

Memorandum

Negative Non-Energy Impacts

To: Fernando Morales, Ameren Illinois; Jennifer Morris, ICC
From: Opinion Dynamics Evaluation Team
Date: February 10, 2020
Re: Literature Review Findings for Negative Non-Energy Impacts (Final)

Introduction

Non-energy impacts (NEIs) are the impacts, both positive and negative, that energy efficiency programs produce in addition to energy savings and demand reduction. Impacts include economic, environmental, health, and other ancillary outcomes of an efficiency project. The added costs and benefits may accrue to the sponsoring utility, the individual participant, or to society at large. While energy efficiency program evaluators often discuss the potential for both added benefits and for added costs, Opinion Dynamics' 2018 NEI literature review identified a gap: there are only a few rigorous studies about identifying and measuring negative NEIs.

This memo focused on collecting the limited readily available research on negative NEIs, determining which negative NEIs have been the most heavily studied and what types of effects have been observed, and exploring the research methods that could be employed to assess negative NEIs in the future. Available evidence confirms that most primary research studies tend to focus on benefits (positive NEIs). We identified 12 studies that specifically explored costs (negative NEIs); even in these studies, researchers found that they are rare. Like positive NEIs, negative NEIs depend on the program design, customer sector, and efficient equipment. The reported negative effects included:

- Increased operation and maintenance costs of commercial efficient equipment compared to conventional equipment;
- Negative customer sentiment about the aesthetic appearance or performance of efficient equipment compared to conventional equipment;
- Negative human health and wildlife effects of cool-temperature LEDs; and
- Ventilation and indoor air quality problems associated with weatherization projects that are not completed correctly.

Search Methods

We focused our review on studies that mentioned negative NEIs, added costs of energy efficiency, or other related terms. We focused our search on publicly available energy efficiency program evaluation reports, as well as conference papers and presentations from the energy efficiency evaluation industry. We identified 23 studies that mentioned negative NEIs. Half of the studies only discussed the potential for negative NEIs at a high level. We completed a detailed review of the 12 that provided greater detail or attempted to quantify and/or monetize the negative association or effect.

Key Findings

This section contains our key findings (organized by program design and measure mix) as well as our observations about available methods to research negative NEIs for Ameren Illinois in the future.

Negative NEIs by Sector and Program Type

- **All Sectors – Lighting:** Generally, LEDs are brighter and longer lasting than conventional lighting, leading to better-lit common spaces and reduced trips and falls. Our review identified few negative NEIs of LEDs.¹ Identified negative NEIs of LEDs appear limited to LEDs that have a cooler color temperature (discussed below), and an isolated number of program participants who have perceived that LEDs are dimmer than conventional bulbs. Outside of the energy efficiency industry, cool color lights and “blue light” have been associated with circadian rhythm disruption, negative occupant health and mental health, and LED streetlights that interfere with nocturnal wildlife. This said, Ameren Illinois plans to stock 3000k streetlights, which the American Medical Association² recommends as the ideal color for outdoor installations.
- Tetra Tech, NMR, and DNV GL (2018): This framework study presented to Massachusetts Program Administrators (PAs) developed an assessment of the available methods for addressing and quantifying NEIs in the residential, low-income, and commercial and industrial (C&I) sectors. According to the report, program staff noted that other studies had reported negative health NEIs due to the blue light associated with LED technology, and that this made PAs hesitant to support energy efficient street lighting. Among these potential blue light effects are increased glare, decreased visual acuity and safety, and melatonin-suppression at night that disrupts circadian rhythms and can cause sleep and health problems. To minimize these effects, the American Medical Association recommends the use of LED lighting that minimizes blue light exposure.³
- NMR (2016): As part of a process evaluation of the Home Energy Solutions (HES) program and the HES Income Eligible (HES-IE) program conducted for the Connecticut Energy Efficiency Board, NMR measured NEIs from the programs through participant surveys and in-depth interviews with landlords and property managers. Negative impacts reported by program participants were ‘very rare,’ including safety issues from perceived dimness from lighting changes. Program participants had received LEDs.
- Gaston et al. (2012): This ecological study addresses the potential environmental consequences of night-time light pollution, which is relevant to LED streetlighting programs that either install new lights or retrofit existing warm-spectrum but less-efficient streetlights with LEDs. The findings suggest that integrating light into previously dark night-time environments negatively affects biodiversity and animal health. Like humans, animals are sensitive to the changes in the spectrum, composition, and duration of lighting. Integrating artificial lighting into naturally unlit outdoor areas at night—or changing the

¹ Standard CFLs—which most programs no longer offer—were more often associated with negative NEIs than LEDs are. Relative to incandescent and halogen bulbs, CFLs took longer to warm up and customers disliked their dimness, bulb appearance, flicker, and added disposal and environmental hazard costs (CPUC, 2011).

² American Medical Association. Policy H-135.927, Human and Environmental Effects of Light Emitting Diode (LED) Community Lighting. <https://policysearch.ama-assn.org/policyfinder/detail/H-135.927?uri=%2FAMADoc%2FHOD-135.927.xml>

³ American Medical Association (2016) “AMA adopts guidance to reduce harm from high intensity street lights” Press Release, <https://www.ama-assn.org/press-center/press-releases/ama-adopts-guidance-reduce-harm-high-intensity-street-lights>

existing light infrastructure—can also negatively affect wildlife sleep patterns and seasonal behaviors. LEDs specifically can affect animals that are sensitive to light cool-color wavelengths.

- **All Sectors – Demand Response:** While AIC does not currently offer demand response programs as part of its core energy efficiency portfolio, we provide the following findings to support any future program planning. Demand response participants are compensated for reducing their energy use at certain times of day or year, such as through a bill credit or payment per event. Because reductions may target heating and cooling equipment, participants may experience indoor temperature changes during events. Program participants report experiencing NEIs both before a demand response event is called and during demand response events. When reducing cooling usage during hot summer months, some business and residential participants may observe increased discomfort, inconvenience, or (for businesses) lost revenue relative to leaving their cooling system on “as usual.”
- **CPUC (2011):** In a framework study conducted by the California Public Utilities Commission (CPUC) for California utilities, the CPUC Energy Division staff examined NEIs attributable to demand-side programs and methods for addressing them in the CPUC’s cost-effectiveness tests. Demand response program participants in California experience non-energy costs both before and during demand response events. Prior to a demand response event, non-energy costs include those associated with developing a load shedding plan. During a demand response event, the associated costs are productivity and comfort losses that stem from reduced energy services. Additionally, if customers use back up diesel generators during demand response events, then a cost is also incurred by society for the added fossil fuel use. Because these costs are difficult to quantify, CPUC required that the utility estimate these costs as 75 percent of the incentives received by participants (as of the 2011 study).
- **Business and Industrial Sectors – Standard and Custom Programs:** Based on one large study of C&I sector NEIs, negative NEIs are rare and tend to be small relative to positive NEIs in these sectors. The most discussed negative NEIs are increased Operations and Maintenance (O&M) costs, including increased preventive maintenance and staff salaries/ administrative costs associated with the efficient equipment.
- **Tetra Tech (2012):** Through a large-scale in-depth interview effort to analyze the NEIs of C&I retrofit programs administered by Massachusetts PAs, the evaluation team found that 3% of the program’s measure installations resulted in net negative NEIs (22 of the 789 prescriptive and custom electric and gas measures installed by 788 interview respondents). Participants were asked to discuss positive or negative changes in each of 12 cost categories⁴ associated with prescriptive electric projects (HVAC, lighting, motors and drives, refrigeration, and other), gas prescriptive projects (envelope, HVAC, and water heaters), as well as for custom electric and gas projects. The prevalence of negative non-energy impacts appears to be primarily measure-specific for retrofit programs due to the variability of installation difficulties and familiarity (or lack thereof) for each type of energy efficient equipment.
- Estimated annual prescriptive program NEIs were net positive and statistically significant for electric HVAC (\$0.10/kWh), lighting (\$0.03/kWh), gas envelope (\$3.62/therm) and gas HVAC (\$755/therm) but not statistically different from zero for other prescriptive electric and gas measure categories. The identified net negative effects were limited to two areas. Electric program participants noted net negative effects due to prescriptive HVAC (other labor, -0.3% contribution to net NEI value for HVAC, n=138 projects) and due to motors and drives (sales revenue, -0.5%

⁴ Cost categories included administrative, fees, material handling and movement, O&M, product spoilage, rent revenue, sales revenue, other revenue, waste disposal, other labor, and other costs.

contribution to net NEI value for motors and drives, n=92 projects). The negative sales effects for motors and drives resulted from a Variable Speed Drive (VSD) malfunction that caused the equipment to shut down for two hours. The negative labor effects for HVAC projects was because some respondents reported an increase in labor due to preventative maintenance and increased time to ensure that all equipment was operating correctly.

- Estimated annual custom program NEIs were often net positive and statistically significant. Five of six custom electric measures had significant positive NEIs; values ranged from \$0.02/kWh (HVAC, n=20) to \$0.06/kWh (Lighting, n=89). Two of four custom gas measures had significant positive NEIs, including Envelope (\$0.48/therm, n=46) and HVAC (\$0.22/therm, n=41). Combined Heat and Power (CHP)/Cogeneration was the only custom measure associated with a significant negative NEI (-\$0.01/kWh, n=6), attributed to increased preventative maintenance and administrative costs for the energy efficiency equipment. For the average CHP/Cogeneration project, the negative NEI amounted to \$12,949 per year. Authors noted that this negative effect “was largely because co-generation requires an entirely new piece of equipment” as well as new back office labor to support it.
- Overall, while the study found that negative effects are generally rare and that average effects stem from a small number of customers or projects, the costs can be quite noticeable for those participants who do experience them. Within the bounds of a large program, multiple customers may experience these types of effects.
- **Residential Sector– Efficient Products:** Negative NEIs associated with efficient products are rare and measure-specific. In some instances, evaluations have found that customers had a negative experience with the installation process or disliked the aesthetics of the efficient equipment compared to conventional equipment.
 - SERA (2014): This residential program framework study of non-energy impacts found negative household impacts to be rare and that they were “not usually found to be important/valuable” quantitatively; however, the authors discuss the potential for negative NEIs including the hassle of installation, disapproval of aesthetic appearance, and maintenance issues. This study also suggests that negative NEIs of energy efficiency could be interpreted as a quantitative measure of program barriers. For example, visual differences between efficient and standard equipment could be a participation barrier for those with strong aesthetic preferences. Because the authors drew on their prior experience to develop this report, it is unclear what reference conditions they used for each NEI—for example, installation hassle may be a factor no matter the equipment efficiency and therefore would not be an NEI of efficient equipment specifically. Future NEI studies of efficient products programs should carefully consider the counterfactual scenario.
 - **Residential Sector – HVAC:** Research on negative NEIs from residential HVAC programs is rare. We identified several studies discussing the aesthetic barriers to ductless mini-split heat pump adoption specifically. As these measures grow in popularity, we expect to see growing literature on their NEIs.
 - ARIES (2014): In a feasibility study conducted on ductless mini-split heat pumps (DMSHPs) in multifamily retrofit programs, findings suggest that aesthetic preferences were a participation barrier for some consumers. For example, Efficiency Maine provided incentives for the installation of MSHPs through their Low-Income Multifamily Weatherization program. Interviews with Efficiency Maine revealed that some residential owners were not interested in DMSHPs due to their dislike of the appearance of the outdoor compressors or line sets.

- IBACOS, Inc. (2017) analyzed heat pump performance and market conditions needed to support uptake. Authors noted aesthetic barriers to DMSHPs, noting that “although the “high-performance story” can convince some buyers to overlook the aesthetics of the [indoor air handling] units, many buyers are deterred from purchasing houses with this equipment installed.”
- Cadmus (2016) As part of on-site participant visits to support an impact evaluation of DMSHPs in Massachusetts and Rhode Island, researchers learned of several positive non-energy impacts for customers replacing window air conditioners (e.g., regained use of windows for ventilation and daylighting, increased security from locking windows, less outdoor noise, and others) and those choosing a ductless system instead of installing a new central cooling system (e.g., avoided ductwork installation costs). Authors do not note whether respondents were asked about any potential negatives, but none are reported.
- **Residential Sector - Multifamily:** In addition to measure-specific outcomes discussed above, property managers may experience general increases or decreases in O&M effort and cost based on the nature of the upgrades. While several studies assess both positive and negative NEIs, effects tend to be net positive from the property manager and tenant perspectives.
 - NMR (2011): In an NEI evaluation of Massachusetts low income and market rate multifamily energy efficiency programs, this study surveyed building owners and managers about the presence and value of non-energy impacts. Some of the managers noted that tenants felt the new equipment was noisier (4%) or less reliable (11%), that lighting was too bright or too dim (4%), or that lighting took too long to come on (4%, n=27). When asked about the overall impact of the NEIs discussed during the survey, 4% of property staff reported negative changes in the durability of the property, while 12% noted increased tenant complaints and 17% reported that other changes were negative on balance. None reported negative changes in rental unit marketability, turnover, property value, or equipment maintenance (n=26). No interviewees perceived a net negative impact of all NEIs together (n=26). Overall, the study found that NEIs are net positive for the multifamily program, equating to about 10% to 18% of energy savings, depending on the impact category.
 - NMR (2016): The process evaluation of the effectiveness of the HES and HES-IE programs in Connecticut also conducted in-depth interviews with participating landlords and property managers in part to determine the prevalence of non-energy impacts of the program. Among the 29 HES-IE landlords and property managers that were interviewed, only one respondent found the net non-energy impacts to be negative while one respondent found the net impacts to have no effect. The remaining 27 of 29 respondents reported net positive impacts. Two of 29 respondents reported tenant safety concerns tied to the difficulty of opening windows or latching exterior doors post-air sealing (2 of 29 respondents). Other reported effects related to CFLs, which most program administrators no longer offer.
 - Opinion Dynamics (2019): In a draft memo to Ameren Illinois, our evaluation team explored the potential for positive and negative NEIs among multifamily property owners. We did not identify a strong potential for negative NEIs. Two-thirds of property managers plan to market the new energy-efficient upgrades they received through the Initiative to potential tenants (n=15). Most tenants (95%) said they are more or just as likely to renew their lease since receiving upgrades (n=75). These trends suggest it will be easier, rather than harder, to find new tenants. At turnover, most property managers (81%) reported they anticipate having to complete the same (81%) or fewer (19%) amount of unit repair and cleaning activities after the upgrades (n=16).
- **Residential Sector – Weatherization:** Weatherization is generally understood to positively benefit indoor air quality. However, researchers have occasionally found that weatherization reduces air ventilation and

that participants observed increased indoor humidity, asthma, allergy symptoms, or home maintenance costs. As NMR (2011) noted, “This is particularly the case if a pollutant source, such as mold or pests, is not removed, so that exposure levels are in effect increased by reducing air infiltration, due to changes in the home made by the efficiency program.” Such negatives and added costs may be limited to weatherization projects where the work was not completed to quality standards, as weatherization upgrades that seal and insulate the building shell should also ensure adequate indoor-outdoor ventilation.

- NMR (2011). This study surveyed recent renters and owner-occupant participants in the Massachusetts residential energy efficiency home upgrade programs, finding that while some participants experienced negative NEIs, all felt that their projects had a net positive effect. Of the market rate and low-income renters and owners who participated, 80% of low income respondents (n=213) and 88% of non low income respondents (n=209) reported that their project had only resulted in positive impacts. A few respondents (2% to 4% by impact type) reported negative impacts after the program including draftiness, dissatisfaction with lighting, hot water that takes too long to heat, ice dams or snow accumulation on the roof, leaks in the attic, ineffective weather stripping, and increased equipment noise. It seems possible that some of these effects could be due to improper installations, while others may be due specifically to the efficient equipment. On net, only 2% of low income respondents and none of the non low income respondents judged the overall change in non-energy impacts to be negative.
- Efficiency Vermont (2018): Efficiency Vermont conducted a post-participation survey (n=318) of qualified customers of the Home Performance with ENERGY STAR program. Efficiency Vermont sought to understand participants’ perspectives regarding NEIs of the program. At least one year following receiving energy efficiency improvements on their homes, 3% of respondents (11 of 318) reported in a post-participation survey that they experienced some negative NEIs since the project. Of this small number of respondents, their primary concerns were related to ventilation and humidity, including indoor moisture accumulation. Participants reported that aspects of their home or health had become either ‘a little worse’ or ‘much worse’ since receiving energy efficiency improvements, including their home’s comfort, home maintenance, noise levels, safety, quality of sleep, allergies, colds/flu, sleep apnea, COPD, and asthma. It is difficult to fully attribute these changes to the weatherization because the study did not use a comparison group to control for non-program factors that could have contributed to these changes. Overall, these effects are rare and appear to be outliers relative to typical participant experience.
- Vermont Department of Health (2018): This literature review analyzed the existing evidence of potential negative and positive health impacts of building weatherization strategies. The preponderance of evidence (17 of 19 studies) suggests that weatherization produces positive impacts on indoor climate and occupant health. In the 19 quantitative studies reviewed for the study, none reported negative effects on indoor temperature, mold, overall indoor air quality, pests, general occupant health, upper respiratory symptoms, cardiovascular health, neurological symptoms, infectious disease, accidental injury, mental health, productivity, financial health, and health care utilization and costs.⁵ However, some studies identified negative impacts on indoor humidity (1 of 11 studies) and asthma symptoms (1 of 9 studies). When these impacts did appear, they were attributed to either insufficient ventilation after the project was completed or projects that had vented in humid air without dehumidifying it. Findings suggest that these negative impacts can be avoided through the

⁵ The authors reviewed between 1 and 14 studies per type of impact.

“appropriate” design of an energy-efficient ventilation system and implementation of a dehumidifier, if needed. The authors review findings by Willand et al. (2015), who acknowledge that concerns exist regarding the potential to create negative health impacts by “over-tightening” a house or unintentionally reducing air circulation below a healthy level. However, if industry standards for ventilation are met, the risk is minimal and will likely maximize the health benefits of weatherization.

- NEEP (2017): This synthesis report identifies that challenges in measuring NEIs can stem from the difficulties in determining net impact in cases where a program generates both negative and positive non-energy impacts. An example of this is the weatherization of a home in a high radon zone, because it could result in negative, positive, or both negative and positive impacts on the home and its occupants.
- LBNL (2014). This 33-state study measured indoor conditions at 514 homes in the one month before and one month after participants received DOE Weatherization Assistance Program upgrades, including 189 homes randomized into a control group. Researchers measured air quality (carbon monoxide, radon, formaldehyde, humidity), temperature, and visual moisture issues over time. Nearly all measurement happened during the heating season.
 - On average, weatherization increased indoor radon levels in proportion to the reduction in natural ventilation that results from air-sealing work. Authors noted two caveats. Because the study included an over-sample of homes in high-radon regions, results may not apply to all regions of the United States. Also, the study was conducted before DOE updated its program ventilation standards to ASHRAE 62.2; authors suggest the observed effects may not apply to programs providing ventilation at the time of weatherization.⁶ Notably, ventilation systems installed in 21 of the study homes often reduced radon concentrations.
 - No increases in the other metrics were detected post-weatherization, but authors caution that small sample sizes and research limitations may have prevented them from detecting any effects.

Research Methods for Negative NEIs

Policymakers call for more information about NEIs in an effort to rebalance cost-effectiveness testing, which has historically skewed towards participant costs and is generally understood to have omitted a number of known but hard to measure benefits, such as health and environmental NEIs. Perhaps given this context, most of the NEI research we have reviewed—save for the studies discussed above—have an implicit focus on capturing new non-energy *benefits*. This appears to have inadvertently created a gap in the understanding of added economic, comfort, health, or other costs of energy efficiency. Although negative outcomes do appear to be rare, to avoid repeating the imbalanced approaches of prior research, we recommend explicitly researching the potential for both added non-energy costs as well as added non-energy benefits when conducting NEI studies. The primary tools for assessing NEIs include participant interviews and surveys (with or without a comparison group) as well as economic and health science models. Benefits and drawbacks of these methods are discussed below:

⁶ US DOE guidance on protecting and improving indoor air quality during weatherization counsels providers to install precautionary measures in EPA Radon Zones 1 and 2 (such as Illinois), where there is a high likelihood that radon may be present and increase without proper ventilation provided alongside weatherization.

- **In-Depth Interviews:** In-depth interviews are an ideal method to explore detailed and nuanced information about NEIs, such as where NEIs are likely to be complex and variable based on program- or region-specific issues (e.g., program procedures designed to avoid increasing radon levels within weatherized homes) or individual participants' measures and experiences (e.g., custom business programs). Interviewers have the flexibility to guide the conversation to focus on the most important topics in each interview. In-depth interviews are also suitable if the participant population is small and hard to reach. That said, in-depth interviews are a lengthier and costlier way to collect data (relative to web surveys), do not offer the sense of anonymity from a survey, and are better suited for qualitative research than for quantitative research.
- **Participant Surveys:** Web or phone surveys can cost-effectively gather data from a relatively large sample of respondents and are best suited to capturing NEI metrics which can be assessed with standardized closed-ended responses. Surveys could be used for both a high-level screening effort (i.e., adding several questions to a survey already planned to support annual program evaluation) or for a detailed large study (i.e., Opinion Dynamics' upcoming standalone survey of Income Qualified participant health, comfort, and safety NEIs). Used for these purposes, surveys are likely to be more cost-effective at scale than interviews. But, because the respondent takes the survey unassisted, there is no opportunity to ask clarifying questions or probe for effects that may not be top-of-mind. For this reason, surveys may be less valuable in cases where researchers want to explore what new or additional types of NEIs may exist, beyond ones that have been documented before.
- **Modeling Software:** A variety of pre-packaged tools exist to model the societal effects of energy efficiency programs on the economy (e.g., economic impact modeling and jobs analysis tools such as IMPLAN and others), the environment (e.g., US EPA's AVERT tool, which models changes in air emissions due to changes in power production), and public health (e.g., EPA's CoBRA tool, which models changes in adverse health effects due to changes in air emissions from AVERT). Published tools like the ones cited here are peer-reviewed and ready-to-use. Tools are suitable for societal or macroeconomic NEIs that cannot be assessed through participant and non-participant self-report; i.e., because effects are too rare or the pathway between intervention and effect is too complex. Tools could be further vetted based on the developer's source assumptions and documentation. That said, tools are only available for some types of NEIs, and a drawback of using these tools is that researchers may be constrained to pre-set levels of granularity and analytic assumptions; they should consider whether model limitations are acceptable for their research needs or policy and regulatory context. Software that allows sensitivity analysis or offers multiple settings may be better set up to capture a range of potentially positive or negative NEIs.

In 2020, the Opinion Dynamics team plans to assess the potential for negative and positive NEIs of the following AIC initiatives: Standard (including SBDI), Custom, and Income Qualified (single- and multi-family), as well as the regional effects of the Residential and Business Programs at large (societal health effects and through continued involvement in regional economic impact modeling).

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