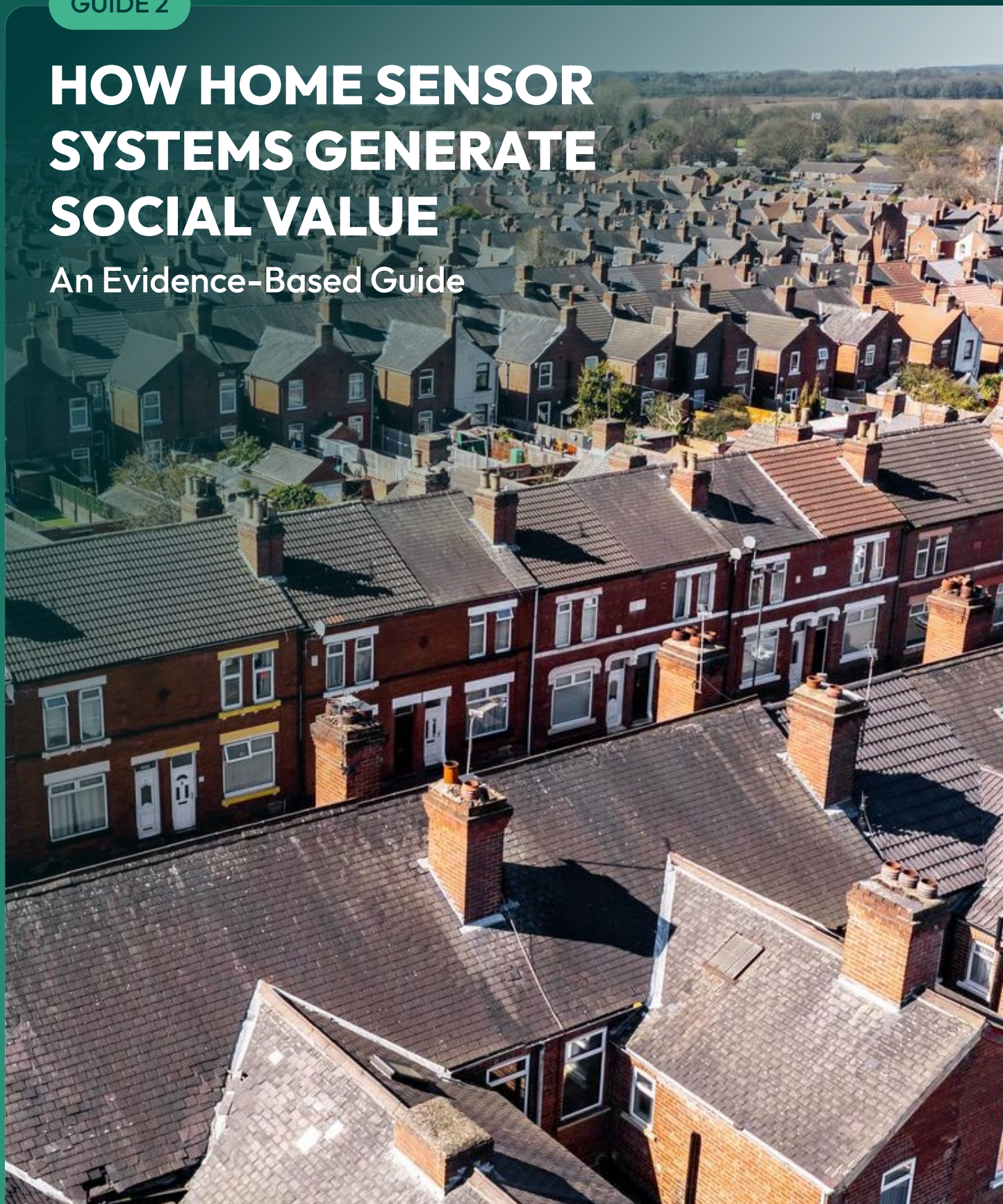
SENSOR SYSTEMS FOR HEALTHIER HOUSING: A SOCIAL VALUE GUIDE

University of Exeter

GUIDE 2

HOW HOME SENSOR SYSTEMS GENERATE SOCIAL VALUE

An Evidence-Based Guide



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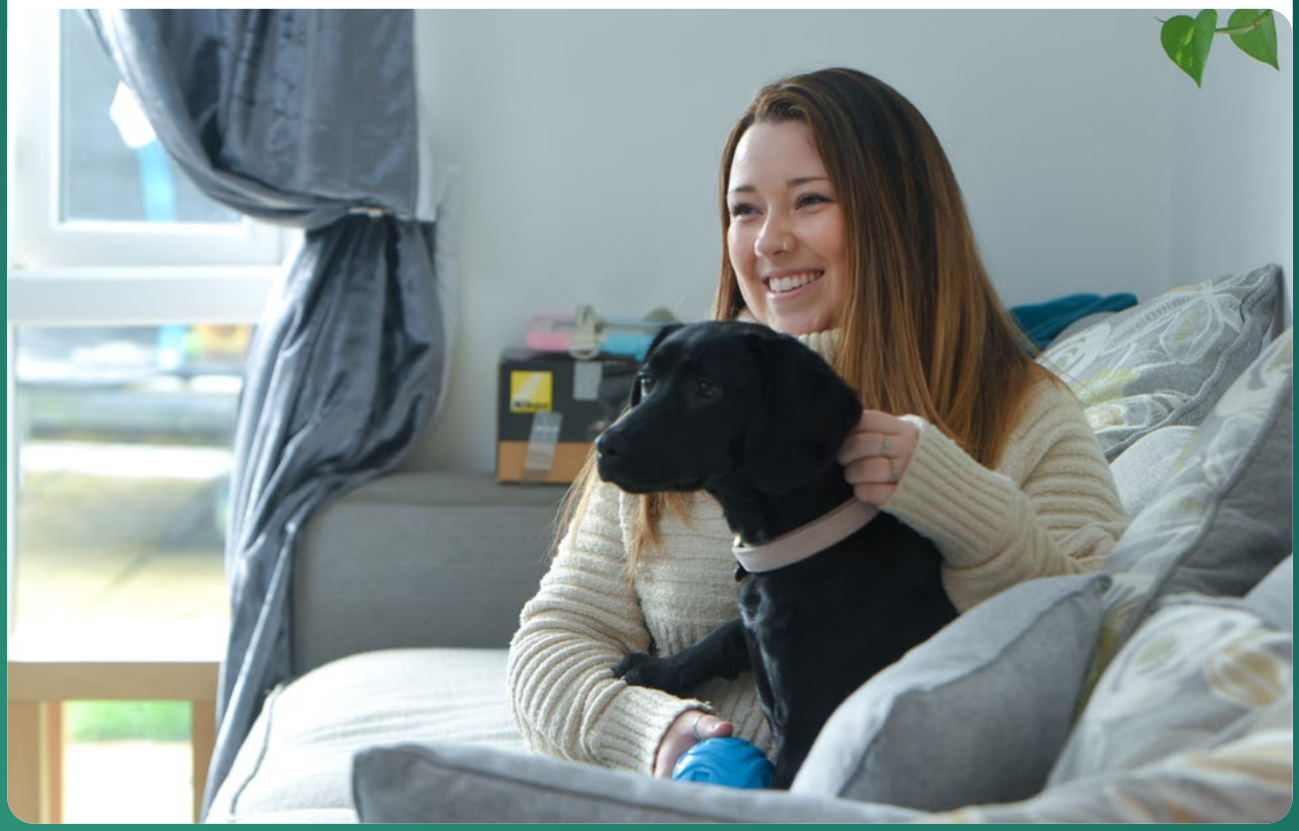

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About this guide

This guide sets out the underpinning evidence for how sensor systems can generate social value. It's designed to help you plan and evaluate your sensor system project. We've produced it specifically for housing providers, to help planning, maintenance and procurement teams have an overview of the process, benefits and risks of investing in a sensor system.

The research informing this guide, along with referenced literature, primarily draws from the social housing sector. However, the insights are relevant to various other housing providers, such as Housing Associations, Local Authorities and Arms Length Management Organisations.

The guide is the second guide in our series, which is made up from:

- **Guide 1:** The Social Value of Home Sensor Systems: An Introductory Guide
- **Guide 2 (this one):** How Home Sensor Systems Generate Social Value: An Evidence-Based Guide
- **Guide 3:** Evaluating the Social Value of Sensor Systems: Case Study and Guide
- An editable "Logic Model" that you can use to plan and evaluate a sensor system project

Introducing the Theory of Change

A project like installing sensor systems in social housing does not exist in a vacuum. There are wider contexts, ranging from the pressure on housing stock to new laws regarding rental properties. There are local and community issues, new technologies, specific demographics: so many things intersect and affect each other during a project.

The Theory of Change (ToC) is a clear way of describing the different components of an intervention, how all these components interrelate and why the intervention works. While a linear model like the Logic Model is useful for explaining cause-and-effect, the ToC is a more in-depth tool for describing the more complex network of relationships that exist within a social project like this one.

A ToC recognises complexity, and is sometimes described as filling in the "missing information" between the inputs and outcomes. Its holistic overview makes it an extremely helpful way to both plan and evaluate a project.

Why the ToC is useful

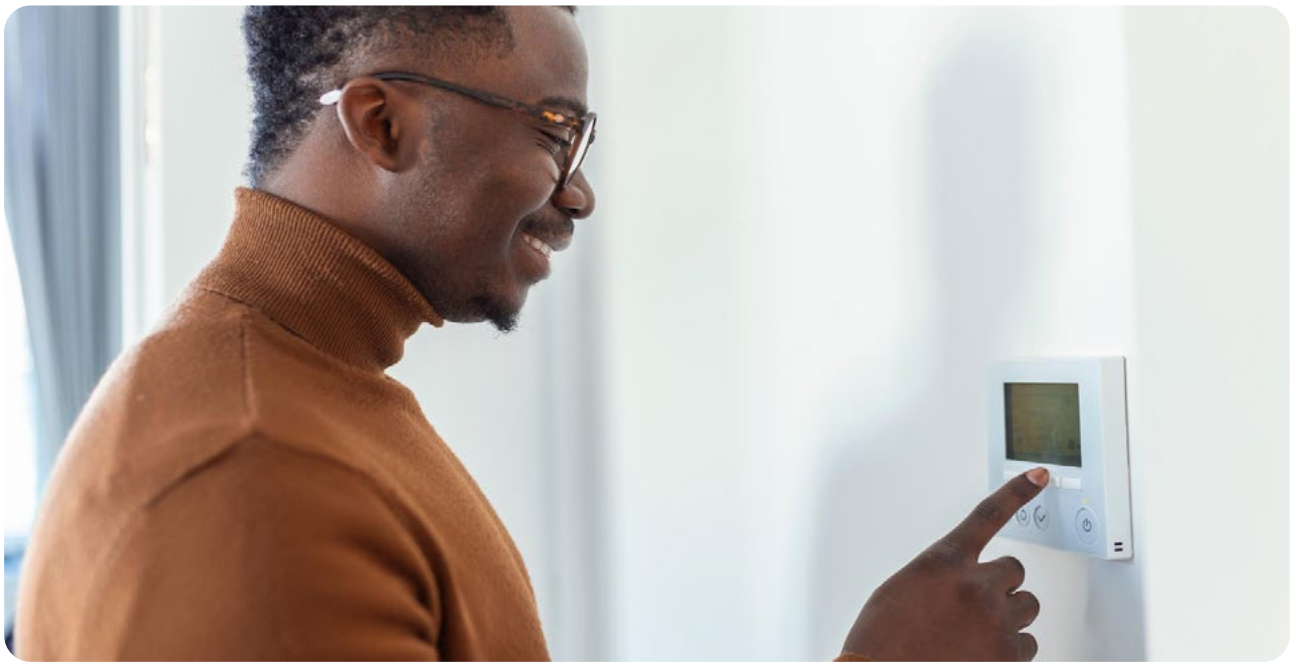
Whether you are looking to understand, design or evaluate a sensor system intervention, the ToC is a useful tool:

For understanding the challenges: this model helps identify the relationships, the wider context, the root causes of problems, the community's needs and how sensor systems can help maintain healthier homes.

For social value assessment: it demonstrates how the implementation of the sensor system will lead to specific outcomes and impacts within the indoor environment. This clarity allows housing providers to assess the effectiveness of their investment and make informed decisions about resource allocation.

For stakeholder communication and engagement: it provides a common language and understanding among stakeholders about the goals, strategies and expected outcomes of the sensor system implementation. This encourages communication, collaboration and buy-in from all parties (including residents, staff and policymakers).

Risk management: housing providers can use the model to anticipate any potential risks and challenges associated with the implementation of the sensor system. They can develop mitigation strategies to minimise negative impacts and ensure the success of the initiative.



Theory of Change components

The theory of change model has seven components...

Context and root causes

What are the broader contexts that contribute to the problems?

Desired results

What short-term and long-term outcomes do you want to achieve?

Community needs

What are the specific local needs behind the design of the system?

Problems

What are the specific problems that your sensor system project needs to target?

Influential factors

What are the factors influencing change in the community?

Intervention strategy

What strategies and best practices will be employed?

Assumptions

What are the underlying beliefs and principles behind the intervention?

Theory of Change for a sensor system

Here's an example of a ToC model for a sensor system intervention. Each one is unique, and we recommend that they're produced in collaboration with both housing providers and residents. Establishing a shared vision will identify your key enablers and any barriers. It's also important to ground your ToC in research and practical evidence, which we'll provide later on in this guide (see Funnell and Rogers 2011; Goldsworthy 2021).

Sensor systems for healthier housing Theory of Change

CONTEXT & ROOT CAUSES

Housing: Determinant of public health outcomes and costs.

Indoor environment: Directly impacts health outcomes.

Social housing: Population at risk due to housing quality, circumstances, and health needs.

Economic and Environmental Factors: Cost of living crisis and climate change.

COMMUNITY NEEDS

Housing Providers:
- Real-time and reliable data for proactive decision making.
- Data for long-term monitoring, evaluation, and planning.

Residents:
- Awareness and knowledge about indoor environment risks.
- Advice & support for self-management
- Property repairs and support to rectify social and financial causes.

PROBLEMS

Physical Health Hazards: Mould and damp, temperature extremes and poor indoor air quality.

Detection of Hazards: Challenges in identifying risks, lack of reliable data compromises decision making.

Management of Hazards: Reactive management is costly, with an impact on customer health and satisfaction.

INFLUENTIAL FACTORS

Healthy Housing Regulations: The Housing Health and Safety Rating System (HHSRS), Decent Homes Standard, Homes Act and Awaab's Law.

Energy Efficiency and Carbon Reduction Targets: 2030 EPC target and 2050 Net Zero target.

Data Management Standards and Legislation: UK Data Standards and GDPR.

INTERVENTION STRATEGY

Philosophy: Proactive and preventative approach to repairs and resident support.

Infrastructure: Sensor system providing actionable insight on indoor environment and risks.

Performance Objectives:
- Proactively identifies immediate risks, supports residents and prevents hazards.
- Monitors property performance for evidence-based planning & investments.

ASSUMPTIONS

Data Privacy and Security: Assuming that residents trust the system to handle their data securely and respect their privacy.

Behaviour Change: Assuming that residents will effectively manage their indoor environment by utilising sensor data and receiving support from the housing provider.

Monitoring and Response: Assuming that the housing provider will monitor the sensor data and promptly respond to risks identified.

DESIRED RESULTS

Outputs:
- Identification and investigation of high-risk properties.
- Advice, signposting and support to residents.
- Proactive property repairs and improvements.
- Actionable insights on housing portfolio.

Outcomes:
- Higher property maintenance quality
- Improved operational efficiencies.
- Improved compliance and transparency
- Enhanced customer service and satisfaction.
- Improved physical and mental health for residents.

Impact:
- Healthy and affordable social housing.
- Reduced inequality in property conditions.
- Improved public health and reduced healthcare costs.

Context and Root Causes

What are the broader contexts and fundamental factors that contribute to the identified problems? In the context of a sensor system intervention, this relates to contributing factors and the links between housing and health within the target population. Take a look at the examples below: how do they compare with the specific factors and context of your own project?

Context and Root Causes: The broader context and fundamental factors contributing to health and housing problems.

Housing

Housing is an unequivocal determinant of public health outcomes and health care costs[1]. For example, the treatment bill cost to the NHS, caused by poor quality housing, is £1.4bn per year[2]. A root cause of poor housing quality is long-term underinvestment[3].

Indoor Environment

The quality of the indoor environment is one of the main ways in which housing impacts health outcomes and costs[4]. This is because Europeans spend 89% of time indoors[5] and around 70% of this time is in the home environment[6]. This increases to around 90% in vulnerable populations such as children, old people and those with health conditions[7].

Social Housing

People living in social housing often experience lower-quality indoor environments[8]. According to the English Housing Survey (EHS), 20% of social renters live in homes deemed "non-decent"[9]. Compared to other housing populations, social housing residents face a higher risk of adverse health impacts[10]. The socio-economic characteristics of social housing populations contribute to the diverse health and wellbeing needs of these residents[11].

Economic and Environmental Factors

Economic and environmental factors influence housing and housing, primarily the cost of living crisis and climate change. Socioeconomic and health inequalities shape public health[12]; for example, the uneven distribution of exposure to substandard housing disproportionately affects low-income groups[13]. The cost of living crisis exacerbates vulnerability, increasing the likelihood of certain populations living in unhealthy homes[14]. Concurrently, climate change intensifies health risks and underscores existing inequalities in the housing sector[15].

1. Marmot and Bell 2012; Sharpe et al. 2018, 2. Garrett et al. 2021, 3. Chaloner, Colquhoun, and Pragnell, 2019, 4. Gibson et al. 2011 , 5. McGrath et al. 2017, 6. Schweizer et al. 2007, 7. Spalt et al. 2016, 8. Pevalin et al. 2008; Wallace et al. 2022, 9. Barnes et al. 2013, 10. Diaz Lozano Patino and Siegel 2018; Sharpe et al. 2020, 11. Boomsma et al. 2017; Rolfe et al. 2020, 12. Gibson et al. 2011; Palimaru et al. 2023, 13. Krieger and Higgins 2002; Richardson et al. 2013, 14. Marmot, Bloomer, and Goldblatt 2013, 15. Paavola 2017

Problems

The sensor system intervention targets specific problems related to health hazards for residents.

Problems: The specific issues the sensor system intervention aims to resolve.

Physical Health Hazards:

Damp and mould

Damp and mould adversely impact both physical and mental health. Exposure to these conditions increases the risk of chronic respiratory, cardiovascular and allergic diseases[16]. Deterioration of their home environment, alongside factors such as the unpleasant smell, can affect residents' dignity, leading to a sense of frustration and helplessness[17].

Extreme temperatures

Both hot and cold temperatures can affect health, especially with vulnerable people. A cold home is associated with respiratory problems, flu, depression, falls, strokes and heart attacks[18]. Over 700,000 homes in England are excessively cold, with the NHS spending over £540mn annually on treating affected individuals[19]. Overheated homes also have adverse health impacts that will worsen with climate change[20].

Air quality

Indoor air pollution can lead to respiratory issues, allergies and other adverse health problems. Short-term exposure (hours/days) to poor air quality causes coughs, wheezing, shortness of breath and asthma attacks[21]. Long-term exposure (months/years) to poor indoor air quality is associated with higher risks of developing chronic respiratory and cardiovascular illnesses[22].

Detection of Hazards

Detection and monitoring of risks to both properties and health are challenging for housing providers without up-to-date and reliable data. Nationally, there is "no clear picture of the state of its stock and its wider performance" within the social housing sector[23], relying on ad hoc reporting of problems. At the household level, identifying risks is difficult due to the complex mix of environmental conditions, indoor behaviours, building characteristics and resident vulnerability[24], compromising decision-making and investment.

Management of Hazards

Reactive management of hazards and building maintenance issues is costly for housing providers, properties and residents' health[25]. The level, timeliness, and quality of support-response impact resident satisfaction and mental health[26]. Within the social rented sector, 37% of renters were dissatisfied with repairs and maintenance, primarily due to landlords being slow to address issues[27].

16. Krieger and Higgins 2002; Moses et al. 2019; Palimaru et al. 2023; Paterson et al. 2021; Pevalin et al. 2008; Rauh et al. 2008, 17. Boomsma et al. 2017; Ejiogu and Denedo 2021; Shenassa et al. 2007, 18. AgeUK 2009; Clair and Baker 2022; WHO 2018, 19. Garrett et al. 2021, 20. Arup et al. 2022; WHO 2018, 21. Al-Kindi et al. 2020, 22. Krieger and Higgins 2002; Rauh et al. 2008, 23. NHF & CIH 2022, 24. CMO 2022; Peek et al. 2023, 25. HO 2021; HO 2023, 26. Wallace et al. 2022, 27. UK Government 2023a

Community Needs

Community needs are the unique requirements of both the housing provider and residents. Understood through engagement, these are the factors that have driven the development of sensor systems as a solution.

Community Needs: The specific requirements driving the design of the sensor system solution

Housing Providers

Real-time and reliable data for decision making

Housing providers need real-time indications of risk across their housing stock for proactive and immediate intervention[27]. Actionable insights are essential, with data presented in a clear and usable format for decision-making and action[28].

Data for long-term monitoring, evaluation and planning

Housing providers need accurate property data for long-term assessments and investment planning. This includes evaluating the effectiveness of interventions like ventilation systems and doors, comparing energy performances and planning energy efficiency upgrades. Reliable data is also crucial for demonstrating compliance with legislation related to healthy homes. The challenges in managing data within the housing sector are significant (such as managing low-quality data, scrutiny and accountability)[29].

Residents

Awareness and knowledge about indoor environment risks

Understanding the connection between the indoor environment and health varies among different types of residents[30]. It is crucial not to attribute issues to resident behaviour[31]. There is a need for effective communication that emphasises awareness and perception of risks, aimed at enhancing resident knowledge with the purpose of improving issues, reporting problems and fostering a shared understanding.[32]

Advice and support for self management

The interaction between resident behaviour and the indoor environment is complex[33], and it is essential that problems are not characterised as a "lifestyle choice"[34]. Residents need advice and guidance on effective use of heating and ventilation practices alongside structural intervention from the housing providers to improve the indoor environment[35].

Property repairs and support to rectify social and financial causes

Residents are constrained in management of cold and damp by factors beyond their control: fuel poverty, household size, low incomes and property attributes[36]. Residents need housing providers intervention to address structural issues like leaking roofs, cold spots and poor ventilation. Support is also needed for tackling the social and financial causes of unhealthy homes, including unemployment and fuel poverty.

While sensor systems are useful for identifying risks, their success relies on human capacity for intervention and social support from the housing association. However, solutions for social and financial causes may extend beyond the housing providers scope, requiring connections with health and community sectors.

27. Filippi and Sirombo 2019; Shukla et al. 2019; Sirombo et al. 2017, 28. Davis 2012, 29. NHF & CIH 2022, 30. Unni et al. 2022, 31. HO 2023, 32. Sharpe et al., 33. Sharpe et al., 34. 2015, HO 2023, 35. Sharpe et al. 2015, 36. Wallace et al. 2022

Desired Results

The desired results are the short and long-term outcomes the sensor system intervention aims to achieve. The logic model provides more detail on these results and how they are achieved.

Desired Results: The vision of the future and what the sensor system intervention aims to achieve.

Outputs

- Identification and investigation of high-risk properties
- Advice, signposting and support for residents
- Proactive property repairs and improvements
- Actionable insight on the housing portfolio

Outcomes

- Higher property maintenance quality
- Improved operational efficiencies
- Improved compliance and transparency
- Enhanced customer service and satisfaction
- Improved physical and mental health for residents

Impact

- Healthy and affordable social housing
- Reduced inequality in property conditions
- Improved public health and reduced public health costs

Influential Factors

The influential factors are the things that are driving change in the housing sector, and will affect the success of a sensor system intervention. These include advancements in housing laws, targets for energy efficiency and carbon reduction and data management standards.

Influential Factors: The factors influencing change in the community.

Healthy Housing Regulations

New policy and legislation around healthy homes is driving progress and increasing standards in the housing sector. At the core is the Housing Health and Safety Rating System (HHSRS), with the purpose to identify and protect against risks and hazards to health in homes. There is the Decent Homes Standard, which sets the minimum standards that social homes are required to meet (including state of repair and thermal comfort). The aim of this standard is to "bring health benefits to tenants and reduce health inequalities"[37].

The Social Housing Regulation Bill 2023, which includes Awaab's Law, requires landlords to fix reported health hazards within specified timeframes[38]. Alongside this, the Hackett Report, the Social Housing White Paper and the Better Social Housing Review are also influencing change in the sector. Sensor systems have a potentially significant role in enabling housing providers to meet these standards.

Energy Efficiency and Carbon Reduction Targets

Targets for energy efficiency and carbon reduction are influencing change in the housing sector. Specifically, the 2030 EPC target of all homes achieving a C rating and the 2050 target of carbon neutrality for the housing sector[39]. These targets propel the need for sensor systems to help monitor and optimise building performance.

Data Management Standards and Legislation

Adherence to data management standards and legislation, notably GDPR, is critical for the efficacy of a sensor system. The ability of sensors to monitor residents' indoor environment, energy use and potentially behaviours means that data management, data security, and privacy intrusion are major issues influencing system adoption[40]. The UK Housing Data Standards serve as a useful tool to ensure sensor data collection is secure, reliable and aligns with established standards for compliance in social housing.

37. DLUHC 2021, 38. UK Government 2023b, 39. NHF 2021; NHF 2021, 40. Kozubaev et al. 2019; Shuhaiber and Mashal 2019

Intervention Strategy

The intervention strategy describes how the desired results will be achieved, as well as the guiding philosophy that underpins the project (in this case, going from reactive to proactive management of properties and the indoor environment).

Intervention Strategy: The strategy for how the desired results will be achieved.

Philosophy

The underpinning philosophy for a sensor system intervention is preventative[41]. Sensor system interventions enable housing associations to move from reactive to proactive property repairs, meeting the Housing Ombudsman recommendations for dealing with home health issues like damp and mould[42].

Infrastructure

Sensor systems provide actionable insights on indoor environment risks across housing stock, coupled with resident support and property intervention from the housing provider.

Performance Objectives

- The housing provider uses the sensor system to promptly identify immediate risks, offer information and support to residents, and take proactive measures to prevent or minimise health and property hazards.
- The housing provider employs the sensor system for long-term monitoring and evaluation of properties, enabling evidence-based decision-making for planning and investments. This leads to improved property performance and enhanced customer services.
- Residents use the resident app/dashboard to effectively manage their indoor environment, preventing and reducing the health risks associated with poor indoor conditions.

41. Smith et al 2015, 42. HO 2021; HO 2023

Assumptions

The assumptions are the beliefs about the intervention strategy and the expected conditions and behaviours which support its success in the target community.

Assumptions: The assumptions behind how and why the identified change strategies will work in the target community.

Data Privacy and Security

Residents perceive sensors to be unobtrusive with regard to practicality and the privacy of monitoring of the indoor environment[43]. Our research (see Guide 3) has demonstrated the potential of internal environmental data in identifying behavioural patterns of residents. The assumption is that housing providers have clear ethical protocols and that users trust the system to handle their data securely. Trust in the housing provider, with regards to data management is known to be an important influencing factor on attitudes and the acceptability of sensor technology[44].

Monitoring and Response

Assumption that the housing provider will actively engage with monitoring the sensor data and promptly respond to the risks identified. Without staff engagement, valuable insights to help better manage properties will be unused and there's a risk that problems in homes are missed.

Behaviour Change

The assumption is that residents will make positive behaviour changes and effectively manage the indoor environment by leveraging access to real-time or historical data on indoor environmental quality, supplemented by support from the housing provider. This may involve actions such as adjusting heating or ventilation settings, or opening windows for ventilation.

43. Walker et al. 2022; Wallace et al. 2022, 44. Pal et al 2021; Pennings et al 2010

Resources

This leads us to our next guide, Evaluating the Social Value of Sensor Systems: Case Study and Guide, which takes you through the process of evaluating the social value of an indoor environment sensor system, showcasing how it has been used in practice by a housing association to improve residents' homes and health.

The other resources in this series of guides are:

Guide 1: The Social Value of Home Sensor Systems: An Introductory Guide

Guide 2: How Home Sensor Systems Generate Social Value: An Evidence-Based Guide (this one)

Guide 3: Evaluating the Social Value of Sensor Systems: Case Study and Guide

An editable "Logic Model" that you can use to plan and evaluate a sensor system project

Open source publications: The research which underpins this series of guides can be accessed at the **Smartline site** and at the **European Centre for Environment and Human Health**.

About us

We're a transdisciplinary team of researchers based at the University of Exeter. We draw on experience from the Smartline and SenseWell projects, which studied how digital technology can support healthy homes and connected communities.

Please get in touch if you have innovative housing and health project ideas!

UKRI Engineering and Physical Sciences Research Council

The Engineering and Physical Sciences Research Council (EPSRC) supported this project through its Translational Funding scheme. This funding aims to speed up the practical application of university research through collaborative projects with partners outside of academia.

University of Exeter

A multidisciplinary team of researchers based at the European Centre for Environment & Human Health at the University of Exeter. The Exeter team is drawn from the Smartline project, which studied how digital technology can support healthy homes and connected communities.

HACT

The Housing Associations' Charitable Trust (HACT) is a leading charity in the social housing sector that drives the creation of social value for communities and individuals through insight-led products and services.

Coastline

This not-for-profit housing provider in Cornwall (UK) manages over 5,000 homes. The housing association is a long-term collaborator with the University of Exeter, working on numerous health and wellbeing initiatives.

aico®

As a market leader in European home safety technology, Aico has been a crucial collaborator on this series of guides. They provided expertise, finance and information, as well as providing costings for our social return on investment models.

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