Opinion Dynamics

MEMORANDUM

To: Tammy Jackson, Nick Warnecke, Ameren Illinois Company; Seth Craigo-Snell, SCS Analytics; and Elizabeth Horne, ICC Staff

From: The Opinion Dynamics Evaluation Team

Date: February 25, 2025

Re: AIC Accessibility Pilot Non-Energy Impact Research

This memorandum presents findings from Opinion Dynamics' exploratory non-energy impact (NEI) literature review for the Ameren Illinois Company (AIC) Accessibility Pilot. In preparation for the literature review, we examined the pilot's materials and database, interviewed AIC staff and delivery partners, and held a planning session with AIC, implementers, and stakeholders. The objective of the literature review was to explore, identify, and document potential NEIs that could be generated by the pilot's measures over time. This research aims to inform future program activities and evaluation strategies for measuring any NEIs AIC opts to promote via the pilot.

INTRODUCTION

The Accessibility Pilot is designed to enhance the lives of AIC residential customers with disabilities by installing various smart home devices at no cost. These smart devices are intended to enhance the functionality of the customer's home, which in turn may foster independence, heighten safety, and support personal agency while potentially helping conserve energy. The measures installed include advanced thermostats, smart speakers, video doorbells, smart lighting and electrical outlet controls, and water-saving measures. Pilot implementers provide customer education on the general functionality and features of the installed products. The installation of measures is customized based on the needs of the pilot participants and is provided through a third-party vendor, Solutions for Energy Efficient Logistics (SEEL), in partnership with AIC.

Interviews with AIC staff and implementers indicate that while the pilot has seen successes in its initial implementation, it has also faced challenges. Establishing operational processes in collaboration with the implementation team took time, delaying early project launches. Additionally, ensuring consistent communication and coordination among various stakeholders remains complex, particularly as new community delivery partners are considered. Nonetheless, after the initial time needed for pilot start-up, the team installed measures in more homes than initially planned and was poised to continue increasing delivery in the future. Interviews with AIC staff and the implementation team revealed uncertainty about possible NEIs, though interviewees did suggest time savings may be a possible measurable impact.

RESEARCH METHODS

The evaluation team completed two types of searches. First, we searched the web for comparable programs. Second, we conducted a formal literature search and review of potential NEIs that the Accessibility Pilot measures could generate; this search also yielded information about comparable programs. For this search, NEIs include any additional benefits beyond energy savings.

To prepare for the searches, we identified pilot measures through a review of pilot materials, quarterly data, interviews with AIC pilot staff, and interviews with Leidos and SEEL. Then, through a collaborative work session with AIC and implementation partners, we identified the highest priority measures for the literature review. This resulted in a prioritized measure list that informed both our program web search and the literature review.

For the literature review, we carried out systematic online searches for research and evaluation publications with the prioritized measure list. We included peer-reviewed academic papers and presentations, reports from government agencies and non-governmental organizations, and industry evaluations. To find these sources, we searched through residential program evaluation studies, conference proceedings, federal and state websites, manufacturer websites, and reports on relevant state energy efficiency programs.

We initially focused on literature published since 2020 from states within the US with climates similar to the Midwest to provide the most up-to-date and relevant information to AIC. However, after our initial search, we realized there was insufficient content within these original parameters. Given that, we expanded our review to include literature from the last ten years and included informal articles that mentioned NEIs for measures with limited research findings.

To focus our literature review, we created a set of search terms that directed our investigation across different platforms and literature sources. See Table 4 in the Appendix for the specific keywords and phrases we used to identify relevant studies, reports, evaluations, and articles. We identified 31 potentially relevant sources. After closer review, we narrowed the list to 21 relevant sources. We read each source to locate information about possible NEIs, paying particular attention to evidence for the NEIs and the direction or valence of impact (positive, neutral, or negative). Finally, we read and summarized findings from the identified studies and articles.

FINDINGS

COMPARABLE PROGRAMS

Through the literature review and web searches, we found programs with goals and measures similar to those of the Accessibility Pilot that also appear to generate NEIs. We excluded programs that only offer technical support, add smart technologies to staffed assisted living or group homes, or exclusively build new smart homes, as well as any short-term grant projects. Currently, three comparable programs exist.[1] We summarize the NEIs and measures for these programs in Table 1, while the following sections provide more information on each program.

[1] It is possible that more than three comparable programs exist; however, we did not find publicly available, online materials making clear the program will fund smart home upgrades or focuses on supporting people with disabilities.

Table 1. Program Designs Comparable to the Accessibility Pilot

Program	NEIs	Measures
Home Usability Program (HUP)	▪ Safety	▪ Cameras ▪ Ramps ▪ Handrails ▪ Shower chairs ▪ Smart home equipment
Tunnels to Towers Smart Home Program	▪ Independence	▪ Multi-zone audio system for treatment of PTSD ▪ Motorized entry and exit doors ▪ Sensor-controlled lighting system ▪ Automatic toilet bowls ▪ Upper kitchen cabinet lifts ▪ Motorized sink and stove ▪ Structural wired phone, TV, and internet jacks in all rooms ▪ Centralized phone system with room-to-room intercom and front door communications ▪ Wireless internet system ▪ Day/night outdoor surveillance cameras with smartphone access ▪ Window and door security system ▪ Automated door locks ▪ Card access-controlled doors ▪ Whole house control via smartphone or tablet ▪ Backup generator ▪ Fire suppression system

Program	NEIs	Measures
		▪ Wider halls and doorways ▪ Showers that accommodate wheelchairs ▪ Central HVAC with Wi-Fi controls
US Veteran's Administration Special Housing Adaptation Program	▪ Quality of life ▪ Safety ▪ Health	▪ Lighting ▪ Doors ▪ Handrails/grab bars ▪ Smoke, fire, and carbon monoxide detectors ▪ Security systems and related items ▪ Room additions ▪ Covered porches ▪ Hard surface walkways ▪ Fencing ▪ Electrical service and panel modifications ▪ Swimming pools ▪ Doorknob covers or lever latches/locks ▪ Relocation of cabinets, countertops, and sinks ▪ Toggle or press light switches ▪ Tap plates to open doors ▪ Keyless entry systems ▪ Automatic garage door openers ▪ Special plumbing fixtures ▪ Window replacement to crank-type windows ▪ Bathtubs and showers ▪ Integrated, whole-house

Program	NEIs	Measures
		climate and lighting smart controls ▪ Automatic door openers ▪ Accessible closets and shelving ▪ Maintenance-free building materials ▪ Air filtration and dehumidifying systems ▪ Carpet replacement

The Home Usability Program (HUP) is managed by the Center for Independent Living (CIL), a nonprofit organization. The program aims to enhance safety, accessibility, and independence for individuals with disabilities in Kansas.[2] HUP includes a home assessment that can be conducted either in person or remotely. Based on the assessment, the programs provide tailored recommendations for home improvements. The solutions implemented specifically target accessibility, including video doorbells, entry ramps, handrails in hallways and bathrooms, shower chairs, handheld showerheads, and other smart home equipment. The Accessibility Pilot shares similar objectives and measures, including handheld showerheads and smart home technology.

Tunnel to Towers' Smart Home Program serves catastrophically injured veterans and first responders across the United States.[3] The program builds mortgage-free new homes tailored to address the unique needs of each recipient, including wide-ranging measures from motorized sinks and stoves that raise and lower for easier access to sensor-enabled lighting. The sole NEI mentioned in online program documents is reclaiming independence, though one program measure—audio systems that may be used for the treatment of post-traumatic stress disorder (PTSD)—could plausibly foster improved mental health.

The Veteran's Administration Special Housing Adaptation (SHA) program provides grants to severely injured veterans, primarily those who are blind, have lost the use of their hands, or have certain severe burn or respiratory injuries.[4] The program funds a wide range of home adaptations to accommodate these disabilities; specific adaptations are tailored to recipients' individual needs. Among the many recommended adaptations, the program includes integrated, whole-house smart controls for climate and lighting and smoke, fire, and carbon monoxide detectors. The program does not appear to measure NEIs but does aim to improve recipients' quality of life, safety, and health.

[2] Kelsey S. Goddard et al., "Examining the Effects of Home Modification," *Disability and Health Journal*, article in press, https://doi.org/10.1016/j.dhjo.2024.101590.

[3] "Smart Home Program," Tunnels to Towers Foundation (n.d.), https://t2t.org/smart-home-program/about-shp/.

[4] US Department of Veterans Affairs, "Handbook for Design: A Guide for Specially Adapted Housing (SAH) and Special Housing Adaptation (SHA) Projects," revised September 2021, https://benefits.va.gov/WARMS/docs/admin26/m26_13/sah-2022-update-26-13.pdf.

NEI LITERATURE REVIEW

Through our NEI literature review, we identified positive and negative NEIs possible for each prioritized pilot measure, as well as one potentially neutral impact when a positive or negative outcome was unclear or contingent on specific circumstances. We summarize these in Table 2.

Table 2. Valence of Measures for the Accessibility Pilot

Prioritized Pilot Measure	Positive NEIs	Neutral NEIs	Negative NEIs
Smart Speakers	✓		✓
Advanced Thermostats	✓	✓	✓
Interior and Exterior Mounted Cameras	✓		✓
Smart Lighting	✓		✓
Handheld Showerheads	✓		
Carbon Monoxide Alarms and Smoke Detectors	✓		✓

NEIs associated with each measure are provided in Table 3 with negative NEIs in red text. The following sections provide detailed findings specific to each measure, highlighting implementation suggestions where relevant.

Table 3. NEIs for Each Measure

NEI	Smart Speakers	Advanced Thermostat	Interior and Exterior Mounted Cameras	Smart Lighting	Handheld Showerheads	Carbon Monoxide Alarms and Smoke Detectors
Convenience	✓	✓	✓	✓		✓
Energy Bill Increases	✓					
Energy Bill Savings		✓		✓		
Comfort				✓	✓	
Control		✓	✓	✓		
Inconvenience	✓					
Independence	✓		✓			
Loneliness Reduced	✓					
Poisonings Reduced						✓
Safety Improved					✓	✓
Security Benefits	✓		✓			✓
Security Risks	✓	✓	✓	✓		✓
Self-Management	✓					
Time Saved				✓		

SMART SPEAKERS

Smart speakers are linked to the NEIs of self-management, independence, reduced loneliness, convenience, and enhanced security. Conversely, some studies have shown that smart speakers can create negative NEIs related to security risks, inconvenience, and increased energy bills.

Smart speakers enable individuals in the home to perform various tasks through voice commands, such as playing audio or music, setting alarms or reminders, and controlling lighting and other entertainment. The 2024 "From Command to Care" meta-analysis highlighted how smart speakers can assist individuals in living independently. [5] The meta-analysis included 59 studies of smart speakers in healthcare settings and indicates that smart speakers can enhance communication with family and friends, entertain, provide information, and facilitate various opportunities for self-management, all of which promote independent living. Opportunities for self-management include using smart speakers for health-related tasks. For example, individuals with diabetes successfully utilized smart speakers to track symptoms and adhere to treatment plans. Furthermore, smart speakers can help improve adherence to medication schedules by providing reminders, which reduces missed doses. Researchers continue to explore how smart speakers can help individuals with other chronic diseases effectively monitor their symptoms, adhere to treatment plans, and adopt healthier lifestyles.

An individual who participated in the 2022 *Smart Speakers Research in the Public* study stated:

> *"For me, it's the multifaceted nature of… my smart speaker, with the capabilities that were there… It is the difference between maintaining independence around the house… my mom or dad, or [carers], don't have to keep getting up every five minutes. Like this evening before this meeting, I was able to just ask it to put these lights on. Years ago, before I had that facility… I would have had to ask people to do things manually, whether it be even putting alarms on to know when carers are coming in to get me up, etc. So, it really is for me that multifaceted approach."*[6]

In addition to improved independence and self-management, smart speakers can help individuals feel less lonely when living alone. One study reported that individuals find that having a speaker to interact with daily helps provide companionship and reduces feelings of isolation.[7]

Smart speakers also provide convenience, another positive NEI. People with limited dexterity and mobility, as well as those with low vision or who are blind, can use smart speakers to control lights, adjust the thermostat, turn on the television, and more, all using voice commands.[8] The 2022 *Smart Speakers Demonstration Project Final Report* also mentions that among survey participants, one of the most satisfying features of the device was its convenience.[9]

Additionally, since smart speakers can connect with other smart devices in the home, a few individuals report that smart speakers can enhance security through connection with their smart doorbells. One participant surveyed within the 2022 *Smart Speakers Research with the Public* report mentioned that the smart speaker helped to notify them of a burglary.[10]

[5] Rishi Saripalle and Ravi Patel, "From Command to Care: A Scoping Review of Utilization of Smart Speakers by Patients and Providers," *Mayo Clinic Proceedings: Digital Health* 2, no. 2 (2024), https://doi.org/10.1016/j.mcpdig.2024.03.002.
[6] Community Research, *Smart Speakers Research with the Public* (Ofcom, December 2022), https://www.ofcom.org.uk/siteassets/resources/documents/research-and-data/multi-sector/general-communications-research/smart-speakers-research.pdf?v=328937.
[7] Saripalle and Patel, "From Command to Care."
[8] John T. Morris and Nicole A. Thompson, "User Personas: Smart Speakers, Home Automation and People with Disabilities," *Journal on Technology and Persons with Disabilities* 8, (May 2020),
[9] Southern California Edison, *Smart Speakers Demonstration Project Final Report*, prepared by Emerging Products & Technologies, (Southern California Edison, July 2022), https://www.dret-ca.com/wp-content/uploads/2022/09/DR19.03-ET19SCE1020-Smart-Speaker-Final-Report.pdf.
[10] Community Research, *Smart Speakers Research*.

Conversely, other sources showed that using smart speakers can result in negative NEIs of security risks, increased energy bills, and inconvenience resulting from lack of voice recognition. We did not find reports of consumers experiencing hacked smart speakers. Still, cybersecurity researchers have demonstrated the risk by hacking into smart speakers using various methods like ultrasonic commands[11] and laser light.[12] Also, a 2019 report conducted lab testing of the energy impacts of smart speakers, finding that using these devices to control televisions may lead to higher energy consumption, which could ultimately result in increased customer bills over the long term.[13] Additionally, one report found that smart speakers may not recognize voice commands or give clear answers,[14] and another mentioned that smart speakers may have trouble understanding certain accents.[15]

When choosing smart speakers, look for devices with customizable voice commands and compatibility with various smart home products that could be used with the speaker. Educate users on effectively using these devices to minimize potential pitfalls, such as accidental activations that could increase energy costs.

ADVANCED THERMOSTATS

Positive NEIs that may result from advanced thermostats include enhanced control, energy bill savings, and convenience. However, these thermostats may also have neutral or even negative impacts.

Advanced thermostats offer improved control over home comfort due to their Wi-Fi connectivity, enabling users to adjust the temperature from anywhere in their home.[16] Advanced thermostats may be paired with smart speakers, allowing users to adjust their thermostats' temperature settings through the speaker and permitting more convenient temperature control settings.[17]

Bill savings are an added benefit of advanced thermostats. According to the 2018 *Redefining Home Performance in the 21st Century* report, these devices monitor household behavior and adjust temperature settings accordingly, reducing energy consumption and lowering energy bills. This not only lessens the effort required from individuals in the home but also simplifies the process of optimizing energy use and achieving savings.[18]

We derived a neutral NEI from the 2019 *Impact Evaluation of Smart Thermostats Report*.[19] The report states that energy bill savings are not guaranteed, as they are influenced by the type of home—such as single-family homes or mobile homes—and the behaviors of the individuals living there.

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[11] Michelle Hampson, "How to Silently Hack a Smart Speaker," *IEEE Spectrum* (December 2019), https://spectrum.ieee.org/how-to-silently-hack-a-voice-assistance-system.

[12] David Nield, "Researchers Show They Can Hack Your Smart Speaker Just by Shing Lasers at It," Science Alert, November 5, 2019, https://www.sciencealert.com/researchers-can-hack-a-smart-speaker-just-by-shining-laser-light-at-it.

[13] Noah Horowitz, Gregg Hardy, and Mike Tian, *The Energy Impacts of Smart Speakers and Video Streaming Devices,* (Natural Resources Defense Council, August 2019), https://www.nrdc.org/sites/default/files/gadget_report_r_19-07-b_13_locked.pdf.

[14] Southern California Edison, *Smart Speakers Demonstration Project.*

[15] Community Research, *Smart Speakers Research.*

[16] Kara Saul Rinaldi and Elizabeth Bunnen, *Redefining Home Performance in the 21st Century,* (Home Performance Coalition, October 2018), https://building-performance.org/wp-content/uploads/2022/11/Redefining-Home-Performance-in-the-21st-Century.pdf.

[17] Southern California Edison, *Smart Speakers Demonstration Project.*

[18] Rinaldi and Bunnen, *Redefining Home Performance*.

[19] California Public Utilities Commission, *Impact Evaluation of Smart Thermostats, Residential Sector, Program Year 2019*, prepared by DNV GL - Energy, (California Public Utilities Commission, June 16, 2021), https://www.calmac.org/%5C/publications/CPUC_Group_A_Residential_PY2019_SCT_Final_Report_CALMAC.pdf.

The sole negative NEI we identified is security risks. A 2019 article highlights that while smart home products, such as smart thermostats, offer various benefits that enhance convenience, they can sometimes come at a cost. Because they are Wi-Fi enabled, these devices can be vulnerable to hacking.[20] In one case, a Nest® smart thermostat user found her thermostat turned up to 90°F,[21] and then was harassed by a voice and vulgar music from her Nest security camera. Google reported compromised passwords, rather than a system breach, have been the source of such issues.[22]

When installing advanced thermostats in customers' homes, ensure they understand how to best mitigate security risks. For example, ensure that their smart thermostat's software is up to date, that they use multi-factor authentication, create strong passwords, and keep their home Wi-Fi network secure.

INTERIOR AND EXTERIOR MOUNTED CAMERAS

Cameras may support increased independence, convenience, control, and security. As with all internet-connected devices, they are susceptible to security breaches.

Like smart thermostats, home cameras can monitor occupant behaviors and provide insights into occupancy patterns. This information can help homeowners make informed decisions about home automation and security settings. Cameras can monitor usual departure times and adjust security settings accordingly. They can also track how often a person uses specific rooms, which can help residents learn when and how to adjust energy usage for lighting and temperature as needed. Overall, these devices present opportunities to enhance the management of the home living environment.

A 2024 literature review described many features and uses of smart cameras.[23] The cameras can also offer a two-way audio channel, enabling communication between individuals within the camera's range. This feature allows household members to connect with family or guests in separate rooms or outside the home. Cameras enable caregivers to monitor their clients from a distance, providing the convenience of communication without their physical presence in the home. Furthermore, integrating smart cameras can connect with other smart devices, such as smart lighting or smart locks. For example, if smart cameras detect motion, they can automatically turn on lights, or individuals can be notified of movement and lock or unlock doors remotely.

Cameras can enhance home security, as has traditionally been their use. With the help of artificial intelligence and machine learning, smart cameras can excel beyond conventional surveillance and provide a variety of functions, including constant monitoring using facial recognition and movement detection.[24] These devices can also use sensors

[20] Steve Karantzoulidis, "Hacker Turns Up Nest Thermostat," *Security Sales & Integration*, September 25, 2019, https://www.securitysales.com/news/hacker-thermostat-vulgar-music/.

[21] All product or company names that may be mentioned in this publication are tradenames, trademarks, or registered trademarks of their respective owners.

[22] Karantzoulidis, "Hacker Turns Up Thermostat."

[23] Radoslaw Wolniak and Wies Grebski, "The Usage of Smart Cameras in Smart Home," *Scientific Papers of Silesian University of Technology* no. 188, (2023): http://dx.doi.org/10.29119/1641-3466.2023.188.42.

[24] Wolniak and Grebski, "*Usage of Smart Cameras.*"

to detect potential threats and notify homeowners of suspicious activity.[25] Such capabilities help homeowners feel secure and empowered to identify threats independently and take action to enhance security. [26]

Ironically, even security cameras can be hacked, which introduces security risks to a home.[27] This negative NEI stands for the majority of internet-connected devices.[28] As noted above, the risk of hacking can be mitigated when users take additional security steps, such as using strong passwords.

SMART LIGHTING

Smart lighting may result in positive NEIs related to enhanced convenience and control, comfort, safety, saved time, and energy bill savings. These lights do introduce security risks, however.

The 2018 *Redefining Home Performance in the 21st Century* literature review demonstrates that smart lighting allows users to turn lighting on and off and dim lighting in other rooms or from outside the home, enhancing convenience and control.[29] Similar to advanced thermostats, smart lighting can be personalized to reduce energy usage, adjusting based on individual behaviors in the home. Customers can easily change the colors of their lighting using their smartphones or tablets, allowing them to create the desired ambiance. The capability to adjust colors and control lighting features is a significant motivator for installing smart lighting.[30]

The 2023 "Impact of Homes on Energy Efficiency and Sustainability" literature review supports these NEIs by stating that smart devices, such as smart lighting, enable homeowners to manage their homes using voice commands and smartphones.[31] This feature is particularly beneficial for individuals with mobility issues, as it allows them to complete tasks without physically turning switches on and off. According to the 2018 *Redefining Home Performance in the 21st Century* literature review, when combined with other measures such as smart speakers and smart thermostats, the NEIs of comfort, safety, saved time, convenience, and bill savings are possible, such as when such individuals can easily turn off lights and devices in rooms they are not using.

As with other internet-connect devices, using smart lighting without adequate security can expose users to hacking. In addition, some infrared-enabled lights introduce a new risk: a hacked light can send invisible infrared commands to other smart devices in the home or steal data from them.[32]

HANDHELD SHOWERHEADS

Handheld showerheads may reduce the risk of injury and enhance feelings of safety and comfort when used with other measures.

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[25] Lipsa Das et al., "The Impacts of Smart Homes on Energy Efficiency and Sustainability." Paper presented at 10th IEEE Uttar Pradesh Section International Conference on Electrical, Electronics, and Computer Engineering, Gautam Buddha Nagar, India, 2023, https://doi.org/10.1109/UPCON59197.2023.10434418.

[26] Wolniak and Grebski, *"Usage of Smart Cameras."*

[27] Karantzoulidis, "Hacker Turns Up Thermostat."

[28] Das et al., "The Impacts of Smart Homes."

[29] Rinaldi and Bunnen, *Redefining Home Performance*.

[30] Bonneville Power Association (BPA). *Future Energy Reductions in Residential Lighting*, prepared by Washington State University Energy Program, (BPA, June 2018): https://www.bpa.gov/-/media/Aep/energy-efficiency/emerging-technologies/ET-Documents/Future-Res-Lighting-Paper-FINAL-DRAFT-docx-018-08-15.pdf.

[31] Das et al., "The Impacts of Smart Homes."

[32] University of Texas at San Antonio Center for Infrastructure Assurance and Security, "Hackers Can Hijack Your Home with these 10 Smart Devices," n.d., https://cias.utsa.edu/hackers-can-hijack-your-home-with-these-10-smart-devices/

We did not locate research that examined the NEIs of handheld showerheads alone. However, one study of the Home Usability Program reported NEIs for handheld showerheads used in combination with other measures.[33] The study surveyed and interviewed recipients of many combinations of the program's home modifications, including bathroom modifications of shower chairs, non-slip bathmats, tub grab bars, and handheld showerheads. Overall, the slate of home modifications reduced the risk and fear of injury for those with limited mobility and contributed to feeling safer and more comfortable at home.

When selecting a handheld showerhead, consider one with an adjustable height. This will ensure comfort and accessibility for users of various heights and mobility levels.

CARBON MONOXIDE ALARMS & SMOKE DETECTORS

Safety alarms, including carbon monoxide and smoke detectors/alarms/monitors, are linked to the NEIs of improved safety and reduced poisonings or death. Combined with other smart home features, they may offer additional convenience and security benefits. However, smart smoke detectors may bring security risks into homes.

Research on the NEIs of safety alarms, such as carbon monoxide alarms and smoke detectors, is limited. We found one study looking at NEIs unique to carbon monoxide monitors. The 2017 *Non-Energy Impacts Approaches and Values* literature review summarizes NEIs of many measures and how various states quantify them.[34] The authors present several of Massachusetts' estimates of carbon monoxide monitors' NEI value, such as nearly $37 per household for the five-year measure life of the monitor because of reduced carbon monoxide poisoning, including the benefit of avoided death. We found only one source for smart smoke detectors' NEIs: an article reporting researchers' successful hacking of smart smoke detectors from 2016, in which they set off false fire alarms.[35] No other, more recent articles mentioned this risk.

We identified two studies addressing NEIs for carbon monoxide alarms and smoke detectors in combination with other measures. The 2017 *Quantification of Non-Energy Impacts* literature review provides monetization estimates for various energy efficiency measures but does not provide details about the NEIs. Instead, the authors estimate that smoke and carbon monoxide detectors, ventilation, and air sealing together improve safety at a value of $0–$1 per measure and $37 per home.[36] The second study finds that smoke detectors and carbon monoxide detectors can enhance convenience and security in the home when combined with other devices such as smart speakers, locks, doorbells, and cameras. For example, if a smoke detector detects smoke, it can trigger a smart speaker to announce an alert throughout the house.[37] Interestingly, the 2021 *Review of Alarm Technology for Deaf and Hard of Hearing* found

[33] Goddard et al., "Examining Effects of Home Modification."
[34] Northeast Energy Efficiency Partnerships (NEEP), *Non-Energy Impacts Approaches and Values: An Examination of the Northeast, Mid-Atlantic, and Beyond*, (NEEP, June 2017): https://neep.org/sites/default/files/resources/NEI%20Final%20Report%20for%20NH%206.2.17.pdf.
[35] Andy Greenberg, "Flaws in Samsung's 'Smart" Home Let Hackers Unlock Doors and Set Off Fire Alarms," *Wired*, May 2, 2016, https://www.wired.com/2016/05/flaws-samsungs-smart-home-let-hackers-unlock-doors-set-off-fire-alarms/.
[36] New York State Energy Research and Development Authority (NYSERDA), *Quantification of Non-Energy Impacts for Residential Programs Phase I: Final Report*, prepared by ICF International, (NYSERDA, March 31, 2017): https://www.nyserda.ny.gov/-/media/Project/Nyserda/Files/Publications/PPSER/Program-Evaluation/2017ContractorReports/SmallResidential-NEI-PhaseI.pdf
[37] Rinaldi and Bunnen, *Redefining Home Performance*.

that smoke detectors with low-frequency audible alarms are more effective for hard-of-hearing individuals and older adults.[38]

	Choose alarms with low-frequency alarm alerts, as they are particularly beneficial for residents with hearing difficulties. Consider linking these alarms to customers' smart home systems for real-time alerts and monitoring.

CONCLUSIONS AND RECOMMENDATIONS

Conclusion #1: Though limited, the research base does suggest Accessibility Pilot measures may offer NEIs. All the measures examined have the potential for positive NEIs, but five of them also have potential for negative impacts. We characterized one measure as having a potentially neutral impact because its positive impacts are contingent on specific conditions. It is also possible the various measures may work in complementary ways to augment positive impacts.

- **Recommendation 1:** Consider prioritizing NEIs the Accessibility Pilot could promote through implementation, taking into account benefits to participants, ability to avoid negative impacts, expense to AIC, implementation difficulty, need for ongoing participant support, measure durability (e.g., susceptibility to device or app obsolescence), ease of impact measurement, and more as relevant. If implemented, track these NEIs over time to ensure participants gain the intended benefits and include them in AIC benefit-cost calculations.
- **Recommendation 2**: Articulate the theories of change linking measures to specific NEIs, including indirect and direct impacts and benefits. For example, create diagrams showing how certain Accessibility Pilot measures may support independent living for individuals with mobility difficulties while other measures may enhance safety. These theories of change could help prioritize NEIs for implementation or further study.

Conclusion #2: Few programs share the Accessibility Pilot's goals or measures.

- **Recommendation #3:** The three identified extant programs offer potentially valuable additional measures for the Accessibility Pilot's consideration, such as handrails, ramps, and shower chairs to further improve accessibility. We recommend reviewing these programs' measures to determine their desirability and feasibility for the Accessibility Pilot.

Conclusion #3: The research base for NEIs from Accessibility Pilot measures is limited, with few rigorous studies to quantify impacts or benefits. We found only two studies that monetize the value of Accessibility Pilot NEIs; the majority of publications are literature reviews.

- **Recommendation #4**: Consider a more formal study of priority NEIs to confirm benefits for program participants and communities. Integrate pre- and post-measurements of possible impacts and benefits into program delivery to build a stronger evidence base while minimizing program expenses.

[38] Erik Smedberg and Enrico Ronchi, *Review of Alarm Technologies for Deaf and Hard of Hearing Populations*, (Fire Protection Research Foundation, August 2021): https://www.nfpa.org/education-and-research/research/fire-protection-research-foundation/projects-and-reports/review-of-alarm-technologies-for-deaf-and-hard-of-hearing-populations.

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APPENDIX

Table 4. Search Terms for Accessibility Pilot NEI Research

Measures	Search Terms
Advanced Thermostats	▪ Smart Thermostat Non-Energy Impact Evaluation ▪ Smart Thermostat Non-Energy Impacts Study ▪ Wi-Fi Thermostat Non-Energy Impact Evaluation ▪ Wi-Fi Thermostat Non-Energy Impacts Study ▪ Digital Thermostat Non-Energy Impact Evaluation ▪ Digital Thermostat Non-Energy Impacts Study ▪ Advanced Thermostats Non-Energy Impacts Study ▪ Advanced Thermostat Non-Energy Impact Evaluation
Smart Speakers	▪ Smart Speakers Non-Energy Impact Evaluation ▪ Smart Speakers Non-Energy Impacts Study ▪ Digital Assistant Non-Energy Impact Evaluation ▪ Digital Assistant Non-Energy Impacts Study ▪ Digital Assistant Health Benefits
Interior and Exterior Mounted Cameras	▪ Video Doorbells Non-Energy Impact Evaluation ▪ Video Doorbells Non-Energy Impacts Study ▪ Video Doorbells Health Benefits ▪ Video Doorbells Research ▪ Mounted Cameras Non-Energy Impact Study ▪ Residential Cameras Non-Energy Impact Evaluation
Smart Lighting	▪ Lighting Non-Energy Impact Evaluation ▪ Lighting Non-Energy Impacts Study ▪ LED Non-Energy Impact Evaluation ▪ LED Non-Energy Impacts Study ▪ Smart LED Health Benefits
Handheld Showerheads	▪ Handheld Showerheads Non-Energy Impact Evaluation ▪ Handheld Showerheads Non-Energy Impacts Study ▪ Showerhead Non-Energy Impacts Study ▪ Showerhead Utility Market Research
Carbon Monoxide Alarms	▪ Carbon Monoxide Alarm/Detector Non-Energy Impact Evaluation ▪ Carbon Monoxide Alarm/Detector Non-Energy Impacts Study ▪ Carbon Monoxide Alarm/Detector Non-Energy Impacts Study ▪ Carbon Monoxide Alarm/Detector Market Research ▪ Carbon Monoxide Alarm/Detector Accessibility Benefits
Smoke Detectors	▪ Smart Smoke Alarm/Detector Non-Energy Impact Evaluation ▪ Smart Smoke Alarm/Detector Non-Energy Impacts Study ▪ Smart Smoke Alarm/Detector Non-Energy Impacts Study ▪ Smart Smoke Alarm/Detector Market Research ▪ Smart Smoke Alarm/Detector Accessibility Benefits