Smart Homes, Healthy Homes: Exploring the potential for remote IoT sensors of indoor air quality to help manage homes in social housing

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## Research Partners

#### This project was a collaboration between scholars in housing, energy use, indoor air quality and public health at the University of York and the University of Leeds; an Internet of Things platform provider HomeLINK that provides home integration and analytics technologies to social housing landlords and their residents; and Leeds City Council. The overarching HomeLINK project was funded by Leeds City Council using central government BEIS SBRI Innovate UK funding.

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# Executive Summary

This report is one of the first to consider the use of Internet of Things (IoT) technologies to better manage social rented homes with the potential for improved health outcomes for tenants. The study was based on the installation of IoT connected environmental sensors in social housing tenants’ homes in the North of England during 2021 and was funded by SBRI/INNOVATE UK via a large local authority. The findings are based on analysis of a tenant survey, qualitative in-depth interviews with social housing tenants who had received the IoT sensor intervention and from those who did not, a focus group of council housing staff and sensor data from a sub-set of tenants’ homes.

The findings demonstrate that tenants were largely accepting of the environmental monitoring in their homes, expressed hope in the possibilities that the additional data generated could reframe tenant and landlord discussions about contested issues, such as damp, mould and cold, and could inform better targeted stock investment strategies. A minority of tenants were digitally excluded or if connected lacked confidence in their abilities to use the tenant mobile app provided. Most tenants thought that it was the property being monitored but the boundaries between monitoring the home and the household were ambiguous, especially when considering data sharing with other services. This was a small pilot but the sensor technology indicated additional insight to landlords about the interaction of occupancy levels, inability to manage household costs and property attributes, with the potential to inform investment and housing management decisions and tenant support.

Despite official statistics making clear that occupant behaviours are not associated with damp and mould, recent reports have identified a tendency for landlords to apportion culpability to tenants’ and unwittingly tolerate conditions hazardous to health. Findings from other surveys and this study identify an interaction of tenant attributes over which they have limited control with poor property attributes more strongly influencing the incidence of damp and mould, not necessarily tenant’s conscious behaviours. Fuel poverty and some repair and property issues underpin tenants experiencing cold or hard to heat homes. Social landlords do signpost to sources of financial and energy cost advice but the study suggests that landlord strategic responses must routinely go beyond the repairs service.

Further longitudinal research is required to measure landlord and tenant actions in response to the data. Future studies should include the factors that facilitate and constrain the adoption of these new technologies in the social housing sector and how best they should be deployed and any subsequent changes in tenant health and wellbeing outcomes.

More detailed insights from the report are provided below.

* Social housing has the lowest proportions of homes of poor physical quality of any housing tenure. However, there has been little improvement in the incidence of serious condensation and mould and homes that lack thermal comfort in the sector over the last decade.
* The sector is subject to increased regulatory scrutiny because of inadequate responses to tenants’ complaints when poor housing conditions have emerged. The Ombudsman has indicated a cultural change in how many housing providers respond to tenants and manage damp, mould and cold homes is required. The Regulator of Social Housing is instituting more stringent oversight of consumer standards.
* There is a well-evidenced relationship between poor quality housing conditions and physical and mental health. Damp, mould and cold homes and poor indoor air quality are all shown to produce adverse health outcomes for residents that place additional cost burdens on the health service.
* Housing providers’ responses to tenants and their effective management of their stock is especially important as social housing is home to some of the most vulnerable households, with greater proportions living with ill-health and on low incomes.
* There is growing interest and investment within housing and health service providers in new digital data driven technologies to improve housing and health outcomes. This study explored the deployment of IoT connected environmental sensors to monitor internal air quality to identify conditions that could be harmful to health. The sensors measured humidity, temperature and carbon dioxide, combinations of which can give rise to greater risk of cold homes, damp and mould, dust mites and other hazardous events.
* Participants were self-selecting but the tenant profile was similar in profile to social housing tenants nationally, with more women, people with ill health, white people and people in receipt of benefits. Tenant satisfaction with their landlord and home was slightly lower than average, tenant reported higher than average problems with damp and mould and hard to heat homes, and a greater than average proportion of their homes had EPC ratings below grade C. Sizeable proportions of tenants showed indicators of fuel poverty.
* Tenants offered narratives that suggest that the landlords’ repairs service was well intentioned but occasionally ineffective when responding to tenants’ complaints, especially of draughts and damp and mould.
* Default landlord responses to tenant reports of damp and mould about having to adequately ventilate their home were, in many cases, reported without landlord’s comprehensive investigation of the problems, or consideration of the appropriateness of the advice.
* In some cases, tenants displayed tenacity in achieving remediation work, often after many years of complaints. Not all tenants had the required energy reserves to pursue the landlord and suffered low mood or were unable to use all their home due to unresolved problems.
* Tenants understood the landlords’ constraints and very few tenants interviewed had sought external support.
* Some tenants drew associations between their experiences of damp or cold and their health, suggesting that the conditions exacerbated existing conditions, not least on their mental health, while others were more circumspect in making such claims.
* Damp and mould in homes were associated with a combination of household and property attributes, including household income source, size of the household, some indicators of fuel poverty and repairs to doors, roofs and windows, but not necessarily to tenant behaviour.
* Hard to heat homes were more closely aligned with fuel poverty indicators and a range of property attributes including repairs.
* The sensors indicated a greater pool of tenant homes were at some risk of damp and mould and heat loss than tenants’ reports alone. As the survey and existing evidence suggest that the risks of damp and mould arise from an intersection of household and property attributes, the sensors seemed to provide greater insight into possible health risks than landlords’ property datasets alone.
* Landlords can also be alerted to properties where the temperature is persistently too cold, to provide support to those tenants. Although there was a high synergy between the sensors identifying homes with rapid heat loss and low EPCs, the sensor's insights could provide additional information to inform energy conservation and retrofit strategies.
* Tenants were largely well connected digitally although some groups would require further support to get online and improve their confidence in using new technologies.
* One in ten tenants would be resistant to any remote monitoring of their home but greater proportions were uncomfortable with data sharing beyond the landlord. Determining when and with whom sharing the sensor data was appropriate and when tenant permissions were needed requires further work. The parameters of sensors monitoring the property and not the household were ambiguous and require further exploration of the data’s potential to reveal tenants in vulnerable positions, such as under-heated homes are to be realised.
* Tenants had rarely considered these issues prior to the conversations so sentiment was weakly held, could change with new information and requires further examination.
* Tenants were largely connected and on board with the potential. Benefits were seen in the new data source informing landlords stock investment strategies but also in underpinning tenant reports of problems in individual homes. Staff views were under-explored but those that participated thought the tenant app would be valuable in prompting tenants to manage their homes effectively.
* Many tenants were constrained in their attempts to manage problems of cold and damp in their homes and ‘do the right thing’ as the issues related to fuel poverty, their household size, low incomes and property attributes that were beyond their control.
* Similarly, social landlords have multiple demands on limited resources and may be unable to react in a timely manner, or be unable to affect change in tenants’ income, energy costs or benefit levels without their own additional support. It was also clear that deployment would demand staff time in integrating the landlords’ data into current housing management and maintenance practices and systems.
* The sensor data may, however, support landlord’s prioritisation in stock reinvestment strategies, make the most of effective use of limited funds and evidence their approaches to more robust regulators.
* Landlords can investigate and direct resources at property repair or improvement but also incorporate income maximisation and fuel economy advice to tenants. While landlords have legitimate concerns about litigation and reputational risks from Ombudsman complaints and the Regulator’s investigations, tenants were often passive or had limited energy and agency to engage their landlord. The remote monitoring of tenant homes could cut through a reliance on tenant reports and evidence new strategies and actions in this area to more robust regulators, or indeed courts.
* Health impacts could not be explored but tenants carried a high health burden, potentially impacted by health hazards and landlord responses that undermined their self-esteem.
* Future research in this area needs to be undertaken at scale, include a longitudinal element and capture issues relating to implementation with a process evaluation, property management and health outcome evaluation and an economic evaluation to appraise whether the intervention can achieve cost savings to housing, health providers and tenants.

# 

# Chapter 1: Introduction

## Introduction

This report outlines a study of how Internet of Things (IoT) technologies can be used to better manage our social housing stock and lead to improved health outcomes for tenants. The study was based on the installation of IoT connected environmental sensors in social housing tenants’ homes in the North of England during 2021 and was funded by SBRI/INNOVATE UK via a large local authority. This report includes the findings of the initial stages of this project and amounts to a small exploration of tenants’ experiences of their homes and the acceptability and potential of using these technologies to support tenants and landlords in mitigating the impacts of damp, mould and cold in tenants’ homes.

Social housing has well maintained and energy efficient homes in comparison to other housing tenure but includes some of the highest incidence of damp and mould which is attracting increased scrutiny (Housing Ombudsman, 2021). The tenure contains some of the most vulnerable people with large proportions of tenants with ill health and low incomes. Housing is a key determinant of health (Rolfe et al., 2020) and poor indoor air quality, including cold, damp and mould and other pollutants, is known to produce adverse health impacts. The environmental sensors remotely monitor homes and provide landlords and tenants with continuous data and alerts if conditions present a range of risks. There is a burgeoning interest in digital solutions in both health and housing, so this project makes a timely contribution to consider the potential of these IoT technologies in the home and their role in managing poor indoor air quality.

The environmental sensors were installed in 49 tenant homes. The sensors comprised three units measuring carbon dioxide, temperature and humidity and were professionally installed in tenants’ living room, bathroom and kitchen. In combination, these sensors can identify risks of damp, mould, cold homes, dust mites and other allergens, draughts and poor indoor air quality in general. The social landlords receive almost real-time data on a ‘dashboard’ that enables staff to look at property performance in aggregate or at an individual property level. Tenants receive the room and property level data on an app on their mobile phones or on tablets provided as part of the project. Artificial intelligence and machine learning techniques are used to classify the data according to the level of risk and provide property and room level alerts to landlords and tenants, advising of possible actions to mitigate the risks identified.

This report is based on tenant interviews, a tenant survey, some staff views of the intervention, and an analysis of the sensor data retrieved. The findings point to a largely connected and supportive tenant population, who view the additional sensor data as providing valuable insight to support landlords’ stock reinvestment strategies, as well as support to tenants to manage their homes and evidence individual tenant complaints. The report highlights issues that warrant further consideration if similar sensors are deployed at scale and in any future research in this area, including the boundaries of tenants’ acceptance of data sharing, and the extent that tenants and landlords control the factors that produce poor indoor air quality in social tenants’ homes.

## Background

### Health and Housing

The global pandemic has exposed the adverse impact of housing inequalities and health (Abbs & Marshall, 2020). The lockdowns challenged the concept of ‘home’ as a safe haven for those people forced to sleep on the streets, for families who live in overcrowded homes, for those who share spaces and amenities or have poor living conditions [(Brown et al., 2020)](https://paperpile.com/c/TTZOT7/pDPT). In these circumstances, the home can be an independent health threat. Hazards posed by damp, mould and cold homes on respiratory problems, cardiovascular disease, and excess winter deaths, were experienced by those most at risk of Covid-19 (Centre for Ageing better and Kings Fund, 2020). Outside of the pandemic, the home can remain a ‘health insult’ (Baker et al., 2017), if the conditions in which people live have adverse impacts on physical and mental illness, with lasting effects (Pevalin et al., 2017). Housing, therefore, forms one of the key determinants of health with housing debts, high housing costs, and physical manifestations of disadvantage, cold, damp or hazardous homes, posing a health threat to many and across generations (Marmot et al., 2020). Indeed, poor housing costs the NHS £1.4 billion a year, including £857 million arising from excessively cold homes and £38 million from damp homes (BRE, 2021).

Outdoor air pollution has been the prime focus of concerns about air quality and human health but more recently attention is turning to poor indoor air quality as a threat to health as people spend most of their time indoors. Known indoor air quality risks of asbestos, smoking, radon gas and carbon monoxide are well evidenced, but the risks posed by volatile organic compounds arising from a greater range of synthetic glues, fibres and other chemicals found within our homes, in carpets, furniture, cleaning and candles, for example are attracting greater attention [(Royal College of Pediatrics and Child Health, 2020](https://paperpile.com/c/TTZOT7/BVMU)). Poor indoor air quality can have adverse health consequences (Cincinelli and Martinelli, 2107), associated with elevated humidity and dust mites linked to respiratory conditions [(Korsgaard, 1998)](https://paperpile.com/c/TTZOT7/klEO) and high levels of carbon dioxide are typically associated with high levels of volatile organic compounds and other pollutants [(Chatzidiakou et al., 2015)](https://paperpile.com/c/TTZOT7/qXIf). However, reduced residential ventilation and improved insulation since the 1970s have meant that air-borne hazards now remain indoors for longer (Carslaw, 2021). Improved ventilation rates are therefore associated with improved health outcomes (Sundell et al., 2011), but ventilation alone is not a panacea as controlling and reducing the source of the problem is also important (Guyot et al., 2018).

There are multiple ways housing impacts health affecting physical and mental health either directly (e.g. through stress, cold, physical hazards) or indirectly (status, satisfaction, inability to socialise, inability to use all space in house impacting family relationships etc.) [(Thomson & Thomas, 2015)](https://paperpile.com/c/TTZOT7/j7Hs). One of the main areas of concern with indoor air quality is the health impacts of damp, mould and cold in homes that requires considerable NHS expenditure to limit the resulting respiratory illnesses (Dick et al., 2014). Poor housing conditions are associated with respiratory diseases such as rhinitis and asthma, with childhood asthma demonstrably caused by mould (Callaud et al., 2018); these issues can interact with psychological stress to produce disease (Sandel and Wright, 2008). Housing debt and affordability problems, thermal discomfort, and worry about the consequences of cold and damp for health, impact on mental wellbeing (Liddel and Gurney, 2015). Cold homes are also associated with negative health biomarkers such as high blood pressure (Shiue, 2016). Age UK notes that cold homes cost the NHS £1.4 billion per annum due to the impact on older people. Interventions addressing warm homes are some of the best evidenced housing interventions with demonstrable health outcomes (Thomson et al., 2013). Every £1 spent on improving warmth in homes occupied by ‘vulnerable’ households can result in £4 of health benefits (Centre for Ageing Better and the Kings Fund, 2020). Remediating coldness, damp and mould and internal air quality in housing can therefore limit the unequal distribution of disease burden, and the associated costs and demand on the NHS.

The coldest homes account for three times more excess winter deaths than the warmest homes, with fuel poverty, limited awareness of the impacts of cold and behaviours including thrift and stoicism being contributory factors to living in a cold home (PHE, 2019). Tackling cold homes is, therefore, one of NICE’s strategic priorities to reduce excess winter deaths, morbidity, fuel poverty, exacerbations of current health problems, timely discharge from hospital, and rates of hospital admissions and readmissions [(NICE, 2016)](https://paperpile.com/c/TTZOT7/9zLq). NICE recommends that health practitioners identify people vulnerable to health problems associated with a cold home, identify a single-point-of-contact for a health and housing referral service and ask people about keeping warm at home (ibid.). [NICE (2021)](https://paperpile.com/c/TTZOT7/phju) also recommends that local authorities produce strategies to identify and mitigate poor indoor air quality due to the adverse health impacts.

Using behavioural change techniques combined with digital and mobile technology to improve health outcomes is a key priority of Public Health England (2014). There is great interest in IoT monitoring devices that collect, send and store health related data, primarily from individuals [(Kelly et al., 2020)](https://paperpile.com/c/TTZOT7/PQIO). Most of these technologies are based on sensors and provide opportunities for data analytics or smart healthcare to improve the identification of risks, diagnoses, remote monitoring and enable the self-management of conditions (ibid.). Horne (2020) identified these technologies emerging along three lines: (i) long term conditions monitoring and management; (ii) supporting health behaviour change; (iii) home care and ambulatory monitoring. Examples of IoT devices at market or in development include smart robots to give people information, vital sign patches, monitoring of blood glucose, or Bluetooth connected inhalers or digital medications (Kelly et al., 2020 - Multimedia appendix 1). All these devices are person-centred, and yet connected monitors can also be deployed to monitor the social determinants of health such as housing and environmental health risks.

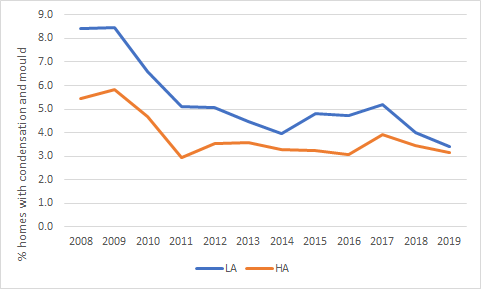
### Social Housing

Social housing is home to households that are more likely to be disabled or have a life limiting long term illness, have lower incomes than people in other housing tenures, have a higher proportion of lone parents, and contain a higher proportion of people living in overcrowded homes [(MHCLG, 2021)](https://paperpile.com/c/TTZOT7/musn). For these people, social housing provides relatively good quality homes, as they are less likely to fail the Decent Homes Standard[[1]](#footnote-1), are more likely to meet energy efficiency targets and have fewer fuel poor households than private rented homes, despite social renters having lower incomes (MHCLG, 2021; BEIS, 2021a).

Social housing does, however, have a high incidence of damp and mould in people’s homes (MHCLG, 2021). Damp may comprise penetrating damp from faulty building components and rising damp from failing or breached damp courses. Damp can also arise from condensation, where moisture held in the air from everyday activities such as cooking, washing and living in the home forms water when it meets cold surfaces, giving rise to conditions where mould can form. In 2019, private renting had the greatest incidence of any damp in the home, 6.7 percent, compared to 5.1 percent of local authority homes and 4.0 percent of housing association homes (MHCLG, 2021, Table DA5101/SST5.1). Serious condensation and mould - where large patches of damp and mould are present on walls or soft furnishings - is the most common form of damp in rented housing with 3.4 percent of local authority homes having serious condensation damp and mould and 3.1 percent of housing association homes, affecting some 133,000 households. Inadequate thermal comfort is the main reason for social rented homes failing to meet the Decent Home Standard in 2019, for both local authorities (3.8 percent) and housing associations (5.3 percent) compounding problems of serious damp and mould. Social rented homes that lack thermal comfort have twice the rate of damp and mould (6.1 percent) compared to those that have adequate thermal comfort (3.1 percent) ([MHCLG, 2021, T](https://paperpile.com/c/TTZOT7/musn)ables DA3201/SSts3.2 [)](https://paperpile.com/c/TTZOT7/musn). The incidence of serious damp and mould is greater among social renting households with children (five percent or 71,000 homes) compared to two percent (or 51,000 homes) of households without children (MHCLG, 2021).

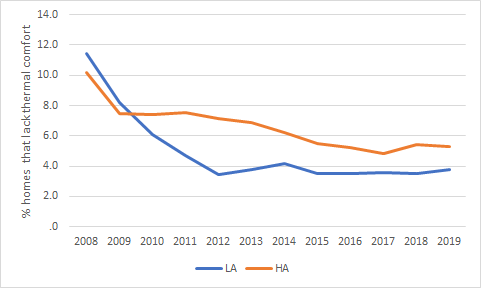
The incidence of serious condensation and mould and a lack of thermal comfort in social rented homes has reduced over the last decade (Figure 1 and Figure 2). Notably, however, improvements in the incidence of serious condensation and mould have largely stalled since 2011 for housing associations, and since 2012 for the incidence of homes that lack thermal comfort in local authorities.

**Figure 1: Incidence of social rented homes with serious condensation and mould, 2008-2019**



*Source: Table DA5101/SST5.1 MHCLG*

**Figure 2: Incidence of social rented homes that lack thermal comfort, 2008-2019**



*Source: Table DA3201/SST3.2 MHCLG*

Social landlords face serious financial pressures arising from the building safety crisis and the need to contribute to the housing supply shortage. Social landlords’ repairs expenditure has increased in recent years with an annual six percent rise to 2020 (to £5.7 bn), an eight percent rise to 2019 and three percent rise to 2018, mainly attributable to spending on the building safety crisis following the Grenfell fire in 2017 ([Regulator of Social Housing, 2021a)](https://paperpile.com/c/TTZOT7/hfos). Capital funding to new homes also rose with a 13 percent increase from 2019 to 2020 (to £13.6 bn) (ibid.). However, up to 2017, the capital spending on major repairs (£1.6 bn) had fallen 14 percent from 2016 due to the one percent rent cut imposed by the government (Regulator of Social Housing, 2018).

Social housing homes are the most energy efficient compared to other housing tenure and the proportion that have EPC ratings of C or above rose from 23 percent in 2009 to 61 percent by 2019 (MHCLG, 2021). Government has targeted funding on energy efficiency in social rented homes to get social rented homes to an EPC C grade by 2035, or 2030 for ‘fuel poor’ households (Inside Housing, 2021; National Housing Federation, 2020). A total of £500 million of the Green Homes Grant scheme has been allocated to local authorities to provide green home improvements for households with an income of under £30,000 and £50 million for a demonstrator project for the Social Housing Decarbonisation Fund (SHDF) to tackle 2000 of the worst performing homes (MHCLG, 2020). Improvements in energy efficiency and thermal comfort may, therefore, be anticipated soon.

The regulatory environment for social housing is changing following the Grenfell Tower fire in 2017, with a greater emphasis on addressing tenant concerns (MHCLG, 2018). The Government have proposed a new charter for tenants, with strengthened regulatory consumer standards for the sector and a review of the Decent Homes Standard (MHCLG, 2021a). New consumer standards are being developed that promote safe homes and quality landlord services (Regulator of Social Housing, 2021) A recent Homes (Fitness for Human Habitation) Act 2018 was introduced to ensure that all rented homes are fit for human habitation at the outset of the tenancy and throughout, and to bolster tenants’ rights of redress should landlords not comply with their legal obligations. The Housing Ombudsman (2021) intends to be more robust in their handling of tenant complaints, notably about damp and mould, calling on landlords to have a zero-tolerance policy and for there to be a cultural change in social landlords routinely claiming tenants are culpable. Social landlords increasingly face disrepair litigation by solicitors dubbed ‘claims farmers’ who take a portion of any compensation, actions that are not always to the tenants’ benefit (Nearly Legal, 2019). As well as these regulatory and financial risks, social landlords also suffer reputational risk in the management of these damp, mould and cold issues and have been subject to extensive public scrutiny with adverse ITV reports involving several social landlords during 2021[[2]](#footnote-2) .

### Internet of Things (IoT) Connected Environmental sensors

Landlords are urged to take a data driven strategic approach to damp and mould complaints or risk more maladministration decisions and legal claims made against them (Housing Ombudsman, 2021). A burgeoning industry is promoting and supplying the use of remote IoT connected environmental sensors to social landlords to control poor indoor air quality. Typically, these sensors detect humidity, temperature and carbon dioxide. Social landlords are increasingly looking to these technological solutions to mitigate the impact of damp, mould and cold homes (Housing Ombudsman Service, 2021; HACT, 2020).

To date pilots have achieved some success with reduced energy bills for tenants, reduced carbon dioxide (an indicator of poor air quality in general as well as an independent health hazard [(Chatzidiakou et al., 2015)](https://paperpile.com/c/TTZOT7/qXIf) ) and enhanced landlord management capabilities (HACT, 2020). Data flows from wirelessly connected sensors can identify the combinations of problems that give rise to cold, damp and mould and produce targeted advice and interventions accordingly in settings such as student homes and hospitals (Chen et al., 2019; Cabra et al., 2017; Fischer et al., 2016; Nepomuceno et al., 2019).

Depending on how the data is presented and communicated, the data could also support tenants to exert greater control over their home’s internal environment (Gupta et al., 2017; HACT, 2020). Tenants often struggle financially, with high fuel costs, so landlords need to signpost tenants to support in minimising their bills, keep abreast of government initiatives to increase energy performance of their homes and involve tenants in the deployment of new technologies in this field and review the options available (Housing Ombudsman, 2020; 2021). The risks do not only, therefore, relate to the physical condition of the property but can be influenced by household finances, occupancy levels, as well as a home’s amenities and tenant behaviours. Landlords can, therefore, also adopt various social interventions in addition to their legal repairing obligations, including income maximisation advice, transfers for overcrowding, or increased investment in energy efficient stock (Housing Ombudsman, 2021b). The environmental data can also inform landlords’ stock reinvestment and asset management strategies, and support landlords to deliver energy efficiency, carbon reduction and retrofitting strategies (HACT, 2020).

To date, these initiatives have generally been small-scale and limited by the lack of independent evaluation.

## Research aims and methods

The overall aim of the study was to explore tenant and staff views of IoT connected environmental sensors and to identify any health and wellbeing outcomes of the IoT environmental sensor data intervention. There was also interest in understanding issues arising from the implementation of the intervention to support future decision making by social landlords and health professionals. The study was, therefore, designed to answer the following questions:

1. Resident beliefs, attitudes, experiences towards and acceptability of the installation and use of sensor technologies and data outputs in their homes. What barriers or opportunities exist for tenants to adopt the use of these technologies? Can residents harness these data to institute behaviour change to reduce problems or demand remedies from others, and if so, how?
2. Housing management and maintenance staff attitudes towards and use of this data driven approach to their work. What barriers or opportunities exist for staff to use the data to realise the potential of the technology to limit adverse impacts on tenant households and help manage their homes?
3. To explore the ethical and legal considerations of collecting these home environmental data. Who owns the data and for what purpose? Is there potential for data linkages to housing or property management data to shape asset management or tenant support strategies?
4. To identify the social and health impacts on the tenants of IoT data supported management of the home environment. To what extent can these technologies begin to mitigate structural impacts of poverty and inequalities?

The project funding ended at the midway point so this paper reports on **the first stage of a before and after study**, comprising a tenant survey, tenant in-depth interviews, one staff focus group and the sensor data from the tenants’ homes in the intervention group. The first question is explored more fully than the subsequent questions. The fieldwork was undertaken between April and June 2021. Ethical approval for the study was obtained from the University of York, data sharing agreements were negotiated between the University of York, the IoT sensors provider and the social landlord and informed consent was obtained from the tenants and staff for participation in the study.

The tenant survey was circulated to 1100 randomly selected general needs and sheltered housing tenants in a northern cities’ council housing stock. For tenants who agreed to receive electronic communications from their landlord (60 percent) an e-survey using the Qualtrics platform was used, and a postal survey was conducted for the remaining 40 percent of tenants who had not agreed to electronic communication. A £10 shopping voucher was used as an incentive and thank you for each response received. A total of 156 usable responses were returned giving a response rate of 14 percent (around 20 percent for the e-survey). A total of 49 of respondents had the sensors installed, 40 of which also completed the tenants survey. The survey, originally designed to offer a baseline, captured details of their homes, tenants' experiences of their homes’ indoor air quality, their management of the property, their health status, sentiment towards new technologies, the sensors and data sharing. The SF-12 is a validated scale used to assess a person’s health and wellbeing and quality of life (Huo et al., 2018). The SF-12 questions suite of questions was used to collect the tenants’ health status, and in accordance with the guidance, composite scores were constructed to reflect a person’s physical health and mental wellbeing.

The number of survey respondents and tenants who received the sensor installation are small and data analysis could not always confirm that the results were not down to chance or the character of the samples. The report flags where the most robust statistically significant data is found.

A total of 17 in-depth tenant interviews were undertaken lasting up to an hour and were undertaken on the telephone or via Zoom, with audio recordings obtained with permission and professionally transcribed. The interviews were designed to capture tenants’ experience of damp, mould and cold homes, their efforts at self-management and liaison with their landlord, their sentiments towards the sensor technology and data sharing. The topic guide was based upon the Theoretical Domains Framework (see Appendix 2), designed to support the identification of the opportunities and barriers to the adoption of new behaviours or practices. The average age of these tenants was 49 years old but ranged from 23 to 76 years old. Nine of these tenants who were interviewed had the sensors installed and the remaining eight did not. Twelve interviewees had pre-existing health problems ranging in severity but including some with chronic conditions. Ten tenants lived in houses and seven in flats. Twelve of the 17 tenant interviews discussed damp, mould or cold in their homes.

One focus group comprised five members of the landlords’ housing management team was also undertaken to explore their views of the environmental sensor technology and its potential. With tenants’ permission, sensors collected environmental indoor air quality data that provided assessments of their property’s risk of damp, dust mites or other allergens, cold and heat loss and these sensor data were appended to the tenant survey data. Information about tenants’ homes was gained from the Energy Performance Certificates (EPCs) Open Communities datastore, but data was only obtainable for just over half (55 percent) of the respondents’ properties. EPC certificates are obtained for new lets, suggesting that many of the properties had not had new tenants for some time. The EPC data included the current energy performance classification (with A the best performing and G the worst) and the property type. Where streets presented a high degree of homogeneity, some gaps in property age data were filled with data from adjacent neighbours, meaning property age data is present for 62 percent of properties.

This study contributes to the growing interest in the deployment of IoT technology in social housing, providing insight into the tenants’ attitudes towards the sensors and the potential of the data to remedy problems in their homes. The study also highlights possible barriers to implementation and use of the data by tenants and landlords that might inform investment decisions. This is the first independent study to consider IoT sensor deployments in social housing to combat damp, mould and cold and points to issues to consider in future research in this area.

## Structure of the report

The next chapter (Chapter 2) outlines what is known about the tenants, their health and their homes, drawing on the tenant survey data. Using data from tenant interviews, Chapter 3 explores tenant experiences of damp, mould and cold homes, how they manage their home to mitigate these risks and their liaison with their landlord when seeking remedies for any problems in their homes. Chapter 4 considers what issues are associated with tenant reports and sensor reports of damp and mould and hard to heat homes, and Chapter 5 explores tenant attitudes towards technology, the sensors and data sharing. Chapter 6 uses the theoretical domains framework to synthesise the various data streams and consider what factors act as barriers and facilitators of the sensor intervention bringing about the desired changes in the management of tenants’ homes. Chapter 7 concludes with a discussion about the limits and potential of deploying these technologies in social housing.

# Chapter 2: People and Properties

## Introduction

This chapter uses tenant survey data to provide an overview of the properties and the people involved in the study with some comparison to the profiles of social housing tenants and their homes nationally.

Tenants in our survey shared similar profiles to social housing tenants nationally, with similar rates of lone parents and single people and households with children, but with slightly greater proportions of women, people on benefits, white people and people with ill health. Significant proportions of the tenant respondents struggled with rent and fuel bills and their scores for mental and physical health were below the national averages. Their homes were typically built in the postwar period, and were mostly houses rather than flats, and half of these tenants’ homes had poor energy performance with EPC ratings below grade C. Most tenants liked the area in which they lived but were slightly less satisfied with their homes, and only around half were satisfied with their landlords’ repairs service. Satisfaction with their home and landlord repairs service were below national figures. Half of tenants reported that they had damp and mould and a third reported that they had hard to heat homes. Many tenants had no outdoor drying space but half of these also had no tumble dryers. Up to a quarter of tenants lacked extract fans in their kitchens or bathrooms. Large proportions of respondents showed indicators that they were experiencing fuel poverty.

The following sections provide detailed profiles of tenant respondent households, their homes and the incidence of fuel poverty, an intersection of these two sets of attributes.

## Tenant’s households

The survey was distributed to a randomly selected sample of the social landlords’ tenants and the respondents largely accord with the population of social housing tenants nationally (see Table 2.1). Tenants in the sample had a similar age and household composition to those of other social housing tenants, with 44 percent single adults and 17 percent lone parents. Our sample had fewer working tenants (36 percent) and fewer receiving a pension (16 percent) than social housing nationally (45 percent and 25 percent respectively), and more respondents receiving benefits (42 percent) than nationally (30 percent). Household reference persons (those with the highest income or the oldest) are generally likely to be men across all households nationally, but in social housing more women are lead tenants and this was especially the case among our sample where more women (69 percent) than men (27 percent) responded to the survey. A slightly larger proportion of white people responded to the survey (87 percent) than is reflected among social housing tenants nationally, although this may reflect local geography.

**Table 2.1: Tenant attributes % (n=156)**

|  |  |  |
| --- | --- | --- |
|  | **Tenant Survey (% respondents)** | **English Housing Survey 2019/20 (% social housing households)** |
| Mean age | 52 | 53 |
| Household composition  single adults  lone parents  couples  couples with children  multi-adult household with children  multi-adult households no children  Household summary  Single adults  Multi adult  Households with children | 44  17  19  8  3  6  44  26  29 | 41  17  13  16  2  13  41  28  35 |
| Income source  working  benefits  Pension  combination of above | 36  42  16  6 | 45  30  25  - |
| Ethnicity  White  BAME  Prefer not to say | 87  9  5 | 82  18 |
| Gender respondent (HRP)  Male  Female  Other | 27  69  4 | 42  58 |
| Paying bills hard sometimes or struggling  Rent  Energy bills  Other bills | 23  34  32 | 27  38  - |

*Source: Tenant Survey and English Housing Survey 2019/2020 (NB: may not sum to 100 due to rounding)*

Around one in four tenants found paying their rent hard sometimes or were struggling (23 percent), slightly below the 27 percent that social housing tenants nationally reported found their rent to be fairly or very difficult. One in three (34 percent) found their energy bills (gas and electricity) hard sometimes or were struggling (27 percent and seven percent respectively). Nationally, 18 percent of households have been struggling or falling behind with fuel bills, rising to 41 percent among the lowest income quintile and 38 percent for social housing tenants (BEIS, 2021). In this respect our sample is in line with national figures.

## Tenant’s health

As with social housing nationally, the tenants carried a heavy burden of physical and especially mental ill health (See Table 2.2). The tenant respondents’ rate of life limiting ill health and disability was higher (63 percent) than of the general population (34 percent) and above that found among social housing tenants nationally (54 percent) (MHCLG, 2021). The SF12 questionnaire suggested that their overall score for physical health (44) was slightly below the national average (a score of 50), but the tenant respondents’ mean average mental wellbeing score was 37, which is significantly below the national average for the whole population (50). The SF12 constituent questions show large proportions of respondents with lives impacted by ill health with *over half* of the respondents saying that their physical and mental health means that they accomplish less than they would like that their health limits their work and other activities, and that their physical or mental health interferes with their social activities most or all the time. [NICE, (2021)](https://paperpile.com/c/TTZOT7/phju) note that certain health conditions can be exacerbated with damp, mould and cold homes (COPD, allergies, asthma, heart problems and pregnancy). A third of respondents self-reported that they had asthma (34 percent), 21 percent reported that they had allergies, 13 percent COPD, and nine percent that they had heart problems. Only one percent of the sample were pregnant.

**Table 2.2: Tenant health attributes (n=177)**

|  |  |
| --- | --- |
|  | **Survey respondents** |
| Life limiting illness  Mean average physical health SF12 score\*  Mean average mental health SF12 score\*  COPD  Asthma  Allergies  Heart problems  Pregnant | 63  44  37  13  34  21  9  1 |

*Source: Tenant Survey \* (50 is national average for all people)*

## Tenant’s homes

Most of the tenants' homes were houses, with the semi-detached house being the most common built form (37 percent) and 21 percent of homes were flats (Table 2.3). Reflecting the development of council housing nationally, most of the homes were built before and after the second world war, with the largest proportion built in the period between 1950-1966 (44 percent). Nearly two thirds of these tenants' homes are over 55 years old, with 10 percent over 90 years old (not shown). Just over half of the EPCs were below grade C (51 percent). Not all properties had extract fans in the kitchen (27 percent) or in the bathroom (35 percent). Although double glazing was universally recorded on the EPCs, only 58 percent of tenants reported that they had trickle vents to increase airflow in their homes. This may have been a problem of terminology, although first generation double glazing did lack ventilation features. Nearly two-thirds (64 percent) had access to outside space to dry their clothes leaving a third without any outdoor drying facilities. A third of tenants had a tumble dryer, most commonly a condenser dryer. A third of people without an outdoor space to dry clothes had a condensing dryer (31 percent), six percent had a fixed vented tumble dryer and 11 percent had a tumble dryer where they placed the hose out of the window. This leaves half of tenants (52 percent) with no outdoor drying facilities with no other means of drying clothes indoors.

**Table 2.3: Property attributes (%)**

|  |  |
| --- | --- |
| Property type  House  -end terrace  -mid terrace  -semi detached  Flat  Bungalow | 76  11  28  37  21  3 |
| Age of property construction  1949 or before  1950-1966  1967 or after | 34  44  22 |
| EPC grade  B  C  D  E  F  Below C | 4  45  37  11  4  51 |
| Property amenities\*  Gas cooker  A cooker hood over the hob that vents to outside  An extract fan in the bathroom  An extract fan in the kitchen  Trickle vents in your windows  An outside place to dry your clothes washing  A condensing tumble dryer  A tumble dryer that has a fixed vent to the outside  A tumble dryer where you put a hose out of a window/door  An open plan kitchen living area  None of the above | 48  3  73  65  58  64  30  7  8  6  4 |
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*Source: Tenant Survey (\*More than one option was permitted) (NB May not sum to 100 due to rounding)*

Table 2.4 shows tenants sentiment towards their home and their use of the home. Tenants were more satisfied with the area in which they lived (76 percent) compared to their actual homes (62 percent). Satisfaction with the repairs service was low at 54 percent, with 25 percent indicating dissatisfaction. Half of respondents trusted their landlord (50 percent), with a large proportion of neutral answers (34 percent). These tenant respondents were less satisfied than their national counterparts, where 78 percent were very or fairly satisfied with their accommodation, were satisfied with their area at a comparable rate to nationally (79 percent) and had lower satisfaction with the landlord's repairs and maintenance service than nationally (66 percent) although *dissatisfaction* with the repairs service was very similar (26 percent) (MHCLG, 2021). Tenants reported that their primary concerns about their homes were damp and mould (46 percent), draughts and insulation (36 percent), hard to heat homes (33 percent) and repairs required to roofs, windows or doors (31 percent). The English Housing Survey includes surveyors’ assessments of serious damp, mould and condensation and is likely to only report cases with a higher threshold than tenants’ own reports of damp and mould in their homes. Therefore, there is a disparity between the three percent of social housing tenants’ homes identified nationally as having serious damp and mould problems (MCHLG, 2021), compared to nearly half of respondents in this tenant survey.

The most common reasons for tenants to contact their landlord concerned repairs (40 percent) or help with benefits (25 percent) and around one fifth were seeking to move because of the property conditions (9 percent) or on health grounds (10 percent). Half the tenants (50 percent) trusted their landlord a great deal or a lot).

**Table 2.4: Tenants sentiment towards their home (%)**

|  |  |
| --- | --- |
| Satisfaction (Very satisfied or satisfied)  Home  Neighbourhood  Landlords’ repairs service | 62  76  54 |
| Tenant concerns about their home\*  Damp and mould  Draughts and insulation  Hard to heat  Repairs to roofs, windows or doors  Nowhere to dry clothes  No concerns at all  Security  Noise  Internal air quality a problem  Heating repairs  Odours  Fire alarm  External air quality  Overcrowding | 46  36  33  31  21  20  19  17  16  14  10  9  5  3 |
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| Tenants requested help from landlord\*  Help with benefits  Help with repairs  Help with transfer due to property conditions  Help with transfer due to overcrowding  Help with transfer on medical grounds | 25  40  9  4  10 |
| Trust in their landlord (A great deal or a lot) | 50 |

*Source: Tenant Survey (More than one answer was permitted)*

The survey asked several questions about how the tenants used their homes and its amenities to generate or mitigate indoor humidity (Table 2.5). The proportion of tenants who used an extractor fan (55 percent) was below the proportion who had extractor fans in their kitchens or bathrooms. This could be because the extractor fans came on automatically via the light switch or the level of humidity in the air and people did not therefore use them consciously but may also be because people forget to turn them on if manually controlled. Almost all tenants had used the bath or shower (93 percent) but almost half would have done so without the support of an extractor fan (55 percent), although high proportions had opened windows (88 percent). Similarly, over half (53 percent) of tenants had boiled pans without using lids but a third of these tenants (37 percent) had no kitchen extractor fan. Only seven percent of tenants had a cooker hood to extract cooking moisture and fumes.

**Table 2.5: Tenants use of their homes in the last two days**

|  |  |
| --- | --- |
| Opened window | 88 |
| Used extractor fan | 55 |
| Used washing machine | 86 |
| Dried clothes indoors | 66 |
| Dried clothes using tumble dryer | 37 |
| Used a shower or bath | 93 |
| Boiled pans with no lid | 53 |
| Boiled pans with lids | 54 |
| Used cooker hood | 7 |

*Source: Tenant survey (NB. More than one option was permitted)*

Two thirds of tenants reported that they had an outside place to dry clothes (64 percent), and this was slightly greater for those who lived in houses (66 percent) than for flats (58 percent). It is unclear why around a third of tenants of bungalows and houses reported no outside drying space, but this could be a lack of washing line or rotary dryer perhaps, rather than an inability to use outdoor space for drying at all. However, behavioural aspects are important here. The proportion of tenants who dried washing indoors (without using a tumble dryer) was 71 percent, greater than the proportion who had access to outdoor drying space (64 percent). Perhaps counterintuitively, 70 percent of those who dried clothes indoors had outdoor drying spaces available. Critically, there was no significant difference between the rates of indoor clothes drying for those who had damp (51 percent) and for those who did not (49 percent). Some tenant interviewees reported that they felt uncomfortable using public drying spaces provided for flats as they did not want to hang personal garments on the line, or they did not trust that their washing would be safe. Other tenants cited rain making drying outdoors uncertain. A survey of clothes washing and drying practices suggested that 51 percent of UK households have a tumble dryer, 75 percent an indoor clothes horse and 76 percent an outdoor drying line [(Yates & Evans, 2016)](https://paperpile.com/c/TTZOT7/96ob). A total of 39 percent of people with a clothes horse used it once or twice a week, 43 percent more frequently, despite only 18 percent of people being wholly reliant on this form of clothes drying (ibid.). This suggests our sample had a lower rate of tumble dryer ownership but were not unusual in drying clothes indoors.

## Fuel poverty

Social housing has some of the most energy efficient homes with 37 percent of local authority homes failing to reach an EPC grade of C or above and, with their newer property profile, 19 percent of housing associations (BEIS, 2021a; MHCLG, 2021). Nearly a quarter of local authority tenants are fuel poor (23 percent) compared to 16 percent of housing association tenants, and over half of social housing tenants with homes that are rated below EPC grade C are fuel poor (53.5 percent), due to the low incomes in the sector. Fuel poverty is a result of the interaction of household income, energy costs and the property’s energy performance that in combination push people into poverty.[[3]](#footnote-3) Fuel poverty impacts 13 percent of households in England, with 27 percent of private renting, 18 percent in all social housing and 8 percent among homeowners (BEIS, 2021- Accompanying detailed tables).

There have been numerous measures of fuel poverty over time, but the tenant survey focused on measures that captured tenants’ lived experience of managing energy costs and poor thermal comfort. A suite of questions drawn from the Poverty and Social Exclusion Survey (Dermott et al., 2012) highlighted tenants’ perception of the temperature of their home and the impact on managing fuel bills (Table 2.6). These are typically regarded as *consensual* measures of fuel poverty and may more readily capture social exclusion and deprivation than quantified measures of fuel expenditure and income (Thomson, Bouzarovski and Snell, 2017).

**Table 2.6: Indicators of fuel poverty (%)**

|  |  |
| --- | --- |
| *Poverty and Exclusion Survey questions* |  |
| Made an existing health problem or problems worse | 22 |
| Brought on a new health problem or problems | 3 |
| Made me/us feel miserable, anxious or depressed | 28 |
| I/we did not feel able to invite friends or family to the house | 11 |
| I/we spent as much time as possible away from the house | 2 |
| I/we stayed in bed longer than we wanted to keep warm | 29 |
| The temperature of the home did not affect the household in anyway | 54 |
| Turned heating down or off, even though it was too cold in the house/flat | 39 |
| Only heated and used part of the house/flat | 24 |
| Cut the number of hours the heating was on to reduce fuel costs | 41 |
| Used less hot water than I/we needed to reduce fuel costs | 24 |
| Turned out more lights in my home than wanted to reduce the electricity bill | 37 |
| Had fewer hot meals or hot drinks that I/we needed to reduce fuel costs | 12 |
| Other cut back on fuel use to reduce fuel costs (specify) | 9 |
| No, I didn’t feel I had to cut back on fuel use to save costs | 30 |
| Tenants agreeing to at least one of these indicators of fuel poverty | 67 |
| *Additional survey and EPC data* |  |
| Find it hard sometimes or struggling to pay gas and electric bills | 34 |
| EPC rating below C (D, E, F,) | 51 |
| Indicators of fuel poverty *and* Below C EPC | 23 |

*Source: Tenant survey (more than one answer was permitted)*

A third (34 percent) of tenant respondents found it hard sometimes or struggled with meeting their energy bills, and there were several indicators that tenants were experiencing fuel poverty issues. Nearly a third of respondents stayed in bed longer than necessary because of the cold (29 percent) and the temperature of their home made them miserable or depressed (28 percent). A total of 39 percent turned the heating off despite being too cold, and 23 percent said the temperature made existing health problems worse. One in eight tenant respondents (12 percent) indicated that they cut down the number of hot meals they had to minimise fuel costs. While 54 percent reported that the temperature of the home did not affect them and 30 percent reported that they did not cut back on fuel costs, a total of 67 percent of tenants reported at least one of these indicators of fuel poverty.

A home’s energy performance is not an independent measure of fuel poverty but combined with people’s low incomes becomes important. A greater proportion of tenants’ homes in our sample had EPCs below C grade (51 percent). A total of 23 percent of tenants expressed indicators of fuel poverty and had homes with low EPC grades closer to the levels of the official fuel poverty definition for social housing. However, the responses suggest that people were struggling with energy bills and cold homes beyond the official definition of being fuel poor.

## Conclusion

Tenant respondents were similar in profile to social housing tenants nationally, with some variation indicating more women, people with ill health, white people and people in receipt of benefits. Tenant satisfaction with their landlord and home was slightly lower than the national average, higher proportions reported problems with damp and mould and hard to heat homes, and a greater than average proportion of their homes among participants had EPC ratings below grade C. Sizeable proportions of participant tenants showed indicators of fuel poverty. The project therefore may have held greater appeal to those with existing property or health issues. Nonetheless, the study provides valuable insight into the experiences and related issues among this vulnerable population and is the first to examine tenant sentiment towards technology and sensors that would be applicable to other social landlords trying to understand the issues and adopt these technologies.

The remaining report focuses on the most reported issues in the home, damp and mould and hard to heat or cold homes. The next chapter explores tenants’ experiences of homes that display damp and mould or that they find hard to heat and how they try and mitigate the impacts of these conditions.

# Chapter 3: Experiences of damp, mould and cold

## Introduction

This section is based on the 17 tenant interviews and explores tenant experiences of damp or mould in their homes or their homes being cold and hard to heat. Additionally, it provides insight into how tenants manage related aspects of their homes that may contribute to damp, mould or cold and how they try and mitigate the impacts on their households or homes.

Tenants were largely positive about their homes and neighbourhood, although this was sometimes despite, or was qualified by, them experiencing problems in their home or in the area. A minority of tenants were less satisfied with their home, unhappy with their physical housing conditions, their neighbours or the poor internal decoration that contributed negatively to their low mood. Twelve of the 17 tenant interviewees had cold, damp and/or mould in their homes, to varying degrees, and the remaining tenants reported that they had warm and dry homes that were not expensive to run.

Tenants reported problems with damp, mould and cold that negatively impacted existing health conditions and induced some to feel shame about their home. Tenants talked about the additional efforts they took to manage their homes and minimise damp and mould spots. In the case of damp especially, to move beyond routine landlord recommendations for tenants to ventilate their homes and receive remedies to the situation required perseverance and energy reserves that not all tenants had. Damp and cold homes were experienced due to poor heating and ventilation systems, unusual building archetypes and unaffordable fuel bills due to low incomes and hard to heat homes. Space is given to tenants’ own words about their homes.

## Experience and impact of damp, mould and cold homes

Tenants who reported damp and mould frequently reported that it was common around windows or in bathrooms, but some had problems with damp and mould present behind sofas, washing machines, in corners of rooms or within cupboards. Constant condensation, damp and mould had spoiled some decorative surfaces, with stained and constantly peeling paint or wallpaper, had damaged furniture and soft furnishings and stored goods when present within cupboards. Occasionally, tenants described their homes as having unusual construction archetypes that meant their homes rapidly lost heat and were cold and/or damp.

Then there's black mould around all of the window frames. I reported it when it first happened, when I first noticed it, so that was about seven years ago, and nothing was done, so I just haven't done it again. It just seems to be around all the window frames. So, I've got the little damp collector thing… I've got one of them on every windowsill, and then two in the bathroom. (Tenant 8, family)

Above the bath, all the mould started coming through so obviously I reported it to the council. Then they came and put this fungicidal wash on it and then they painted it, but then obviously it's just been a continuous thing. Now I've got a wet floor room in there - which has been there probably for the last two years - I'm still having problems with the paint peeling off, the black mould coming through the tiles, and I'm just constantly at the council (Tenant 58, family)

Some tenants had homes that were hard to heat, or they had poor quality heating systems including expensive uncontrollable electric storage heaters. Hard to heat homes resulted in additional expense to maintain adequate warmth, exacerbating tenants’ financial constraints and increasing the emotional strain of managing on low incomes.

Then, obviously, it being hard to heat is really hard, because we struggle quite badly financially as it is. Obviously, in the winter when things are more expensive and trying to keep the kids happy and then I've got to buy new clothes, and we've got Christmas, and I've got my son's birthday. On top of all of that, having to find quite a bit of extra money to put on an already expensive meter payment, it's crippling to be quite honest. [...] It's harder because my son's 12. They know what's going on, but then they've got all of this, 'Well, my friends have got this, and my friends have got that.' I'm like, 'Yes, we've got to pay for gas.' It's a strain on money, but it's a bit of an emotional strain, as well, if that makes...does that make sense? (Tenant 18- working lone parent).

If you put the storage heaters on, it costs so much money and of course it's either too hot, too cold and we've been having… There's not heating in some areas so there's been damp in particularly the hall area, but there's not a heater in the dining area. We are having that; the council are doing that - which is great, I can't wait! (Tenant 26- family, includes health issues)

It's 15 [degrees Celsius] downstairs in the front room, 14 in the bathroom and 15 in the kitchen. (Tenant 37- single woman health issues, fuel poverty)

The presence of mould in various rooms of the home contributed to tenants’ low mood and depression, some feeling shame at the condition of their home. Issues of damp and mould compounded other difficulties tenants faced, such as being unable to undertake internal decoration themselves due to ill health but being unable to afford the costs of someone to do the work for them.

After the breakdown, I don't have people round anyway [but] beforehand, I was too embarrassed. (Tenant 37- single woman health issues)

Obviously, the mould in the bathroom isn't very nice to look at and it's a pain in the butt to try and clean. I work hard to make - I don't work hard, but I decorate the house and I try and make it look nice. To go through all of this and then not look nice is a little bit crap, if that makes sense. (Tenant 18- lone parent

The presence of damp and mould also increased the effort required to maintain the home. Many tenants put in great effort with different kinds of dehumidifiers, fungicidal sprays and regular cleaning regimes to combat damp, condensation and mould in their homes. It is possible that some of the sprays could also contribute to poor indoor air quality.

Q: Is there any other impacts that these ongoing issues have on you?

A: No. I mean, I can't think of any. Because I treat it on a regular basis, I don't think it has time. Even things like, in the corner cupboard at the bottom, I only do that once a month. It means getting down on my knees and lifting a heavy box out with books and binders and folders in. My knitting machine's down there and that hasn’t gone rusty. It's literally at the side of the chimney breast, is that. I can clear it with Milton. I get everything out. Some of the papers are ruined now. (Tenant 38- sheltered housing, partner with respiratory problems)

For me, obviously it looks awful! I think that's another reason why we clean it quite a lot. My daughter tries to clean it too, but obviously the spray and stuff that we use is quite strong. So, when I am cleaning it, I have to make sure there's no one else around. So, it's probably why I'm the one who gets affected most by it all, to be honest! (Tenant 8)

Cold homes meant that some tenants reduced the space they used within their homes, retreating to the warmest areas or taking to bed earlier or rising later to keep warm.

I tend to sleep in my spare room a lot because it's little and cosy, because it's small and cosy, do you know what I mean? (Tenant 40, single middle-aged woman, multiple health issues)

The other thing as well is they've put the sensors in the front room, but actually I spend more time in here because this is the warmest room in the house. It's upstairs at the front, and it's always warmer in this room, so most things go on in here. (Tenant 37, single woman health concerns)

Some drew direct parallels between their ill health and property conditions, often with cold exacerbating pain and discomfort of existing physical and mental health conditions, or damp, mould and/or cold contributed to low mood and depression.

Yes, it affects my asthma and also, I find it's a bit more worse in winter. Also [husband], yes, it does actually; it makes his legs hurt more if he's cold and things. He suffers more in the winter, yes. (Tenant 26, couple with children)

I have metal plates in my feet and obviously, eventually I will suffer terrible with arthritis, but if I do get cold, my feet are very painful. When I first get up in the morning, really painful. That's not an exaggeration of any kind, trust me. (Tenant 40- single middle-aged woman, multiple health issues)

Certain rooms I can't stay in for so long. When the damp was behind the sofa, obviously, I didn't realise that it was there. I had coronavirus, so I couldn't breathe anyway and then I was sitting in the living room, and I was just like, 'What the hell? I cannot breathe in this room. I can't breathe.' I was opening all the windows and all the doors, and it was just like I just could not breathe at all for the life in me. Then, obviously, when I pulled the sofa out, I was like, 'Oh, that's why I can't breathe.' [...] I feel like I didn't even know that I even had asthma until I moved in here.

(Tenant 44- young couple, asthma)

It gets me down; I suffer from mental health issues as well. I don't go out anywhere, it's like a motivation. I'm very tired. I sit here every day and I say, 'Oh right, tomorrow, I'm going to do some painting, tomorrow I'm going to do this,' and then because I'm in that much pain, I just can't get going and things like that, so it's a mixture of one thing or another, and then obviously with kids and stuff like that, it's a mixture of everything. (Tenant 45- single middle aged disabled man)

Other tenants were more circumspect and were uncertain if their conditions were related to their home, offering alternative explanations.

I couldn't say really because he has his good days and bad days, but it's mainly wintertime when he has - when [the asthma] flares up. (Tenant 58)

## Managing cold, damp and mould

Interviewees with problems expended energy in managing damp, mould and condensation in their homes, frequently using electrical and gel dehumidifier products, opening windows, wiping down wet windows and walls, using extract fans and trying to dry clothes outside or using condensing or vented machines, or even using a local launderette to only to dry clothes.

All in the tiles. I give it a scrub, and stuff like that, and I'll put a mould and mildew spray on it and then scrub it away. It goes away for a bit, and then it comes back. Then, it goes away, and it comes back. I can't really blame them. They only gave me a bath and I put a handheld shower in which is probably my own fault. I can't really blame them. I also can't work, look after a child, and a house and have to have baths all the time. It just takes too long. [...] No, there's one of those stupid little vent things, but other than that there's no extractor fan that I could turn on to take anything out. If we have a shower, we have to have the window open, which is fine in weather like this, because it's gorgeous. In the winter, not so great. (Tenant 18)

I got a dehumidifier and I run that a lot. I got this spray - mould and mildew killer. Yes, I've been treating it with that, but the council says that with COVID and everything else they can't come out and, so…[...] I were buying those from Asda where you put a big tablet in, and it changes it to water, but I was buying so many of them that I thought I'd buy a dehumidifier and use that instead. [...] If I leave it on all day, I think it's got a ten-litre tank and it fills the tank up. [...] Yes. Obviously, it flashes red then and I empty it and then start again but I've not been running it since it got warm weather. (Tenant 23)

Well, the condensation, if it's on the windows; daily. [Q: The mould?] That doesn't come daily but if I left it, it would come. My daughter's bedroom at the back, that's quite a cold room so you get a lot of condensation that I'd have to wipe it every day, so I love the summer! (Tenant 26)

Well, I've got one of them goes, like a little plastic tube, it's got, you peel the top off, it's got like an air vent, and it's got some balls at the top, and once it's like moisture, once it's put on windowsill, and after a while it disintegrates. It depends on how much moisture is there. (Tenant 45)

While many tenants reported drying clothes in tumble dryers and putting hoses out of windows or drying in their garden or communal drying spaces, other tenants felt that they had little choice but to dry clothes inside due to having no or insufficient outside space to use, or not trusting or feeling comfortable about using communal drying areas, if provided. The design of tenants’ homes did not always lend themselves to accommodate tumble dryers. A lack of privacy meant some felt uncomfortable drying underwear in shared spaces or worried about the security of their clothes. Tenants knew indoor clothes drying was to be avoided and said they took precautions to open windows.

It's [the tumble dryer] actually in the lounge because there's no room in the kitchen for it and I've got a balcony, so I open the balcony door and put the pipe outside. (Tenant 14)

I don't have a tumble dryer anymore because… Not because of the cost. My neighbours complained because it was in the outside cupboard. They said it was a fire hazard, so yes, I have to turn my heat-… I've got an outside communal garden, but obviously, that's no good to me in the winter, is it? I have to turn my heating on and hang stuff on doors. (Tenant 40)

Some tenants had hard to heat homes that lost warmth quickly making managing fuel bills even more challenging, especially when they were on low incomes.

Heating wise, in the summer, it keeps you lovely and cool. Then, in the winter, you heat it up and then as soon as you turn the heating off it just goes clap, cold again! [...] I'm on gas meters, because I had a lot of debt with gas companies, because I couldn't afford to pay the bill. Now, I've got pay my debt and my meters! Obviously, during the summer, the gas isn't so bad. Then, if everyone's out at school and work, everything is all right? During the winter it costs a fortune to heat. (Tenant 18)

The property itself is in pretty good condition. It's quite hard to heat. It either gets boiling or freezing. If it's a hot day out and I want to cool down, I can come home! Do you know what I mean? Yes, but my bills are extortionate. My gas and electric bills are probably, I would say treble what the recommended amount is. [...] I put a dressing gown on and go to bed early. I don't sit in my front… I very rarely sit in my front room, very rarely. It's huge and it does get warm quick, but then I just think, I'm on my own. What's the point of heating the whole house when I might as well just go to bed? (Tenant 40)

No, I'm not comfortable in [the cold], but poverty means that you get used to it. You've got no choice when you can't put the heating on. You just wear lots and lots more clothes on until you… Then you think I'm going to have to put the heating on. (Tenant 37)

Well, the storage heaters are really expensive anyway, so plugging the electric in costs a lot of money. This week I've spent £60 on electric. (Tenant 44)

Cold homes were mitigated in essentially three ways. Firstly, tenants heated their home as required but did so by attracting high heating bills, which not all tenants could afford but they had made it a priority expenditure or had cut back elsewhere. Secondly, tenants did not heat their home sufficiently to manage costs, using heating appliances sparingly, heating for a minimal time period or retreating to smaller spaces within the home. Thirdly, tenants veered between these two positions, muddling through.

A few tenants interviewed indicated that their homes were at maximum capacity or overcrowded, increasing the volume of moisture internally, but this was not something that they could control. Most tenants' homes were not overcrowded, although some were at maximum occupation, but did not have amenities that would help them manage the humidity in their homes. Some reported that they had no extractor fans in the kitchens or bathrooms, or where they did tenants reported that the fans were inefficient or not working. Some tenants had brick air vents in their walls but felt these increased the cold or worried they let more water in.

## Landlord responses

Landlords provide advice to tenants about managing condensation, damp and mould suggesting that tenants ventilate, heat and remove moisture in the air to prevent moisture forming condensation on cold surfaces. Some tenants felt that the advice was often inadequate as there were problems with the properties or that they felt unable to fund additional heating or manage the internal moisture in the home due to the number of occupants or lack of drying facilities. Several tenants had repeatedly contacted their landlord to bring attention to the problems they were experiencing with advice to ventilate being a default response, despite other underlying repair problems being present, inadequate heating such as dated electric storage heaters that were not in every room, or there being other reasons why that advice may not be appropriate, such as the security risk of opening windows for long periods on ground floor properties. These reports of damp and mould were from a range of people including those with disabilities, older people and families with pre-existing health conditions.

We got the mould, condensation, etc. The council did tend to fob us off for a year or two before they actually put a new damp-proof course in and re-did one and a half walls completely, the bottom half. [...] It did eventually [solve the problem], but before that, all under the house had flooded and was in two or three foot of water. [...] Two years; it was a nightmare. I'm just saying, this is what caused most of the condensation and all they would say to us was, 'Ventilation. You need loads of ventilation.' We'd never close the windows then and we never close them now, to be honest. We keep a window open all the time for air to circulate. [Tenant 38]

I've told them about me. I bought a dehumidifier and I've told them about the container getting full of water and things but it's… They just say, 'What you need to do, you need to open all your windows and doors and keep them open, really.' I say, 'I live in a downstairs flat. People can…' If it were a floor higher or if it were a multistorey then it would be all right to open windows and doors, but… I tried that at start, when they told me, and I got my key stolen. (Tenant 23]

Oh, just the usual, 'Open your windows, keep your windows open and don't dry your clothes in the house.' The stuff that is obvious, which we all know, but it's not that easy to do. If the house is cold, you're not going to open the window anymore and stuff like that. If there are a lot of people in the house, I've got to just dry my washing; there's just nothing I can do, so they say the obvious things. I have had them out before for the mould and they just say - they basically say it's my fault. (Tenant 26]

Engaging with the landlord over damp, mould and cold was seen by some tenants as exhausting. Some tenants had made repeated calls to the call centre, experienced tradespeople visiting but with no resolution as a further surveyor inspection was required or the contractor had to relay information to the centre for permission to proceed but with no follow up received. Some had given up despite persistent problems, some severe, as poor physical or mental health meant they had depleted resources and had low resilience to make the effort required to engage the landlord. Periods of repeatedly trying to get the council to respond was burdensome, meaning some with ill health or other commitments had given up, leaving people feeling disempowered.

No, you just need to keep ringing them [the landlord] constantly, honestly. I realise they've a lot of properties to manage and I realise I'm not the only one, and the COVID situation and everything, but [....] I had a nervous breakdown, so it would have been two years ago. I rang the council office and said can you come out and look at the windows again? They said, we'll send out an inspector and it never happened. I just had other things, like the breakdown to deal with. What does happen, and I know this sounds possibly trivial, but I can't explain enough the impact this has on my mental health. When it starts raining and I'm sat on the sofa reading and I start to hear drip, drip, drip. I will know within about ten minutes; it's going to be whoosh. I have to get out of the room and close the door because I can't cope with it anymore. I just can't. (Tenant 37)

I have managers and surveyors out, and they've done tests and that, and says, 'Oh, we'll get things sorted,' and I'm still waiting two-and-a-half years. I mean, obviously, I know with COVID and that, I haven't really complained about it because with COVID. The other issue I've got is because of, I have to have the heating on a lot, because the heat helps me with my back, but once I turn the heating off, with about half an hour, to 45 minutes, it's freezing cold again because there's a horrible draught coming in right through the flat. At the bottom of my doors, there's about a two-inch gap at the bottom of my doors and that and they all know about it. (Tenant 45)

I say it to them then... What you need to do with them is you need to ring them up, but all of the time I keep pushing and pushing and pushing. I just don't have the time. I've got too much to do! (Tenant 18- lone parent)

Occasionally tenants had received piecemeal responses to symptoms rather than resolutions of the core problem. For example, a tenant with damp bathroom walls had anti-fungal paint applied to damaged bathroom ceilings and walls on multiple occasions only for this to fail after some months. In this case, a faulty manually operated extractor fan was left in place, and it was only when the sensor data identified persistently high levels of humidity did the landlord install an automatic humidistat to deal with the excess moisture. Or in the example below the landlord fixed a gutter but left a hole that lets water into a child’s bedroom.

The guttering and fascia is all rotten in front of my son's bedroom. When it rains it just literally is like somebody tipping a bucket of water down the front of his bedroom the whole time. I've been waiting for about seven months. I've just come out and then all they've done is cleared the gutter. That's great. It doesn't fix the massive hole! (Tenant 18-lone parent)

There's black mould on the back wall. I keep all my files and papers in there, and when you open those cupboard doors, you can smell it. They do not fit tightly, if you understand what I'm saying. There's obviously air being able to get into there. The black mould on the back of the outside wall is next to a chimney breast, and then the corner of the other side of the chimney breast. […] There's no ventilation in this chimney breast at all, and I think that is one of the causes of the damp. So, I'm sure it is. (Tenant 38, after extensive damp works)

Tenants, even some with problems of damp, mould or cold, talked positively about council refurbishment programmes delivering double glazing, insulation and new heating systems. This accords with the overall reduction in damp, mould and cold problems across social housing nationally as the decent homes programme of work conducted up to 2010 (MHCLG, 2021).

Again, give credit to the council, we had metal window frames when I first moved in that were awful. Back then, yes, the condensation, the humidity was terrible. The double-glazing came in and there was a huge change because you didn't need to constantly wipe down the windowsills and all that. Then the water just… In a sense, the windows and the central heating and the loft insulation, very grateful for, but the houses are fundamentally flawed. (Tenant 37, ongoing problems of water ingress around windows)

More recently, some tenants with old electric storage heaters had been informed that they were to get new air source heat pumps and were delighted. For some tenants, however, previous upgrades, particularly to windows, were the source of their concerns as they allowed water ingress and draughts.

They are double-glazed, but I've actually paid somebody to come out and have a look. They said that the windows need to be put back in properly, because they left the metal frame in. He said these windows aren't in correctly, the rain is just going through and down, and the sealants have been eroded with all this water. He said the whole window needs to be taken out and the job needs to be done properly. (Tenant 37)

I was having what they call whistling windows in the front room. Anyway, they came out and they've sealed all round and it was still doing it. Then they sent somebody else to investigate further and he actually took one of the windows out, and he says, 'What's happened is when they've put these windows in, because it's a hollow cavity, they haven't filled round the cavity properly.' Yes, so… (Tenant 41)

By and large tenants reported a repairs service that was well intended but occasionally slow to respond to their needs. There were also complaints about staff and contractors having a negative attitude towards tenants, and that not all repairs were resolved first time, or calls were logged but no response was received.

They've still got the same responsibilities as any other landlord, except, obviously, they do more than other ones in some respects, but things still need to be done without being fobbed off. (Tenant 14)

It was a few years ago now. Because they work, but because they keep leaking... The guy was like, 'You can tell by the seal around it.' He was like, 'If you weren't council, I'd say to you, "Get new radiators," but if you apply for them, they won't give you them.' They literally just send them out to put a new seal on. Then, obviously, because it's corroded it doesn't last long. Then, it comes back. (Tenant 18)

When I ring up, when I contact them, I don't get very far with it [broken extractor fan]. I'm made to feel like it's not important. (Tenant 23)

I found that individuals in the council system were really nice people, but the council system itself is biased and very, very difficult to navigate your way through and I just ran out of energy. [...] (Tenant 37)

Some tenants understood the pressures that the council were under and were frustrated but patient. As mentioned in quotes above, several tenants understood the pressures the landlord was under due to the Covid pandemic.

I have sent pictures to council, and they've sent an email, saying they'll sort it, and I'll say I know there's a backlog with council and that with Covid and that. That's why I've not really done anything about it. I'm just waiting for them to sort it, but I'm not one of these, what - I don't push people. I'm ready as soon as they're going to do something, I'll be like, I'll leave them to get it done. I've got sympathy with everything with [the] backlog of the council. That's probably a silly thing to do, but that's just how I've always been brought up. (Tenant 45, single man)

Very few tenants had sought external support to remedy problems in their home, understanding that some of the issues were about funding, or properties missing out on upgrades due to previous tenants not wanting them, and appreciated that the landlord was generally responsive to repair requests. Only one tenant interviewee had received a visit from a lawyer, one had approached Citizens Advice and another a local councillor. One tenant reported that he had tried to make an appointment with the Citizens Advice, but his mental health was poor, and it was too much for him to pursue. Most tenants with problems had been patient and had not taken their cases further, with some giving up for lack of energy. Some tenants may have adapted to the problems, feeling the issue was not a priority, but the conversations also indicated a backlog of repairs requests or calls chasing up previously reported issues when covid restrictions were lifted.

## Conclusion

Tenants offered narratives that suggested that the landlords’ repairs service was well intentioned but occasionally ineffective when responding to tenants’ complaints, especially of draughts and damp and mould. Default responses about tenants having to adequately ventilate their home were offered without comprehensive investigation of the problems, or the appropriateness of the advice given for individual tenants. In some cases, tenants displayed tenacity in achieving remediation work, often after many years of complaints. Not all tenants had the required energy reserves to pursue the landlord and suffered low mood and/or were unable to use all of their home. Tenants understood the landlords’ constraints and few tenants interviewed had sought external support. Some tenants drew associations between their experiences of damp or cold and their health, suggesting that the conditions exacerbated existing conditions, not least on their mental health, while others were more circumspect.

The next section examines the relationships between property and household attributes with damp, mould and hard to heat homes.

# Chapter 4: Risks of damp, mould and cold

## Introduction

This section uses the tenant survey data to explore the associations between various tenant household and property attributes and tenant reports of damp and mould or hard to heat homes. Insights from the 49 homes that had the IoT environmental sensors installed and the 39 homes where sensors were installed, and the tenants also completed the tenant survey are also examined.

The strongest associations were those where the statistical tests showed that the results were unlikely to be due to chance or the sample of tenants drawn and are therefore those that give the most confidence in the results. Most associations reported were not statistically significant. The key significant associations with tenants reporting damp and mould were those relating to the household size, income source, some indicators of fuel poverty and older homes, hard to heat homes and tenant reports of repairs to doors, windows or roofs and issues with draughts or insulation. Tenant behaviours were not indicated nor the energy performance of the property. Tenant reports of hard to heat homes were strongly associated with many indicators of people with fuel poverty, had issues with draughts or insulation and damp and mould.

The sensors identified more homes at risk of damp and mould and homes that were subject to rapid heat loss one and a half times more often than tenants themselves. Around half of the tenants who had the sensors installed reported damp and mould and cold, but the sensors suggested nearly three-quarters of homes were at high or medium risk of damp and mould or rapid heat loss. High risks of damp and mould were identified more frequently than heat loss. Few homes were identified as being persistently too cold, as homes had poor energy performance, suggesting that tenants were heating them but would be doing so at an additional cost.

## Exploring tenant reports of damp, mould and cold homes

### Property attributes

Tenant reports of damp and mould were associated with older homes, hard to heat homes, reports of problems with draughts or insulation in their home and repair issues with windows, doors or roof, and this relationship was statistically significant and therefore not likely to be down to chance, or the sample used. A total of 69 percent of tenants that reported repair problems with doors, windows and roofs and 69 percent that reported issues with draughts and insulation also reported damp and mould (Table 4.1). These two indicators could be proxies for the general repair quality of the fabric of the building. Over half of tenants (54 percent) who reported problems with draughts and insulation in their homes reported that they were also hard to heat, again this was unlikely to be down to chance. Tenants of homes built before 1949 were more likely to report damp and mould (66 percent compared to 30 percent of homes built since 1967. There was no significant difference in the rate at which tenants reported damp and mould whether the property EPC rating was C or above or not.

**Table 4.1: Incidence of damp and mould and hard to heat homes by property attributes (% of attributes)**

|  |  |  |
| --- | --- | --- |
|  | **Damp and mould** | **Hard to heat** |
| All | 46 | 33 |
| Property type  House  Flat  Bungalow | 53  35  - | 42  35  - |
| Property age  Before 1949  1950-1966  1967 or after | 66\*  47\*  30\* | 41  40  45 |
| EPC below C | 51 | 40 |
| Property concerns  Repair problems doors, windows and roofs  Issues with insulation and draughts  Repair issues with boiler or heating system  Hard to heat  Damp and mould | 69\*\*\*  69\*\*\*  60  63\*  n/a | 42  54\*\*\*  40  n/a  45\*\* |
| Property amenities  No outdoor drying area  No bathroom extractor fan  No kitchen extractor fan | 45  49  48 | n/a  n/a  n/a |

*Source: Tenant Survey \* statistically significant p>0.05 \*\*p>0.01 \*\*\*P>0.001*

Tenants reported that their homes were hard to heat at the same rate regardless of whether the EPCs were grade C or above (40 percent) or below EPC C (38 percent).

Reports of damp and mould were strongly associated with hard to heat homes and vice versa. Nearly two-thirds of tenants with damp and mould reported that their homes were also hard to heat, and this was statistically significant (63 percent), compared to 38 percent of homes with damp and mould were not described as hard to heat. Conversely, 45 percent of hard to heat homes tenants reported damp and mould, compared to 23 percent who did not report damp and mould.

### Indicators of fuel poverty

The survey included a range of questions about tenant responses to the temperature of their home and managing fuel costs. There were strong associations between damp and mould and hard to heat homes and tenant reported health impacts. A total of 31 percent of tenants who reported damp and mould and 44 percent of those that reported their homes were hard to heat felt that the temperature made existing health problems worse (Table 4.2). Additionally, 40 percent of homes with damp and mould and 52 percent of tenants that reported hard to heat homes felt that the temperature made them miserable, anxious or depressed. Hard to heat homes were associated with other negative sentiment among tenants, with nearly a quarter (23 percent) feeling that the temperature was such that they could not invite visitors to their home, or that they stayed in bed longer to keep warm (54 percent).

Significant proportions of tenants with damp and mould reported that they took actions to control fuel costs but turning out lights more often which was reported by 49 percent was the only action that was statistically significant. In contrast, hard to heat homes were strongly associated with tenants cutting back on fuel consumption, with two-thirds (69 percent) turning the heating down even though it was cold, 38 percent using only part of their home, and 58 percent turning lights off. A total of 92 percent of tenants with hard to heat homes showed some indicators of fuel poverty.

**Table 4.2: Indicators of fuel poverty by damp and mould and hard to heat (% damp/mould or hard to heat)**

|  |  |  |
| --- | --- | --- |
|  | **Damp and mould** | **Hard to Heat** |
| Made an existing health problem or problems worse | 30.8\*\*\* | 43.8\*\*\* |
| Brought on a new health problem or problems | 1.5 | 6.3 |
| Made me/us feel miserable, anxious or depressed | 40.0\*\*\* | 52.1\*\*\* |
| I/we did not feel able to invite friends or family to the house | 10.8 | 22.9\*\*\* |
| I/we spent as much time as possible away from the house | 4.6# | 6.3\* |
| I/we stayed in bed longer than we wanted to keep warm | 30.8 | 54.2\*\*\* |
| The temperature of the home did not affect the household in anyway | 44.6 | 18.8\*\*\* |
| Turned heating down or off, even though it was too cold in the house/flat | 44.6 | 68.8\*\*\* |
| Only heated and used part of the house/flat | 23.1 | 37.5\*\* |
| Cut the number of hours the heating was on to reduce fuel costs | 49.2 | 47.9 |
| Used less hot water than I/we needed to reduce fuel costs | 23.1 | 33.3 |
| Turned out more lights in my home than I/we wanted to, to try to reduce the electricity bill | 49.2\* | 58.3\*\*\* |
| Had fewer hot meals or hot drinks that I/we needed to reduce fuel costs | 10.8 | 14.6 |
| No, I didn’t feel I had to cut back on fuel use to save costs | 40.5 | 16.7\* |
| Indicators fuel poverty | 74.6 | 91.7\*\*\* |
| Indicators of fuel poverty *and* EPC below C | 33.3 | 42.4 |
| Keeping up energy bills hard sometimes or a struggle | 38.5 | 45.5\* |

*Source: Tenant Survey \* Statistically significant p>0.05 \*\* p>0.01 \*\*\*p>0.001*

### Tenant behaviours

The survey asked questions about tenants’ use of their home in the last two days, using a short time period to capture the most frequent activities that improved or reduced indoor humidity. A large portion of people who reported damp and mould were concerned about clothes drying (67 percent) but no statistically significant association between clothes drying and damp were found in this sample.

Across all tenants, 61 percent of tenants dried washing indoors on radiators or clothes horse and 37 percent dried clothes with a tumble dryer (Table 4.3). Over half (53 percent) boiled pans without lids on and 93 percent showered or bathed. A high proportion opened windows (88 percent) but only 55 percent used extractor fans to reduce moisture in the home.

Fewer tenants had tumble dryers than dried their clothes indoors, but the tumble dryers did not appear to reduce the incidence of reported damp and mould. A total of 51 percent of people who dried their clothes indoors experienced damp and mould, compared to 38 percent who did not but this could be a result of chance. However, a greater proportion of those using tumble dryers also reported damp and mould than tenants who did not use a tumble dryer, although tumble dryers may still contribute moisture to the air. None of this moisture generating or mitigating activities were significantly associated with tenants reports of damp or mould, maybe as these activities (boiling pans without lids, or drying indoors) were too ubiquitous and the sample too small.

**Table 4.3: Proportions of tenants reporting damp and mould by moisture generating or mitigating activity in the last two days (%)**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Damp and mould** | | **All sample** |
|  | **Did not do activity** | **Did activity** |
| Dried clothes indoors on radiators or clothes horse | 37 | 51 | 61 |
| Dried clothes with tumble dryer | 41 | 54 | 37 |
| Boiled pans with lid off | 45 | 47 | 53 |
| Opened windows | 41 | 47 | 88 |
| Used an extractor fan | 42 | 49 | 55 |

*Source: Tenants survey (No statistically significant findings)*

### Household attributes

The strongest statistically significant factors associated with reports of damp and mould in the home related to the household size and their income source. Household attributes were not strongly associated with hard to heat homes.

Tenants with larger households reported damp and mould in the home more frequently than those with smaller households (Table 4.4). The mean number of people in the home for those without damp and mould was 1.77 but rose to 2.33 for homes where tenants reported damp and mould. Families with children also reported damp and mould more frequently (66 percent) than multiple adult households (48.6 percent) or single people (33 percent). Households with children held the greatest number of occupants, with the mean number of people being 3.33, while multi adult households were 2.32 and single households were obviously 1 (statistically significant).

Tenants’ income source was also significantly associated with damp and mould with 60 percent of working households reporting damp and mould compared to 48 percent on benefits and 22 percent of those on a pension. This is likely to be a combination of intermittent heating of the home associated with people working outside the home and larger households. The mean number of people in working households was 2.40 compared to 1.98 for those on benefits and 1.50 for those receiving pensions (statistically significant). Most families live in houses (86 percent) compared to 53 percent single adults.

**Table 4.4: Incidence of damp and mould and hard to heat homes by household attributes (% of household factors)**

|  |  |  |
| --- | --- | --- |
|  | **Damp and mould** | **Hard to heat** |
| Single adults | 33\*\* | 30 |
| Multi adults | 49\*\* | 32 |
| Households with children | 66\*\* | 42 |
| Mean number of occupants without ... | 1.77\*\* | 1.94 |
| Mean number of occupants with ... | 2.33\*\* | 2.21 |
| Working | 60\* | 39 |
| Benefits | 48\* | 33 |
| Pension | 22\* | 30 |
| Combination | 33\* | 11 |

*Source: Tenant survey \* statistically significant p> 0.05 \*\* p>0.01*

The incidence of damp and mould therefore appear to relate to the intersection of property and household attributes, rather than determined solely by the physical amenity of the home or behaviour of tenants within the home, in terms of drying their washing indoors, for example. BEIS (2021b) found that nationally 83 percent of all households dried clothes indoors and 47 percent did not ventilate the room when doing so. However, they also found occupant behaviour had little bearing on the incidence of damp and mould, which was more closely associated with fuel poverty, lone parents, low-income households, and energy inefficient homes. The English Housing Survey (MHCLG, 2021) found that serious condensation did not vary by whether the dwelling lacked thermal comfort.

Hard to heat homes were strongly associated with indicators of fuel poverty, struggling or finding energy bills hard to meet and issues with draughts and insulation but not the energy performance of the home. This generally accords with national data where the incidence of people feeling their living rooms were uncomfortably cold in winter was not related to EPC rating but to household income (BEIS, 2021). Income source whether working, benefits or a pension was not statistically associated with hard to heat homes for this study’s survey. Income source is, however, a crude income indicator and cannot differentiate those in household poverty or identify measures of low or moderate incomes.

## Exploring sensor insights identifying damp, mould or cold homes

The sensor data included measures of temperature, humidity and carbon dioxide, and identified risks of:

* damp and mould
* cold homes
* dust mites and allergens
* draughts
* rate of heat loss, and
* overall indoor air quality.

The sensor identified risks were graded into low, medium and high with landlords advised to investigate medium and high-risk properties. An Overall Risk Score combining all the risks and their levels provides landlords with a mechanism to prioritise the properties showing the greatest risks of having poor indoor air quality conditions. (Please see Appendix 1 for further details about how these risks were identified.)

A total of 49 tenants had the sensors installed in their home and of these 39 completed the tenant survey. These are relatively small numbers and, therefore, we are limited as to what inferences can be drawn.

The sensors identified damp and mould, dust-mites or other allergens and heat loss as the greatest risks (Table 4.4). Twenty-four homes were identified as having a high risk of damp and mould and 11 of having a medium risk (meaning 71 percent of homes were flagged as a concern). A rate in excess of the roughly half of tenants who self-reported that their homes had damp and mould in the tenant survey. Six properties were identified as having a high risk of heat loss with 33 other properties having a medium risk. Again, these are proportions in excess of the one third of tenant reports of hard to heat homes in the tenant survey. Two homes had a high risk of poor indoor air quality and three a medium risk, inferred from high levels of carbon dioxide, an independent health risk but also a signal of other air pollutants. One property had a high risk of having dust mites or other problem allergens and 29 a medium risk.

**Table 4.4: Indoor air quality risks (n=49)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | High | Medium | Low | Pending | % High and medium risk |
| Damp and mould | 24 | 11 | 13 | 1 | 71 |
| Cold | 0 | 7 | 39 | 3 | 14 |
| Draughts | 0 | 5 | 40 | 4 | 10 |
| Dust mites or allergens | 1 | 29 | 16 | 3 | 61 |
| Excess heat | 0 | 0 | 49 | 1 | 0 |
| Heat loss risk | 6 | 33 | 10 | 0 | 80 |
| Air quality risk | 2 | 3 | 41 | 3 | 10 |

*Source: Environmental sensor data*

### Damp and mould risk

Table 4.5 shows property and household attributes associated with sensor identified risks of damp and mould in the home. These are small numbers so of course caution must be exercised, but there seems to be a general accord between the types of households and homes associated with tenant identified damp and mould and the sensor identified risk. More people in the home, people working and people reporting repairs of some sort of accord with the tenant reports of damp and mould and their circumstances. The sensors also identified more homes as at risk of damp and mould (33) than the tenants (20). Houses were identified at risk of damp and mould at a higher rate than flats, and heat loss was also a risk for those with a risk of damp and mould, similar to the association between tenant reports of damp and hard to heat homes. Various repair issues were also frequently associated with damp and mould risks, and larger households were also again associated with sensor identified medium risks of damp and mould. Mental health scores, but not physical, were lower and, therefore, worse the higher the risk of damp and mould. Due to small numbers any statistical significance of these results cannot be identified.

**Table 4.5: Number of homes at high and medium risk of damp and mould by property and household attributes (number of people out of total with that attribute)**

|  |  |
| --- | --- |
| Heat loss risk | 23/27 |
| Dust mites risk | 21/27 |
| Tenant reported damp and mould | 16/20 |
| Tenant reported hard to heat | 14/18 |
| House | 19/23 |
| Flat | 5/12 |
| Bungalow | - |
| EPC below C | 13/17 |
| Tenant reported issues with repairs to heating system | 5/9 |
| Tenant reported issues with repairs to roofs, windows and doors | 8/10 |
| Tenant reported issues with draughts and insulation | 8 /12 |
| Single adults | 11/19 |
| Multi adults | 7/9 |
| Households with children | 8/11 |
| Total number of people in household | High 2.06  Medium 2.60  Low 2.0 |
| Income source Working | 10 /13 |
| Benefits | 13/19 |
| Pension | 4/8 |
| Fuel poverty indicators | 19 /27 |
| Find it hard or struggling with utility bills | 9/27 |
| Physical health score | High 42.05  Medium 39.62  Low 39.63 |
| Mental health score | High 37.67  Medium 37.53  Low 39.40 |

*Source: Environmental sensors and tenant survey NB: The table reports the number of tenants of that variable where the sensor data identified risk of damp and mould/ total number with variable.*

The sensor insights appear to accord with these associations found in the tenant survey data that suggests that the risk of damp and mould relates to the household attributes (income, struggling with bills and household size) as well as property profiles (issues with some repairs, low EPC and heat loss). Future research in this area needs to test the sensor data and its associations at scale to strengthen our understanding of their potential in this area. The sensor data insights appear to provide more refined information about damp and mould risks than would typically be held on a repairs services dataset that relate to property attributes alone. This is because there is an element of the sensor data reflecting the household attributes, in terms of the number of people in the home and their day-to-day activities as well as their ability to heat the home adequately due to finances as well as the property. This sensor data also obviates reliance on direct tenant reports to the landlord, that not all tenants can pursue, as mentioned in the previous chapter. Landlord responses to the remotely identified risks by undertaking property repairs or improvements, or by providing fuel poverty or income maximisation advice. These data could also provide additional insight into health risks for transfer applications.

### Cold homes

Most homes being remotely monitored presented a low risk of being cold, meaning these homes did not spend substantial periods of time below 18C. However, the sensors identified five homes as a medium risk. Four homes had a high risk of rapid heat loss, so the thermal efficiency of the property was poor, 29 were of medium risk of rapid heat loss with seven having a low risk. Of the 33 homes that were identified as having a low risk of being cold, two had a high risk of rapid heat loss, and 25 a medium risk, suggesting that a large proportion of tenants were adequately heating their homes but would be doing so at a greater energy cost, compared to a home that did not lose heat rapidly.

Table 4.6 explores the property and household attributes associated with the 33 homes that had a high or medium risk of losing heat quickly and where the tenants had also completed the tenant survey. There was a high level of synergy between the high and medium risk of rapid heat loss indicated by the sensors and tenant reports of hard to heat homes, as well as other property and household attributes.

**Table 4.6: Number of homes at high and medium risk of rapid heat loss by property and household attributes (n=33)**

|  |  |
| --- | --- |
| Tenant reported the home was hard to heat | 15/18 |
| House | 20/23 |
| Flat | 9/12 |
| Bungalow | - |
| EPC below C | 15/17 |
| Tenant reported issues with repairs to heating system | 8/9 |
| Tenant reported issues with repairs to roofs, windows and doors | 8/10 |
| Tenant reported issues with draughts and insulation | 11/12 |
| Tenant reported damp and mould | 17/20 |
| Dust mite or other allergens risk | 1/2 |
| Damp and mould risk | 7/10 |
| Single adults | 15/19 |
| Multiple adults | 7/9 |
| Households with children | 10/11 |
| Total number of people in household | High 2.00  Medium 2.32  Low 1.71 |
| Income source Working | 11/13 |
| Benefits | 17/19 |
| Pension | 5/8 |
| Find hard or struggling with fuel bills | 10/12 |
| Fuel poverty indicators | 25/30 |
| Physical health score | High 40.26  Medium 41.47  Low 37.75 |
| Mental health score | High 28.64  Medium 39.16  Low 39.65 |

*Source: Environmental sensors and tenant survey NB: The table reports the number of tenants of that variable that also have sensor identified risk of rapid heat loss/ total number with variable.*

### Other risks

There was little accord between tenants reporting problems with draughts and the sensors indicating a risk of draughts. Of the 12 tenants who had the sensors installed who had concerns about draughts, the sensors indicated that only one was at risk of draughts.

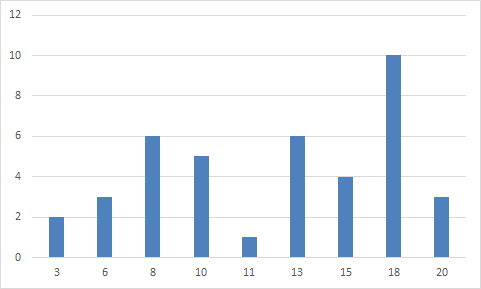
Indoor air quality risks among the homes with sensors was lower than other risks identified, with only three homes showing a medium risk and one a high risk. Over a landlords’ whole housing stock, a small five or six percent of properties at risk could mean a sizable number of households at risk of indoor pollutants. This measure is based on high CO2 readings[[4]](#footnote-4) as these are proxy indicators of poor air quality, with independent risks of CO2 bringing on drowsiness but also as a proxy indicating that limited ventilation means that other volatile organic compounds (VOCs) or nitrogen oxides or other known pollutants are likely to also be present. Of the four medium and high indoor air quality risk homes, none had fried food, one had smoked, one vaped, all four had used cleaning products, and three had used candles in the last two days. All four had opened windows and three had used an extractor fan.

A medium risk of dust mites was identified in 29 of the 49 properties with sensors installed, including 22 who also completed the tenant survey. Of these respondents with a medium dust mite risk, 11 also reported that they had allergies, and 10 that they had asthma.

### Overall Risk Scores

The sensors provide risk indicators across a range of measures as described above and in Appendix 1. The Overall Risk Score attached to a property provides a high-level view of a property. Every property is given a score of 20, which is reduced by 5 for any high-level insights and by 2 for any medium risk insights, meaning the lower the score the greater priority the property is for the landlords’ attention. Seventeen of the 49 properties had their scores reduced by half or more due to the high number of sensor risks detected (Figure 4.1). Landlords could draw a priority threshold at any point of course, but the score provides a mechanism to prioritise problematic homes.

**Figure 4.1: Number of properties by overall sensor risk scoring (n)**



*Source: HomeLink environmental sensor data*

## Conclusion

This chapter reveals the household and property attributes strongly associated with tenant and sensor reports of damp and mould or cold hard to heat homes. Damp and mould in homes were associated with a combination of household and property attributes, including household income source, size of the household, some indicators of fuel poverty and repairs to doors, roofs and windows, but not necessarily to tenant behaviour. Hard to heat homes were more closely aligned with fuel poverty and a range of property attributes including repairs. The sensors indicated a greater pool of tenant homes were at some risk of damp and mould and heat loss than tenant reports alone. As the survey and existing evidence suggest that the risks of damp and mould arise from an intersection of household and property attributes, the sensors seemed to provide greater insight than landlords’ property datasets alone. Landlords can also be alerted to properties where the temperature is persistently too cold, to provide support to those tenants. Although there was a high synergy between sensor indications of homes with rapid heat loss and low EPCs, the sensor's insights could provide additional information to inform energy conservation and retrofit strategies.

The following chapter examines tenant attitudes towards technology, sensors and data sharing.

# Chapter 5: Tenant attitudes to technology and sensors

## Introduction

This chapter considers tenants digital connectivity, their attitudes and confidence with new technologies, their sentiments towards the remote sensors and towards data sharing. The evidence is drawn from the tenant survey and tenant interviews.

Tenants were largely well connected although one in ten of those on benefits and one in eight of those in receipt of a pension were not. Pensioner households and some tenants in receipt of benefits may also require support to bolster their confidence in using technology if the tenant app is to be widely adopted. Survey and interview participants were largely positive about the potential of sensor technology, particularly those with existing damp problems who saw the opportunity to change the conversations with landlords and bring new evidence to the discussions about repairs and management of their homes. Data sharing beyond the landlord was not well supported although tenants had not previously considered these ideas so were open to change. The sensors were viewed as monitoring the home rather than the person, although boundaries were blurred when thinking of using the data to support the landlords’ social obligations to support vulnerable tenants, so more detailed work may be required to determine the boundaries of data use.

## Attitudes to technology

The sensors can be installed, and landlords can use the data without tenants having their own broadband connection. This project’s sensors ran on a local council installed LoRaWAN (Long Range Wide Area Network) network in the city, but telecom networks such as AICO’s SmartLInk system which is based on sim cards can also be used to connect the sensors and relay data to the landlord. Digital exclusion is therefore not a problem for landlords’ to remotely monitor people’s homes and use of the data. Tenants can receive the data on a mobile phone or tablet app that presents the readings and risk profile for each room where the sensors are installed and suggests actions to reduce any risks. Obviously if tenants are not connected to the internet their ability to use the mobile app and receive the data is limited.

Only seven percent of respondents did not have any kind of digital technology (Table 5.1). The most common device by far was a smartphone (86 percent), then a tablet (62 percent) and laptop (48 percent). A total of 83 percent also had broadband. Tenants were largely connected, but their confidence in their ability to use technology was lower (58 percent). Although few considered their skills to be very poor, the results suggest that a sizable portion of tenants considered themselves average in their use of technology, perhaps suggesting that they may need some support to feel confident in their use of digital technology (33 percent). Tenants were also largely ambivalent about their trust in technology companies.

**Table 5.1: Use of technology (%)**

|  |  |
| --- | --- |
| Type of technology in the home  Laptop  Tablet  Smartphone  Alexa or similar  Ring doorbell or similar  Nest heat control or similar  Broadband  None of the above | 48  63  86  37  9  2  83  7 |
| Ability to use technology  Excellent or good  Average  Poor or terrible | 58  33  9 |
| Trust in technology companies  A great deal or a lot  Neutral  A little not at all | 23  53  24 |
| Trust in their landlord  Excellent or good  Neutral  A little or not at all | 49  35  16 |

*Source: Tenant survey*

The tenant interviews revealed that some tenants were familiar with using technology to manage their home, buying fuel tops ups on mobile apps, and were becoming increasingly familiar with IoT technologies, particularly the virtual assistant Alexa or Echo type devices. Other tenants, however, had devices but lacked confidence to use them routinely, including one tenant participating in the study who had put the project tablet in a cupboard and later withdrew.

The tenants that lacked confidence in their ability to use technology or were unconnected were mostly those on benefits and those in receipt of pensions (Table 5.2). One in ten (10 percent) of those on benefits and one in eight (13 percent) of pensioners did not have any digital devices, and one in five (22 of those receiving benefits and 21 percent of those receiving a pension) had no broadband connection at home. One in ten of those on benefits and one in five pensioners may require help to bolster their confidence in using technologies if tenants will be asked to engage with the mobile app or similar digital technologies.

**Table 5.2: Exploring barriers to using technology by income source (%)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Working** | **Benefits** | **Pension** | **Total** |
| No broadband | 8 | 22 | 21 | 17 |
| No technology | 0\* | 10\* | 13\* | 7 |
| Little or no confidence in ability to use technology | 0\* | 9\* | 21\* | 8\* |

*Source: Tenant survey \* Statistically significant p<0.05*

## Attitudes to sensors

Looking across the whole tenant survey, a high proportion of respondents felt extremely or somewhat comfortable with the idea that the sensors could monitor the indoor air quality of their home (74 percent) (Table 5.3). Only nine percent were uncomfortable with their home being monitored in this way.

The landlord was the professional group tenants’ felt most comfortable sharing the environmental sensor data with (73 percent) followed by health professionals (56 percent) and family (51 percent). Social workers and social care staff were the sectors tenants were least likely to be comfortable sharing the sensor data with (19 percent each), but only 11 percent were uncomfortable sharing any data at all. Interview data indicated that some tenants saw potential in sharing with health or social care professionals, but often only when prompts about the data’s potential use in supporting vulnerable or older adults. In these circumstances, some tenants considered landlords would not have to always seek the tenants’ permission to share data with authorities or other services if there was a risk of harm and it was in the tenant’s interests. The boundaries of what data is being recorded and with whom it could be shared need time and further exploration with tenants.

**Table 5.3: Tenant attitudes to data sharing (%)**

|  |  |
| --- | --- |
| *How would you feel about having environmental sensors in your home monitoring indoor air quality, heating, temperature or ensuring that your fire alarms, for example, are working?*  Extremely or somewhat comfortable  Neutral  Extremely or somewhat uncomfortable | 74  17  9 |
| *Which of the following people would you feel comfortable with sharing the internal air quality sensor information from your home or property?*  Landlords  Family  Social workers  Social care  Health  Lawyers acting for tenants  Researchers  Share with no-one | 73  51  19  19  56  26  56  11 |
| *How tenants saw data being shared*  Automatically  Only with tenants’ permission  My decision would depend on who the data is being shared with  I would not want the information shared | 18  45  30  7 |

*Source: Tenant survey*

Tenants' responses to the sensor technology were positive and some were enthusiastic about the potential of the technology to alter the conversations tenants had with their landlords about problems in their home. This was the case regardless of whether the tenants had the sensors installed or not. Tenants saw the data that the sensors would produce as strong evidence to support their reports of property issues. Many tenants considered the benefits of the technology beyond their own home viewing the sensors’ building performance data positively as it could support landlords’ investment decisions. The provision of a tenant’s app to display their home data was also viewed favourably, providing an opportunity to increase their control of the home. Identifying problems before tenants reported to the landlord was also seen as beneficial, especially for older or other vulnerable tenants, who needed repairs or could not heat their homes.

They sound like quite a good idea. I suppose if the landlords can see it as well, if you're ringing up telling them that you've got these problems, at least they've got an idea of where you're coming from with it, because they will be able to see it. That's probably a bit of a reassurance for some people, I would have thought. I think that they're quite a good idea. They're worth a shot at, aren't they? (Tenant 18- no sensors installed)

I think it's proof when I explain things to them. It feels like I'm being fobbed off but if there's that information there saying that there is damp and... then maybe… Yes, it's definitely a good idea that. [...] It's all positive for me, really. Obviously, the information is going to be secure. What I like the idea of is I've got an app on my phone, and I can view things and statistics and everything else and its a plus for me, really. [...] I've not felt this positive in a long while, just speaking to you about these sensors. It really, it's like giving people a voice. I really like the idea and if [the landlord] take up on it I'll definitely put my name down for one of the first ones. (Tenant 23 - no sensors installed)

I definitely think it would be, it could be used as part of a wider package for care. [...] it could be an early warning system that somebody's not coping. Either financially or mentally. I just think one of the psychological parts of being a council tenant is the belief that the council just don't give a shit about you. Maybe this could be a way of the council taking on board that and trying to change the way that they, not only relate to their tenants, but also the way that they provide services, based on this information that they're getting. I do think as an early warning system, alongside other things would be helpful. (Tenant 37- sensors installed)

Some tenants' participation was motivated by an interest in these IoT technologies, indoor and outdoor pollution and air quality, for the greater good of all council tenants, or frequently because of their ongoing and unresolved issues with cold, damp and mould in their own homes. Of the 40 tenants who answered the survey and had the sensors installed in their home, 16 (40 percent) said they did so as they had damp and mould and thought the sensors might help. Sixteen tenants (40 percent) were motivated to have the sensors as they said their homes were hard to heat and 17 (43 percent) as they had a health condition and thought the sensors might help. Three quarters (30 tenants) said they were also motivated to participate in the project by their interest in new technology. Tenants’ most common reason for not opting for the sensors was that they simply did not know about the project, so must not have seen the recruitment advert which had been distributed by email and out in tenant newsletters.

A small portion of tenants were not comfortable with the idea of environmental monitoring in their homes and did not trust their landlords or technology companies. In this survey, acceptance of the sensors was not related to this trust in landlords or technology companies. Tenants in receipt of benefits (31 percent) and pensions (25 percent) had little or no trust in technology companies, but no people receiving pensions lacked trust in their landlord. Those on benefits (21 percent) and who were working (19 percent) lacked trust in their landlord the most. People on benefits had the highest proportion of respondents who were uncomfortable with sensors monitoring their home (10 percent). Tenants who did not feel comfortable with sensors in their home trusted their landlord or were ambivalent about them. None distrusted their landlord. Only four people, 30 percent of those that did not feel comfortable with the sensors did not trust tech firms. Neither of these results were statistically significant.

**Table 5.4: Barriers to using environmental sensors by income source (%)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Working | Benefits | Pension | Total |
| Little or no trust in technology firms\* | 9 | 31 | 25 | 22 |
| Little or no trust in the landlord# | 19 | 21 | `0 | 17 |
| Uncomfortable with sensors in the home | 6 | 10 | 8 | 8 |

*Source : Tenant Survey \*p<0.05 #p=0.052*

Interviewees acknowledged that other tenants may be wary of the technology, and the conversations included many jokes about discreet surveillance, the sensors not including spying, cameras or microphones, for example. Tenants recognised that these environmental sensors were operating in a narrow field and did not include these features, and that the sensors would be viewed negatively if they did. A minority accepted other technologies (including Ring and Alexas) into their home that could be perceived as having a wider range of recording or surveillance capabilities beyond their immediate use. Tenants, however, talked positively about the uptake of these technologies among family and friends.

Extending the technology to remote monitoring of boiler functions, detecting fire alarm defects, and allowing the environmental sensors into tenants’ bedrooms was largely accepted and viewed as unproblematic, allowing landlords to identify problems automatically and throughout properties. Largely, the sensors were seen as recording the property not the household. However, the boundaries between whether the people or the property were the data subjects became blurred when people considered the support for vulnerable people who may not be adequately heating their home, for instance. Overall, these interviewees viewed the sensors as allowing landlords to fulfill their legal and social obligations, improve their knowledge of the homes, inform investment strategies and respond to individuals' circumstances.

Occasionally, attitudes and any pitfalls of the technology and data sharing appeared shallow, as it was evident that tenants had not previously considered the issues. Prompting for alternative uses of the data got interviewees thinking about related issues for the first time and not all had a firm response, although some were adamant that there was no issue and that the data collection was in the tenant’s interest so could not envisage any issues arising. Central beliefs were that tenants wanted privacy maintained, the data to be confined to the property and data sharing with the landlord was a given.

## Conclusion

Tenants are largely digitally connected although some groups would require further support to get online and improve their confidence in using new technologies if they were to be provided with the tenant app or other mobile technologies. One in ten would be resistant to any remote monitoring of their home. Data sharing beyond the landlord was not well supported and determining when and with whom sharing the sensor data was appropriate and when tenant permissions were needed would require further work if the potential of these technologies was to move beyond the landlord tenant relationship. There were therefore blurred lines between the general sense that tenants felt the sensors were monitoring the property and not the household and the potential of the data to reveal tenants in vulnerable positions, such as under-heated homes that the landlords may want to investigate. Tenants had rarely considered these issues prior to the conversations so sentiment was weakly held but requires further examination.

# Chapter 6: Potential and limits of environmental sensors monitoring indoor air quality to manage tenants’ homes

## Introduction

The evaluation examines the potential of the environmental sensors and their accompanying tenant app to change behaviour in how the homes are managed to bring about changes in health and wellbeing. This would involve both landlord and tenant behavioural change. The original project brief included reference to landlords being committed to providing good housing for residents, but that “it can be difficult to identify when *lifestyle* or environmental issues begin to manifest within properties which may have a detrimental effect on a tenant’s health and wellbeing” (Author emphasis). Recent reports note that often social landlords place culpability of resolving condensation, damp and mould on tenants and their lifestyles (Housing Ombudsman, 2021). This was the key theme of the staff housing management focus group although the problems with property conditions and fuel poverty were also acknowledged. The findings of this study indicate that a greater focus on the latter issues and the intersection of property and tenant circumstances, and to a much lesser extent, tenant behaviour and their ‘lifestyles’, is warranted.

We have used the Theoretical Domains Framework (TDF) to organise the synthesis of the research material. The TDF approach identifies factors that influence behavioural change that can contribute to public health ambitions. Critically, these approaches recognise that health outcomes are influenced by structural, social and behavioral determinants, including incomes, disease burden and the distribution of resources (McManus et al.[, 2018](https://paperpile.com/c/TTZOT7/fZH5Q); Michie et al., 2014).

The framework outlined in Appendix 2 has been used to synthesise the study findings to identify what facilitates and what acts as a barrier to the potential of environmental sensor technology to improve the management of social rented homes (Table 6.1). The framework considers factors that may facilitate or limit the capability, motivations and opportunities for people to adopt new practices and technologies.

## Capability

Tenants and landlords were mostly capable of engaging with the intervention, although there were a small portion of tenants, mostly those in receipt of benefits or pension, who were not digitally connected or confident so would need support to engage with the tenant app if the sensors were deployed in their homes. Tenants knew what was required of them in managing their home, knowing about the importance of ventilation, heat and reducing moisture in the home. Tenants were open to engaging with the environmental sensors and largely had the skills and knowledge to do so. Tenants who experienced damp and mould had extensive routines of using various dehumidifier products, wiping away condensation and/or dealing with mould that accumulated in their homes and did not need to be reminded to do this. However, the tenant app alerts were viewed positively in principle, as tenants felt that they could more closely monitor internal conditions and take preventative actions, although this was not tested in the study.

Table 6.1: Factors that could influence whether IoT environmental sensors change can occur

|  |  |
| --- | --- |
| Capability | |
| Knowledge | * Staff thought the project was beneficial to educate tenants about how to manage their home to minimise risks of damp and mould. * Tenants appeared to understand what was required to control damp and mould, in terms of heating, ventilation and reducing moisture, but some elements reflected widespread behaviour (drying clothes indoors) and critically, there were financial and other constraints on tenants’ ‘doing the right thing’. * Many tenants displayed indicators of fuel poverty and landlords could use the data to support tenants on energy consumption, finding cheaper suppliers, and income maximisation to enable them to heat their homes more effectively. |
| Skills | * Over half of tenants were confident in their technological skills with less than one in ten reporting that their tech skills were poor or terrible. People in receipt of a pension were the least confident. A third of tenants were neither confident or unconfident meaning a large minority may require their confidence bolstered to effectively use the tenant app and a mobile device. * Guidance would be required for some tenants to engage with mobile devices and use the tenant app if implemented. Over half of tenants were confident in their skills, one in ten considered their tech skills to be poor or terrible and a third were ambivalent, suggesting support would be required. * Staff skills of interpreting the dashboard sensor data would need to be explored in future studies. |
| Memory, attention and decision processes | * The app had not begun providing alerts but tenants who had the sensors welcomed the preventative information about their home and were positive about receiving action prompts to manage their home. * Where damp and mould had already taken hold, people often reported regular cleaning regimes to wipe away condensation and mouldy deposits and did not indicate that a reminder was needed for them to do this. |
| Behavioural regulation | * Tenants, like the wider public, often dry clothes indoors even when outdoor space is available. * Many tenants routinely wiped condensation and mould away, using a variety of products and dehumidifiers not requiring reminders to do this. * Tenants were positive about using the app and alerts to understand more about their home. The study could not identify if this interest would be sustained over time. |
| Motivation | |
| Motivation and goals | * Tenants thought that tenants and landlords could benefit * Tenant interest focused on alleviating existing problems, improving the wider stock and interests in technology. * Interviewees thought the sensor technology could give tenants a stronger voice in getting landlord action on damp, mould and cold homes. * Tenants also thought that sensor data could help the landlord’s strategic investment decisions |
| Environmental context and resources | *Property and household attributes*   * Several household and property issues were beyond the control of tenants. * The number of people breathing, bathing and cooking in the house cannot be controlled but household size is a strong factor associated with the incidence of damp and mould. * There were many indicators that tenants were experiencing fuel poverty, associated with both damp and mould in homes and strongly associated with cold homes. * Half of tenant’s homes had EPCs below grade C and therefore lacked thermal comfort, although this was not associated with damp and mould but was associated with hard to heat homes. * Damp and mould were associated with repair issues to roofs, windows and doors, issues with insulation and draughts.   *Tenant behaviour*   * The study did not find strong associations between tenants generating moisture (drying clothes indoors etc.) and reports of damp and mould. * Most tenants dried clothes inside, not always using tumble dryers, even if they had an outside drying space. * Some flats had no drying facilities, and when they did not all tenants felt comfortable using them, for security and privacy reasons (but see above about people not always using outdoor drying space when available anyway). * British weather made outdoor drying uncertain (May 2020 30% days rain, June 2020 14% rain (Metroguru.co m)   *Digital connectivity and confidence*   * Most tenants were digitally connected, but there were small proportions of people in receipt of benefits who were not, and to a lesser extent those in receipt of a pension.   *Landlord constraints*   * How staff could incorporate the dashboard sensor data into their property management practices was not explored * Limited staff time and resources to engage with any introduction of new modes of working or indeed rectify problems identified were evident. * Staff fear of data being used to litigate against them * Social landlords can and do support tenants to claim benefits or support them into employment, neither of which preclude tenants from being in poverty. There may be limits to landlords’ control of the financial aspects relating to damp, mould and cold. * Limited accessibility to new social housing lettings means landlords may also be constrained in offering tenants waiting for transfers to new homes. |
| Social Influences | * Three quarters of tenants considered IoT technologies to be acceptable and only one in ten reported that they were uncomfortable with sensors. * Interviewees largely saw the sensors as recording information about the property, not people, underpinning the sensors’ acceptability. * Many tenants talked about the acceptability of Alexas and other IoT technologies that they, or their friends or family. |
| Opportunities | |
| Social and professional identity | * Housing management staff felt that tenant education about managing their home would be the prime benefit of the intervention. * The Ombudsman called for cultural change in the sector, so the professional judgement and practice of housing staff could change, and data used in landlord’s assessments of the problem. |
| Beliefs about capabilities | * Most tenants’ interviewees reported that the technology could offer clear benefits to them and the landlord |
| Beliefs about consequences | * Tenants' belief in their landlord’s capacity to act on the sensor information was less certain than their confidence in the technology to identify problems. * The landlord was largely trusted but tenants recognised constraints on the service, but three quarters agreed to share the data with their landlords. * Positive sentiment about data sharing with landlords was lower among those on benefits. * There were limits on data sharing, with few tenants agreeing that social workers or social carers should have access to the data. * Beyond landlords only family and researchers had a lower but sizable degree of support for data sharing. * Discussions with interviewees suggested that sentiment towards data sharing were weakly held and could be turned with new information or suggested uses. |
| Emotion | * The impact of having a cold home left over a quarter of tenants feeling miserable or depressed. * Interviewees reported feeling exhausted and lacking energy to engage their landlord in rectifying problems in home as it takes tenacity that they lacked due to mental and physical health issues. * People on benefits were less comfortable with the sensors and less trusting of their landlord |
| Nature of the behaviours | * Tenants may have ill health from a mixture of social, physical and hereditary factors unrelated to their homes. |

Staff knowledge and capability of interpreting and using the data was also not explored. Conversations with project managers indicated that there were considerable demands on staff time and introducing new practices would be resource intensive.

## Motivation

Tenants were motivated to know about their homes, or for their landlords to have greater insight into their homes and their management. Tenants thought the data could help landlords identify problems that were beyond the tenants’ control, prioritise investment and change the type of conversations tenants had with their landlords about the issues within the home.

Tenant circumstances limited their agency, however. There were many factors over which tenants had limited control, for example, the number of people in the home, their income and fuel expenditure, repair problems, and poorly functioning heating systems. Tenants often dried washing indoors, although not at all universally, reflecting wider societal norms that in other circumstances is less problematic. Challenges here included limited outdoor drying space for some, and concerns about the weather, privacy and security. Drying habits were however, not significantly associated with damp and mould.

Similarly, while landlords may be able to remedy the physical housing conditions associated with some damp, mould and cold properties they have limited funds, and competing demands on those funds. Landlords also lack recourse over tenant incomes and energy prices, and although they can and do provide advice and support to use energy efficiently and maximise income, they have no power over benefit levels and in work poverty or fuel costs, so are bounded in their ability to affect change in this area.

A small proportion of tenants were not digitally connected or confident, so their ability to use the tenant app to receive prompts about their home is obviously limited. Sensor firms could think about alternative methods to provide visual displays and prompts, or landlords will have to think about connectivity and devices for a small number of tenants when deploying the sensor technology.

In combination, these tenant and landlord constraints could limit the effectiveness of the sensor data, indicating measures tenants or landlords need to do but would find hard to enact, at least in any timely manner. However, the sensor data provides insight beyond the property data alone and therefore can ensure that landlord funds are spent more effectively on the worst performing properties. These data can underpin more nuanced conversations with tenants about energy and home management, fuel poverty and income maximisation which would enable more tenants to be able to achieve the required ventilation and heating the properties need. Where tenant behaviour is indicated in the data and inspections, then there is scope to think laterally about communal or neighbourhood drying facilities, for example. Landlords could also include sensor data in maintenance strategies and demonstrate to regulators that they are using all means to combat problems in this area.

Staff sentiment towards the technology was under-explored, but it was clear that deploying sensor technology would require the integration of the data into landlords’ current work policies and practices and therefore demand time to implement. Staff also clearly had concerns about the boundaries of the data use, especially as there could be the potential for the sensor data to support tenants’ claims against the landlord.

Tenants viewed the sensors as socially acceptable, viewing the monitoring to be of the home not the household, although these boundaries could be blurred, suggesting further work about the limits of the data use would be required.

## Opportunities

The conversation with housing management and support staff indicated that the sensor data’s’ primary function would be to educate tenants about the management of their home, suggesting that there could be professional resistance to data that goes beyond identifying tenant culpability. As mentioned above, however, new conversations underpinned with data about the tenants’ homes’ air quality can move beyond mutual blame and look at what issues need to be tackled to enable the homes to be heated and ventilated adequately. Landlord responses may include but also routinely go beyond the scope of the landlords’ repairing obligations and be informed by landlords’ financial inclusion, debt management, energy efficiency and housing management teams. Staff training would be required to ensure that they could effectively interpret the sensor data dashboard.

Landlords were largely understood to be meeting tenant concerns and tenants frequently understood the funding constraints and impact of the pandemic on landlords’ services. Nonetheless, tenants were less confident of their landlords’ ability to affect change by using the data than the technology's ability to identify the changes that might be required. There was widespread support for the landlord to use the sensors, but beyond sharing data with landlords, the potential for other services to be informed by these sensor data was weaker. Allowing landlords’ to also fulfill their social obligations by identifying vulnerable people with cold homes, for example, could be acceptable. However, further work is required to realise the potential for the sensor data to be used beyond the landlords and tenants and inform other public health or social care functions. Tenant's views were not always strongly held or considered and therefore could change, so there is scope for development in this area.

Tenants reported that pursuing landlords to look at more complex issues like damp, mould and cold could sometimes be exhausting for them, compounding feelings of low mood to which their homes contributed. The sensor data could therefore alert the landlord to problem properties remotely, bypassing the traditional tenant-initiated reports.

Identifying and isolating the sensor data’s effectiveness in mitigating adverse tenant health outcomes is likely to require long term interventions at scale as tenants often had pre-existing health conditions that some believed were exacerbated by their home.

## Conclusion

This chapter examined many positive aspects to deploying an intervention based on IoT connected environmental sensors to improve the management of social housing homes, with tenants largely connected and on board with the potential. Benefits were seen in this new data source informing landlords stock investment strategies but also in underpinning tenant reports of problems in individual homes. Staff views were under-explored but those that participated thought the tenant app would be valuable in prompting tenants to manage their homes effectively.

However, the various data point to limits on the ability of the sensor technology to affect change as many of the constraints on tenants to ‘do the right thing’ related to problems of fuel poverty, their household size, low incomes and property attributes that were beyond the tenants’ control. Similarly, social landlords have multiple demands on limited resources and may be unable to react in a timely manner, or be unable to affect change in tenants’ income, energy costs or benefit levels without their own support. It was also clear that deployment would demand staff time in integrating the landlords’ data into current housing management and maintenance practices and systems. The sensor data may, however, support landlord’s prioritisation in stock reinvestment strategies, make the most of effective use of limited funds and evidence their approaches to more robust regulators.

# Chapter 7: Conclusion

This report reflects the findings of a small-scale exploratory study into the deployment of a small set of digitally connected environmental sensors that record indoor air quality in social tenants’ homes. There was no doubt of the profound impact of poor indoor air quality, of damp, mould and cold, on tenants’ homes and their lives. For this low-income population with a heavy burden of ill-health, problems within their homes compounded other social, financial and health inequalities.

The issues of damp, mould and cold homes has to date been a contested area for landlords and tenants with problems of discerning where the responsibility exactly lies for these poor property conditions. Despite official statistics making clear that occupant behaviours are not associated with damp and mould, recent reports have identified a tendency for landlords to apportion culpability to tenants’ and unwittingly tolerate hazardous conditions. Findings from other surveys and this study identify an interaction of tenant attributes over which they have limited control with household size and poor property attributes more strongly influencing the incidence of damp and mould, not necessarily tenant’s conscious behaviours. Fuel poverty and some repair and property issues underpin tenants experiencing cold or hard to heat homes.

Increased scrutiny and regulation demand that landlords adopt a more comprehensive strategic approach to managing these issues, although they do so when any increased expenditure available to them has been diverted to fire safety issues and increasing new housing supply. This exploratory study shows that there is the potential for the sensors to support tenants and landlords in managing these issues, providing risk alerts that reflect in aggregate the property and the household’s use of their home. Landlords can investigate and direct resources at property repair or improvement but also incorporate income maximisation and fuel economy advice to tenants. While landlords have legitimate concerns about litigation and reputational risks from Ombudsman complaints, tenants were often passive or had limited energy and agency to engage their landlord. The remote monitoring of tenant homes could cut through a reliance on tenant reports and evidence new strategies and actions in this area to more robust regulators, or indeed courts.

Tenants were largely connected and gave a positive reception to the digital monitoring of indoor air quality to support social landlords and tenants manage the incidence of problems, notably including damp, mould and cold homes. Staff views were under-explored but those that participated considered the tenant app most valuable in supporting tenants to better manage their homes to prevent damp and mould. However, tenants also saw the new sensor data as offering strong evidence of the veracity of their complaints to the landlord about their home conditions. Critically, the data was also seen as the basis for new conversations between tenants and their landlord about problems in their homes.

Challenges were evident in that a small minority of tenants are not digitally connected and therefore may not be able to use the tenant mobile app, and some tenants are not confident with using technology.

Possible limits on the effectiveness of the intervention were also apparent in that some issues go beyond the landlord or the tenants’ control, in terms of earnings and benefit levels, the number of people in the homes, energy costs and possibly resources to remedy all property defects. Nonetheless, the sensor data seemed to offer landlords a more nuanced picture of their housing stock’s performance and its interaction with the occupants than property data alone and could support stock reinvestment strategies and effective use of limited resources.

Further work is required to determine whether interventions based on installing remote environmental sensors that provide information to a landlord dashboard and tenant app can bring about improvements in property conditions and can demonstrably benefit health outcomes. This study is positive about tenant acceptability of the intervention but does show some limits in terms of the limits of data use and sharing and the limited connectivity of a small minority of the tenant population. Tenants' engagement with the mobile app, their ability to respond to the risk alerts and modify their actions and whether they would persist with using the app over time were not established. Staff views of the use of sensor data to support their work and its integration into existing systems were also under-explored. This study could also not identify changes in health status after landlord and tenant use of the data.

Future research in this area needs to be undertaken at scale and include a process evaluation, outcome evaluation and economic evaluation. The process evaluation could identify issues with ensuring connectivity in the city or neighbourhood and tenant’s homes, integration of the new data into existing systems, how staff engage with the data and the actions that flow from it and how the data may have changed landlord responses to reports of damp, mould and cold, or indeed other reports of poor indoor air quality. An outcome evaluation should explore changes in health status over time to see if improved management of the homes has led to clear health outcomes, and whether there are tangible improvements in the housing stock. An outcome evaluation would be aided by the inclusion of the randomisation of participating tenants to the intervention or a control group, which would offer the most confidence in any findings about the role of the sensors and their data in influencing any changes in health or property status, for example. The economic evaluation should identify if any changes in behaviour accrue financial benefits to tenants, landlords or the health services. This would inform our understanding further about what such interventions might achieve but also inform procurement decisions in the social rented sector as well as among health agencies working with housing colleagues.

The IoT connected environmental sensor technology shows a potential to provide landlords with insight about a range of risks, and tenants with greater information about how to manage their home. The sensors are being deployed but remain at the margins of social landlords’ asset management practices. Further research of the sensors used at scale could make strong contributions to the knowledge base of how best to manage their deployment, what these sensors can and cannot achieve, for whom and at what cost or savings.

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# Appendix 1: IoT Sensor information

Three environmental sensors, two temperature and humidity sensors and one temperature, humidity and Carbon Dioxide sensor, were installed into the kitchen, living room and bathroom of 49 tenant’s homes as part of the project. In combination, the information from these sensors can detect the environmental conditions that give rise to risks of cold homes, poor air quality, draughts, damp and mould, dust mites and other allergens, rapid heat loss, and excess heat. Artificial intelligence and machine learning are used to classify the properties’ risks into high, medium and low and produce an overall score that would assist landlords to prioritise properties that require their attention.

The following information provides details of how the various risks have been identified.

**Damp and mould**

This Insight indicates the risk level of a room or property developing or already having visible Mould. Internal temperature, external temperature and internal humidity data is used to identify scenarios that are ideal for this problem to occur; typically, this means high humidity and low temperature, but the algorithm considers how long these conditions are sustained for within a rolling eight-week period. This is recalculated every day to ensure that the risk level is as up to date as possible.

**Cold risk**

Public Health England recommends indoor temperatures of more than 18°C to minimise morbidity and reduce the risk of death, especially for the elderly and vulnerable. This Insight looks to identify homes that are spending a significant amount of time below that

threshold, with lower temperatures resulting in progressively higher risk levels. This may be due to the resident being unable to afford to heat the home, an inability to effectively heat the home due to poor thermal efficiency (see Heat Loss Risk) or a combination of the two,

resulting in a resident living in fuel poverty. This Insight looks at data from the last seven days and is recalculated each day. It is much more prevalent in the colder months, as it is

obviously heavily influenced by the weather.

**Heat loss risk**

How quickly a property loses its heat is a good indicator of its thermal performance. This Insight looks for time periods where the resident is not using the heating and doesn’t have windows open to assess the rate heat is lost through conduction, rather than any other

means which typically means late at night. This is only run once every two weeks, as changes to the performance will only change if retrofit or repair works are completed and looks at six months’ worth of data at a time.

**Draughts risk**

Finding a balance between how well sealed a building is (minimising energy and carbon footprint costs to keep a home warm) and the level of ventilation available (ensuring indoor air quality doesn’t drop) is a challenge within both newbuild and the aging housing stock. This Insight identifies homes that appear to have too high a rate of ventilation (by utilising CO2 data), providing an indication of if a property is not well sealed and may benefit from replacement doors or windows, for example. Recalculated every day, this Insight utilises up to 8 weeks of historical data.

**Dust mite and other allergen risk**

Dust Mites - or more accurately Dust Mite faecal matter - is a common allergen, commonly causing sneezing, itchy eyes, wheezing and rashes. Asthma and other respiratory illnesses can be exacerbated, too. These tiny insects thrive in humid conditions, with the system requiring seven days’ worth of data to identify a risk. The system will use up to 28 days and recalculates each day. This Insight is largely for the benefit of the Resident, and recommendations will be provided via the HomeLINK Resident App.

**Excess Heat Risk**

Although cold weather is much more likely to increase morbidity and mortality rates, heatwaves also cause excess deaths in the UK. Temperatures of over 25°C have been shown to increase mortality and the incidence of strokes. The elderly and the very young can also become dehydrated due to the loss of moisture through sweating. This Insight identifies homes that have been at or above 25°C for prolonged periods of time, signifying that they may benefit from improved insulation or ventilation - resident education can also help, by recommending that blinds or curtains are closed, for example. Calculated every day - due to the nature of heatwaves in the UK - historical data from up to 8 weeks ago can be considered by this Insight.

**Indoor air quality risk**

Carbon Dioxide (CO2), as well as being detrimental to health in large concentrations itself, is considered a good proxy for other pollutants in the air, such as formaldehydes and Volatile Organic Compounds (VOCs). By monitoring the CO2 levels in the home, our system can identify properties that have a poor indoor air quality, which will result in a resident being given the recommendation of increasing ventilation and airflow through a property.

Indoor air quality risk is recalculated every day and can utilise up to 8 weeks’ worth of data. A high risk IAQ represents a temporary decline in handling cognitive tasks higher than 35%. The model identifies time spent above 1500ppm and 2000ppm which we overlay a cognitive decline model from recent publications.

**Overall risk scores**

The overall risk score uses this formula:

Overall Risk Score = 20 - [(5h + 2(h-1)) + (2m+(m-1))]

where 'h' = number of high-risk insights

and 'm' = number of medium risk insights.

A home with two high risks and one medium would lose 14pts, giving it an Overall Risk Score of 6. A property loses 5pts for the first high risk, 7pts for the second high risk, 9 for the third etc. and 2pts for the first medium risk, 3 for the second, 4 for the third, etc. Therefore, a house with high risks always scores worse than a house with just medium risks. This overall score provides a simple method to compare properties across all data that is monitored. The lowest score would probably be the priority for investigations and repairs. For example, the lowest scoring homes would benefit the most from a retrofit programme and so should be scheduled in first.

# Appendix 2: Theoretical Domains Framework

This framework considers a range of factors that may relate to their appetite or ability of a person to make the desired changes to achieve a health or wellbeing outcome and is based on the cognitive, affective, social and environmental influences on behaviour (Atkins et al., 2017) (see Box 1). These factors may influence both population and professional behaviours in response to issues, although in this study staff views are under-explored in comparison to tenants. This TDF can then help policymakers diagnose the circumstances by using the COM-B framework by looking at the Capability, Opportunity and Motivation for someone to engage with a given program [(West et al., 2019)](https://paperpile.com/c/TTZOT7/qcoD) (Box 2).

Box 1: Theoretical Domains Framework

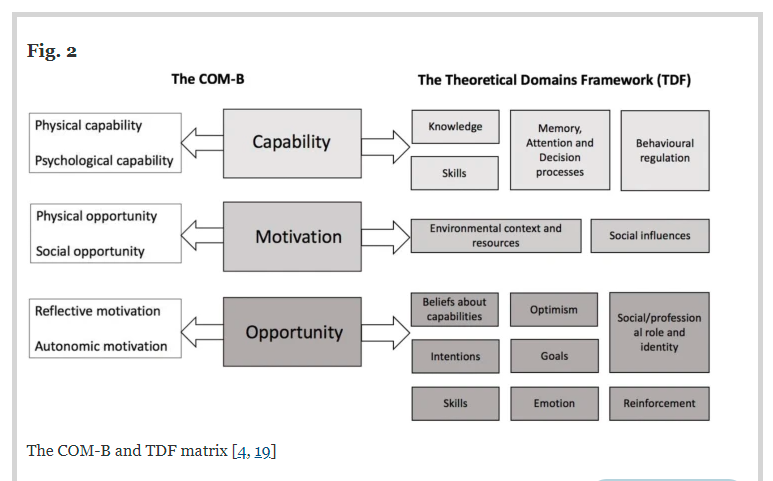
|  |
| --- |
| * Knowledge * Skills * Social and professional identity * Beliefs about capabilities * Beliefs about consequences * Motivation and goals * Memory, attention and decision processes * Environmental context and resources * Social Influences * Emotion * Behavioural regulation * Nature of the behaviours |

Source: Atkins et al. (2017)

Box 2: COM-B Framework

|  |
| --- |
| Capability   * Do they know what the desired behaviour is? * Are they physically capable of doing it? * Do they have the mental or physical skills required? * Do they understand why it is important for them to do it and how to do it? * Do they have the self-control required to do it and keep doing it if necessary?   Opportunity   * Do they have the time, financial or material resources to do the desired behaviour? * Do they have the social support required? * Is it seen as normal in their social environment?   Motivation   * Do they find it genuinely more attractive than competing behaviours? * Is it an established part of their routine? |

Source: West et al. (2018)



Source: Atkins et al. (2017)

The TDF and COM-B frameworks dovetail as outlined in Fig.2, supporting analysis of an intervention.

1. For a dwelling to be considered ‘decent’ under the Decent Homes Standard it must: meet the statutory minimum standard for housing under the HHSRS. Homes with a Category 1 hazard under the HHSRS are considered non-decent be in a reasonable state of repair have reasonably modern facilities and services provide a reasonable degree of thermal comfort (MHCLG, 2021) [↑](#footnote-ref-1)
2. <https://www.itv.com/news/2021-09-12/britains-housing-shame-shocking-conditions-and-despair-at-a-lack-of-action> [↑](#footnote-ref-2)
3. Fuel poverty in England is now measured using the Low-Income Low Energy Efficiency (LILEE) indicator1, which considers a household to be fuel poor if: it is living in a property with an energy efficiency rating of band D, E, F or G and its disposable income (income after housing costs (AHC) and energy needs) would be below the poverty line (BEIS, 2021). [↑](#footnote-ref-3)
4. Poor air quality produces cognitive decline and is highlighted when the length of time the air shows CO2 concentrations are above 1500ppm and 2000ppm. [↑](#footnote-ref-4)