highly inconsistent, e.g., values that differ by a factor of 100 across reports (Myers and Skumatz, 2006; Skumatz and Dickerson 1998; Freed and Felder 2017). As another example, Myers and Skumatz (2006) found the value of NEIs ranged between 50% - 400% of the value of energy benefits. Some drawbacks to the above approaches might help explain the inconsistency of results. The direct query approach is criticized for pushing the occupants to estimate the monetary value of their experience, which is often difficult for users to do (Barkett et al. 2006). This is particularly true for non-market goods such as NEIs (Clendenning et al. 2012). Relative valuation is criticized for comparing NEIs to energy savings as occupants tend to conflate the benefits with energy savings (NMR Group 2011). Conjoint analysis is criticized for being hypothetical; it does not actually measure user experience with actual retrofit measures, but instead estimates non-price factors and preferences more generally (Barkett et al. 2006).

Capturing the monetary values of NEIs can aid cost-benefit analysis, but it is rarely used to provide insights about user experience that can improve retrofit practices. In a comparative review of the different ways to measure NEIs, Skumatz (2002) recommended a change of approach from marketing such retrofits on the basis of efficiency and energy savings to marketing them based on the NEIs identified by previous participants. "*It may be time to respond to what customers are telling us they care about from the programs. This information can be used to design, target, and market programs to maximize benefits to participants and utilities*" (Skumatz 2002, 318). Through our review of the literature, it seems that this approach is still

rare[2], underscoring the need for an approach to measuring NEIs that gathers occupants' feedback on actual benefits, rather than the monetary value of those benefits.

Toward Understanding Relationships between Retrofit Measures and NEIs

Out of the 20 publications reviewed, only a few (Hawkins et al. 2016; Skumatz et al. 2000; Mills and Rosenfeld 1995) described causal relationships between specific energy retrofit measures and NEIs. For example, Skumatz et al. (2000) specified NEIs related to central air conditioning, window measures, lighting, etc. Potential air conditioning retrofit NEIs included higher house value, bill saving, greater comfort, and a quieter environment; window measure NEIs could include higher house values, greater comfort, and easier cleaning and use, etc. This approach enables possible associations between specific retrofit measures and impacts, yet it does have some limitations.

Mapping NEIs to specific upgrades in the case of deep retrofits with many measures is very challenging. In some cases, participants might not be able to attribute impacts to specific measures. However, many energy retrofit programs only install a few measures at once making ours a useful tool to assess the impact of individual measures. Previous attempts to assign values of NEIs to specific measures have relied on statistical models, which will provide an initial reference to our tool (McClain and Skumatz, 2006). The next step in the development of our framework will work on framing the survey questions in a way that helps the respondent spell out the possible role of each impact and its relation to installed measures. With the full development of our database, new users will be able to see the percentage of correlation between impacts and specific measures based on the results of past projects that used our database.

We triangulated our NEI typology (Table 1) with the retrofit measures in the National Residential Efficiency Measures Database (NREMD), a centralized resource of residential building retrofit measures (and costs) for the U.S. building industry. Supported by the U.S. Department of Energy, the tool helps users determine the most cost-effective retrofit measure for improving the energy efficiency of existing housing. We mapped the NREMD measures to the NEIs to which they could potentially contribute. Figure 2 presents this framework as a matrix that can be used two ways: (1) to identify NEIs potentially associated with specific retrofit measures, and (2) to identify potential retrofit measures that could contribute to a desired NEI. For example, a user can easily identify all the potential NEIs of an air conditioning retrofit (Figure 3).

This matrix could be used to help guide and evaluate energy retrofit projects. For example, in an online format, users could filter retrofit measures by potential associated NEIs, or select a set of measures to generate a potential NEI profile. Modules of survey questions could be linked to each NEI, retrofit measure, and/or combination thereof.

[2] New construction programs such as Zero Energy Ready Home which was established in 2012, have managed to market the program through its comfort qualities, but this approach does not seem to be as common with retrofits.

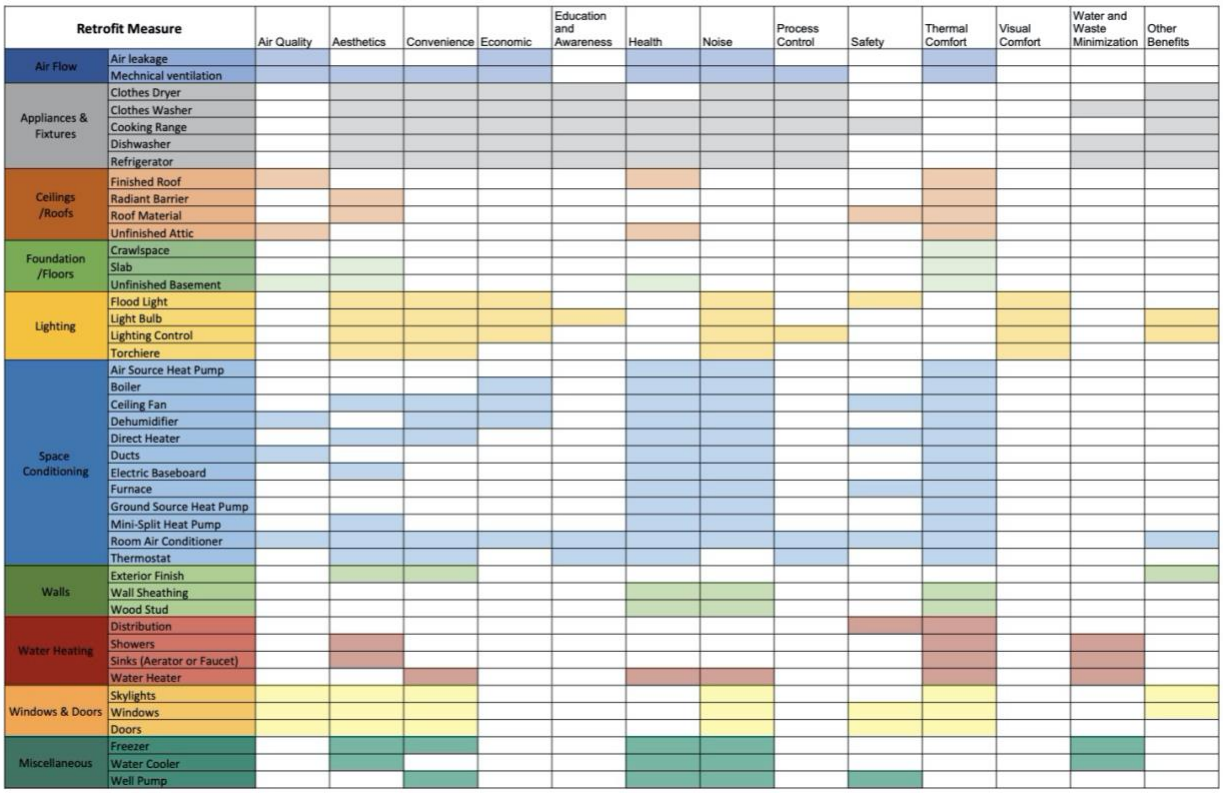

Figure 2: Proposed matrix connecting NREMD retrofit measures with potential NEIs

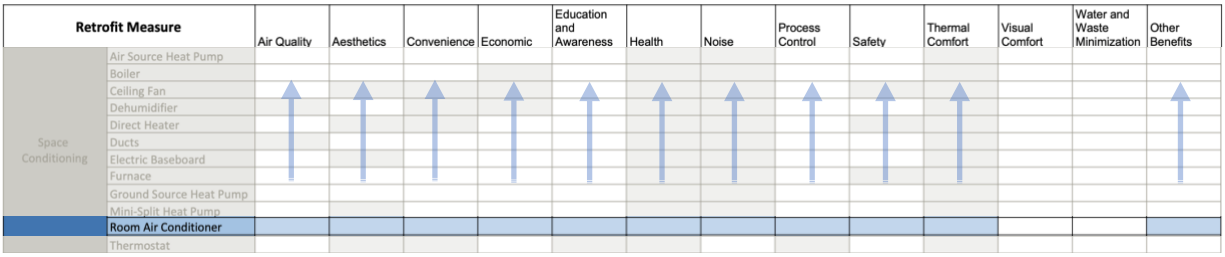

Figure 3: Tracking NEIs associated with room air conditioners.

Toward Valid, Reliable, and Unbiased Results: NEI Research Design

Pre-post measurement. Some studies recommend measuring NEIs via surveys or interviews conducted both before and after retrofits (these are pre-post designs to measure change in perceptions from baseline; see for example APPRISE Incorporated 2018; Cluett and Amann 2015). This recommendation can also be found in the Post-Occupancy Evaluation (POE) literature (Leaman and Stevenson, 2010), especially when trying to understand user experiences and satisfaction (Knudsen and Jensen 2015). However, few NEI studies actually use this approach, likely due to challenges such as attrition (APPRISE Incorporated 2018) and greater resources required for multiple data collection efforts.

Insights from the field of experimental psychology suggest additional reasons that the pre-post method might not be optimal. For example, pre-post designs are prone to response shift bias whereby an occupant's internal standards shift in response to the intervention (e.g., retrofit)

to which she was exposed (Schwartz and Sprangers 1999). This shift can be in the respondent's values, conceptualization, or understanding of the initial construct being questioned. This makes the results internally invalid (Howard et al. 1979; Howard 1980). Studies in fields such as education and health have identified response shift bias (Klat and Powell 2005; Sibthorp et al. 2007; Blome and Augustin 2015), but it has not been discussed in the context of NEI evaluation.

There are three types of response shift bias that can potentially skew results of pre-post tests. The first is *reprioritization,* in which the value an occupant assigns to something changes between the pre-test and the post-test (Blome and Augustin 2015; Schwartz and Sprangers 1999). For example, when an occupant's prioritization of comfort vs. affordability changes between the pre- and post- test, her assessment of a retrofit measure may shift. The second type of response shift bias is *reconceptualization*, which occurs when an occupant changes her definition of the construct that is being questioned (Blome and Augustin 2015). For example, "efficiency of use" for a home appliance might be interpreted by the respondent as ease of use in the pre-test, but later the same respondent might interpret "efficiency of use" as speed of operation. The third type of response shift bias is *recalibration*, which occurs when the occupant's internal standard of interpretation changes after the pre-test, resulting in understanding the response scale differently in the post-test (Blome and Augustin 2015). For example, an occupant may assess the air quality in her unit as good in the pre-test and very good in the post-test as a result of an experience with poor air quality in the intervening period that raised her assessment of the otherwise consistent air quality at home. Finally, pre-tests on their own can introduce bias by influencing expectations of the retrofit program, making them a part of the intervention (Sibthorp et al. 2007), thus influencing the "pre" period.

Another potential problem with the pre-post test is a phenomenon called "environmental numbness". This phenomenon questions the extent to which occupants have opinions about their surrounding environment. Since the environment is composed of many elements, occupants cannot monitor all of them, and therefore limit their attention to selected aspects. This can make the occupant unaware of many aspects of her physical surroundings, even if it is causing some difficulties (Gifford 1976). In the process of capturing NEIs, occupants are typically asked about detailed aspects in their environment, such as smell, air quality, light quality, and thermal comfort. In many instances, the occupant might not have a ready answer because she is being asked about aspects that she has never considered. This is an example of environmental numbness. In the context of pre-post tests, the occupant might not have any clear cognitive or evaluative judgment with regards to some aspects of her home, but after exposure to the pre-survey and the retrofit measures, her awareness is heightened. In this case, the responses from the pre- and post- tests should not be directly compared because they were answered with different levels of knowledge (Gifford 1976; Weenig and Staats 2010).

Retrospective measurement. To address the drawbacks of the pre-post tests, other disciplines with a focus on intervention measurement, including experimental education and health, recommend using retrospective questions, called a "post-then" approach or a "then test" (Howard 1980, Rohs 1999; Sibthorp et al. 2007). The retrospective approach asks the participant to assess the conditions after interventions and to reflect back on the same conditions prior to the intervention. For example, an NEI evaluation tool based on the retrospective approach would include pairs of questions: the first to ground the respondent's assessment in the present time (e.g., How convenient is your current air conditioner?), and the second to compare that with conditions before the retrofit (e.g., Is your new air conditioner more, less, or equally convenient

compared to your previous one?). Since the pre- and post- evaluations are taken at the same time, occupants apply the same internal frame of reference to both periods (Gorrall et al. 2016), which eliminates the potential for response shift biases. The retrospective approach is perceived as a more accurate and sensitive assessment of human perceptions of change (Schwartz and Sprangers 1999).A retrospective approach to measuring NEIs at a single time point can also avoid the hassles and additional resources required for multiple collection efforts.

Drawbacks to the retrospective approach include recall bias, in which participants misremember their previous state as better or worse than it actually was (Blome and Augustin 2015). This bias can be mitigated by asking the occupants to report on their perceived memory (Schwartz and Sprangers 2010); e.g., "To what extent do you feel able to recall the unit conditions before the retrofits?"). Another approach is to include questions in the retrospective tool that can be compared with another independent measurement such as air quality, temperature, or humidity data. In such a case, the researchers will have an indication of the potential amount of recall bias in the data for which they can adjust.

Finally, it is important to note that the use of a retrospective tool to measure change does not eliminate the need for baseline assessments. These are valuable for determining the needs of the community when prioritizing potential retrofit measures. To clarify, we do not question the usefulness of baseline assessments to guide retrofit decisions; we challenge their validity when compared to post assessments to detect (and quantify) occupant NEIs.

Conclusion

This paper synthesizes current approaches to measuring the NEIs of energy retrofit projects and highlights shortcomings by drawing on literature from related disciplines. We identified many challenges that collectively make efforts to collect data on NEIs inaccurate, incomplete, and non-comparable. We make the case that a new measurement tool for NEIs is needed, one that supports more comprehensive and standardized indicators that can be used over different projects while minimizing biases. We present a framework for a new tool, highlighting how it avoids the potential pitfalls of other approaches we reviewed. To conclude, we summarize the key critiques of existing approaches to measure the impacts of energy retrofit projects, and the advantages our tool offers.

Positive and negative impacts: Our review indicated that there is a strong tendency to assume NEIs are positive. Many studies ignore, or do not treat with equal precision, the potential negative impacts of NEIs. Understanding both the positive and negative impacts of energy retrofits is vitally important for informing future retrofits and avoiding repeated mistakes.

Monetary value versus qualitative impacts: Assigning monetary values to qualities such as comfort and safety can be a useful way to standardize the costs and benefits of an energy retrofit project. But estimating monetary values has its limitations. Assigned values are often highly subjective, and therefore controversial and inconsistent. Furthermore, they obscure qualitative details. More attention to the qualitative impact of the values being measured rather than the monetary value can help to prioritize measures and estimate the full range of their contribution to the occupants' quality of life.

Pre-post versus respective approaches: While the current energy retrofit literature recommends using pre-post approaches to measure NEIs, there remains a vast amount of literature from other disciplines that criticizes this approach for its potential biases. Retrospective tools avoid or account for these potential biases in a way that improves resulting measurements.

Stand-alone studies versus a database: Our review indicates that the range of impacts identified, and how they are measured, are not always consistent, depending on the scope of the research and the questions being asked. The diversity of approaches to identify and measure impacts limits the ability to make comparisons and build a collective knowledge base. A more robust tool that is flexible enough to be used over many projects can help in generating a database for NEIs across many projects.

In an attempt to address these drawbacks, this paper introduces a framework for a comprehensive tool to measure NEIs. We based our framework on a typology of NEIs that is carefully operationalized to enable standardized conceptualizing and consistency of NEIs. The framework facilitates the measurement of both positive and negative impacts along with avoiding the use of terms such as 'Non-Energy Benefits' due to its underlying positive connotation. The framework introduces a more qualitative measurement approach that can capture the different impacts affecting the occupants' quality of life while avoiding the high variation and inconsistency of current approaches. The framework adopts a retrospective survey approach to avoid the current response shift biases and administration hassles associated with the pre-post approach. We linked our framework with a centralized residential retrofit database to help users determine which measures can potentially lead to desired NEIs. Once fully developed, our framework will be an open-access database that is easy to grasp and offers suggested questions for measuring each NEI with relevance to its retrofit measure. We hope that this tool proves valuable to program implementers, utilities, energy experts, builders, contractors, residents, as well as researchers and policymakers.

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