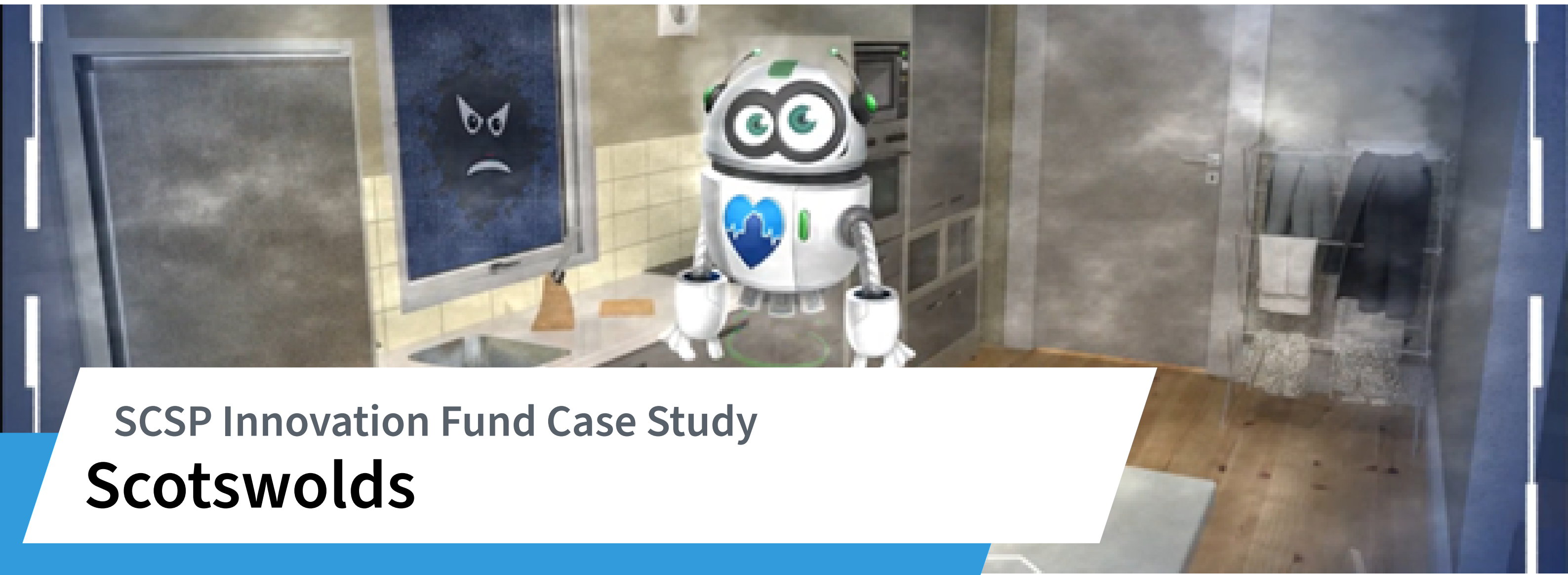

SCSP Innovation Fund Case Study

Scotswolds

Summary

The **Healthy Homes** project addresses indoor air quality issues in West Dunbartonshire Council's social housing by analysing data from environmental sensors and engaging tenants in citizen science.

This initiative combines advanced data analytics, real time connectivity via 5G and broadband, additional sensor deployment, and community engagement to provide actionable insights into the relationship between ventilation, air quality, and tenant well-being.

Key collaborators include **Scotswolds Ltd**, **West Dunbartonshire Council**, and **Vodafone Business**.

Watch the Scotswolds case study video.

Introduction

Context and Rationale

Indoor air quality has emerged as a critical issue in social housing, where lack of ventilation, cold homes and excessive indoor water vapour contributes to mould growth and worsens respiratory health. While tenants can be reluctant to ventilate due to concerns about heat loss and outdoor pollution, innovative approaches can address these barriers by providing evidence-based education and practical interventions.

This project leverages existing data from environmental sensors to develop effective strategies for improving air quality and tenant well-being.

Project Objectives

- Analyse existing environmental data from ~1,000 homes to understand indoor air quality characteristics.
- Deploy additional sensors in outlier homes to gain deeper insights.
- Develop educational materials for tenants to improve ventilation practices and reduce excessive indoor moisture sources.
- Inform broader strategies for addressing air quality and mould in social housing.

Problem Statement

- West Dunbartonshire Council's environmental sensors programme is rolling out sensors to their 10,400 homes over the next five years to allow them to become more proactive in tackling dampness and mould. They are the first landlord in Scotland to plan for full stock roll out and thus this is a highly innovative project.
- At the end of year one of their programme and initial findings revealed significant indoor air quality and

mould concerns. Due to the innovative nature of the programme, we cannot compare with other landlords because few others have data on this scale.

- From initial assessment of the data from the first 1,000 homes (see Figure 4) with environmental sensors (Figure 2) installed, around 20-30% of these have shown levels of moisture that could result in black mould growth. Furthermore, levels of CO2 within these homes show that inadequate ventilation practices are commonplace.
- Initial tenant engagement suggests there is widespread reluctance to ventilate which stems from concerns about heat loss, the cost of energy and outdoor pollution ingress, particularly in homes near major roads, retail parks or industrial premises.

Glasgow City Region Context

- The project aligns with Glasgow City Region's goals of improving living conditions through smart technology and tenant empowerment.
- The project supports the transition to the Social Housing Net Zero Standard by addressing air tightness and ventilation challenges.

Project Objectives

- Characterise indoor environments using internet-enabled sensors and advanced analytical methods.
- Identify and address outlier properties requiring intervention.
- Empower tenants through education on smart ventilation practices and other behavioural patterns.
- Deliver scalable methodologies for improving indoor air quality and mould occurrences in social housing.

Approach

The project was a collaborative effort involving:

- **Scotswolds Ltd**: Project management, sensor deployment, tenant engagement, expertise in indoor air quality and analytical methods.
- **West Dunbartonshire Council Housing**: Data provision and access to homes.
- **Vodafone Business**: Sensor connectivity and infrastructure optimisation.

Scientific Background

Damp and mould can lead to health problems like asthma, eczema, and allergies, as well as impacting wellbeing, mental health, and job prospects. The issue is particularly prevalent in social housing, with tenants reporting a significant increase in damp and mould complaints.

Water availability is the primary factor controlling mould growth in buildings. Spores are always present in air and even in the winter concentrations rarely drop below a few hundred spores per cubic metre of air.

Moisture production inside a building can lead to excessive water vapour and condensation that would increase mould growth risk. Accepted wisdom shows that the most intense moisture producing activities in a house include drying clothes, cooking, and the occupants themselves (Figure 1). The variability between different households indicates the need to raise awareness among the public to adjust their behaviour to reduce indoor air pollution and mould growth risks will reap significant benefits.

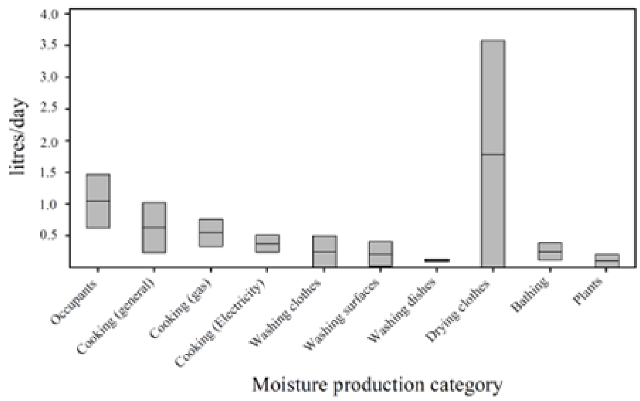

Figure 1: Moisture producing activities identified in the literature. On average a family may produce 3-20 litres/day.

Implementation

1 Stage 1: Analyse data from existing sensors in ~1,000 homes to identify trends and outliers.

Figure 2 - AICO CO2, Temperature & Humidity Sensor. Measures 7 cm2, and is battery operated. www.aico.co.uk

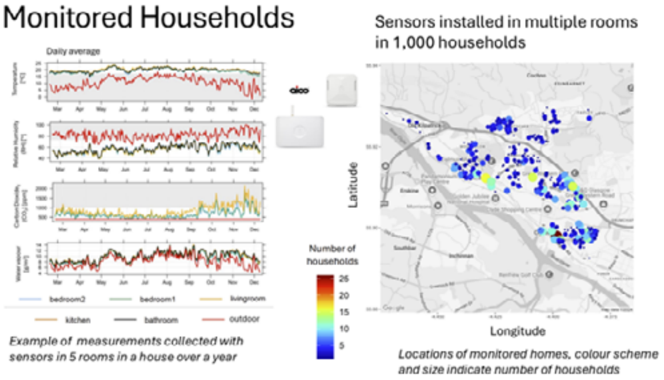

Figure 3: LEFT: Example of collected time-series data from 5 rooms in one household over a year. Indoor temperatures remain within a relatively narrow range indicating central heating. Indoor CO2 levels increased during the colder months of the year, possibly due to decreased ventilation for thermal comfort. Outdoor water vapour (moisture) influences indoor levels strongly particularly during the summer when occupants ventilate more. *RIGHT: Spatial distribution of monitored homes.* The colour-scheme and size indicate the number of homes in each postcode.

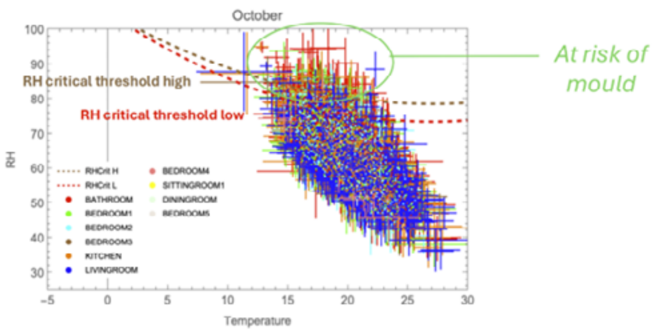

Figure 4: Scatter Plot of indoor Relative Humidity vs Temperatures from multiple rooms in 1000 homes for 1 month out of the 12-month deployment. Dashed lines indicate mould growth risk determined with a validated microbiological model (MOGLI). Points falling above these curves indicate rooms with high mould growth risk (in green circle). It is worth noticing that bathrooms are the most likely rooms that mould can opportunistically grow due to lower temperatures and higher relative humidity levels that permit condensation. Although not shown, the most critical period for mould growth appears to be in the autumn due to higher levels of outdoor moisture.

Approach

We utilised quantitative analysis to understand sensor data to identify mould risk, and to assess air quality improvements.

The analytical methods used were custom designed data analysis packages, using high level analytics to process the data from the indoor sensors and allow a network wide view of which homes present the greatest risk of potential mould development.

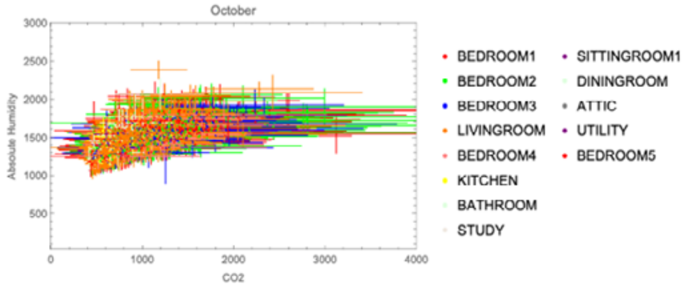

Figure 5: Scatterplot of indoor CO2 levels vs indoor water vapour. This graph shows all 1000 homes for October 2024, where many exceed levels considered healthy (around 800 -1000ppm). In some cases, CO2 levels reach almost three times those levels. There is a positive correlation between indoor water vapour levels and CO2 indicating that increased occupancy numbers and high humidity go hand in hand, linked largely to low ventilation.

Findings

Initial analysis highlighted high CO2 levels and insufficient ventilation in many homes. Figure 6 shows a correlation between high CO2 levels and moisture further strengthening the importance of ventilation in reducing mould risks. Increased moisture levels were found in many homes, mainly in kitchen and bathrooms, but high moisture levels were also found in other rooms in certain locations and seasons.

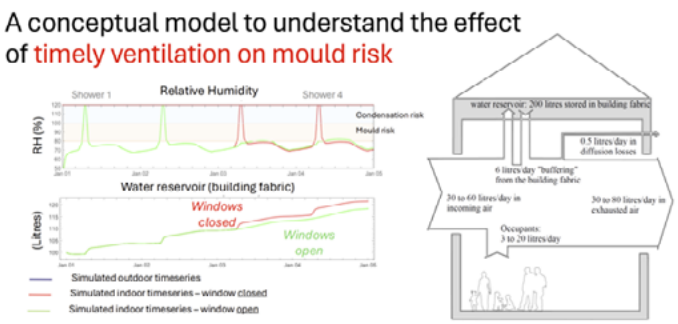

Figure 6: RIGHT: Schematic of a conceptual model that illustrates indoor moisture transfer in buildings. Occupant activities and ventilation are the primary drivers of indoor moisture levels. The building fabric acts as a "sponge" which buffers moisture. Without adequate ventilation this water reservoir is likely to increase over time. *LEFT: Time-series of simulated indoor relative humidity measurements and the resulting water reservoir in the building fabric.* Four moisture production events (representing showering or cooking) can be seen in the time series that elevate indoor relative humidity (top) and the impact on the building reservoir (bottom). Two ventilation patterns and their impact were simulated, green signifies ventilation during and immediately after emission events, and red signifies no additional ventilation. Without additional ventilation, indoor relative humidity levels increased within the range associated with mould growth. It also shows that excess humidity is absorbed by the building materials increasing the water buffer without additional ventilation.

We developed a conceptual model to demonstrate moisture transfer in a building. The model includes moisture generating activities (see Figure 1), and two ventilation behaviour patterns (see Figure 7 green = additional ventilation, red = no additional ventilation). We also found that the fabric of the home, walls, furniture, floor, and wall coverings can act as a "sponge" absorbing moisture from the air and releasing it under certain conditions.

This presence of the "sponge" is important because it demonstrates the need to take a year-round, long-term approach to managing day to day moisture. Usually, building structures tend to dry over the summer, however, moisture builds up in homes, particularly during damp summers like that of 2024. When the building and air cools in autumn and the dew point drops, this moisture is released and becomes visible as indoor condensation or mould because cooler air can hold less moisture.

Evaluation / Reflection

The team were supplied with information about the sizes of the properties, number of bedrooms, typology, and construction type of the homes in the study. This allowed us to develop an automated algorithm to determine whether certain homes were more likely to be experiencing damp and mould. The algorithm was verified against an (anonymised) list of houses known to be at risk of mould demonstrating a framework for the advance detection of mould, allowing planned remedial work to be more effective both in terms of costs and health impacts (see Figure 7).

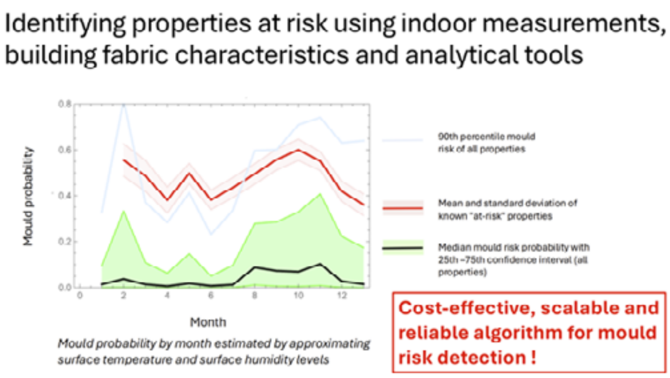

Figure 7: An automated algorithm was developed to identify homes with increased risk to develop mould. The properties identified by the algorithm were compared with known "at-risk" properties and showed a high agreement providing compelling evidence that such deployments can detect problems at an early stage when remedial work can be more effective both in terms of costs and health impacts.

There appeared to be little correlation between damp and mould risk and construction types such as concrete versus sandstone and instead the correlation was more linked to ventilation and heating. This links to the building fabric sponge concept implying that actions throughout the year are required, by both landlord and tenant, to keep moisture levels managed.

However, whilst a reasonable data set of 1,000 homes it is hard to fully test this hypothesis in a short window of a year and instead probably would require longer analysis with more detailed property information such as levels of insulation, orientation and occupancy levels. A caveat is that there is a need to balance data analysis ambitions with tenants' right to privacy in their homes.

2 Stage 2: Deploy additional sensors (PM2.5, CO2, temperature, humidity) in five targeted homes, both indoors and around the WDC region outdoors.

Figure 8 - Air Gradient Indoor and Outdoor Sensors www.airgradient.com

Approach

Internal sensors were fitted in five properties. The properties were chosen based on the criteria that the homes already have the environmental sensors installed so there was base data for the home. We also sought out homes where tenants had expressed concerns about pollution or were experiencing mould. We also tried to get a range of property types including new build, multi-storey and tenemental stock; the outcome was 2 x multi storey, 2 x older tenemental and 1 x new build tenement.

Figure 9 - Outdoor solar powered air quality monitor, Montrose Street Clydebank.

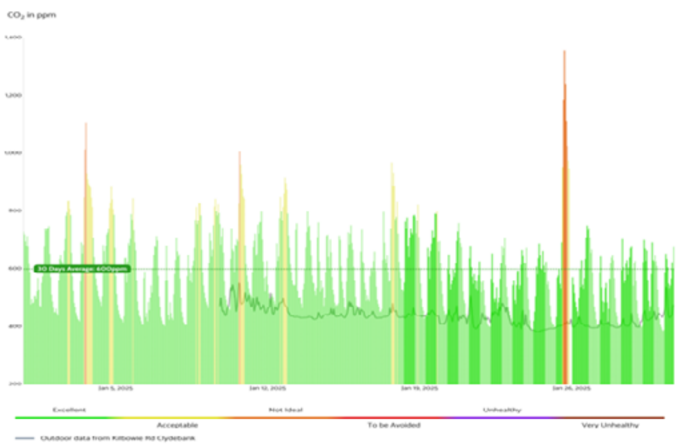

Figure 10: This graph shows the typical hourly variation of CO2 in one of the homes monitored during Phase 2. CO2 levels are mostly within healthy limits, but there are times when ventilation could be improved. The outdoor CO2 levels are also shown as the solid green line.

Findings

Additional sensors are providing critical data on the relationship between indoor and outdoor pollution. We have seen elsewhere that fine particulate matter such as PM2.5 prevalent in outdoor air can find its way indoors even in the tightest of building types in ventilation terms.

We have observed PM2.5 concentrations both indoors and outdoors where indoor air quality closely follows the levels measured by the outdoor monitors (Figure 11).

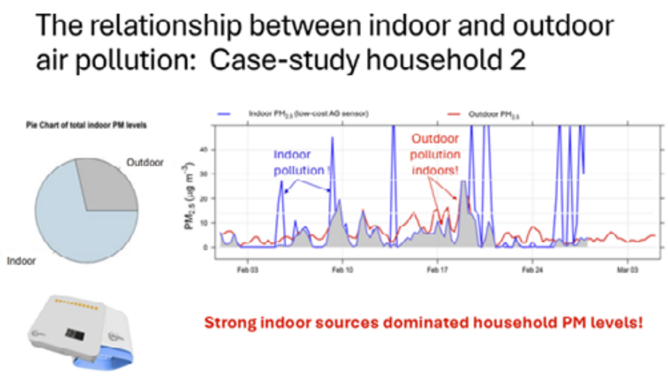

Figure 11: Example of indoor and outdoor PM2.5 levels measured in a case-study home. The contribution of outdoor air pollution levels indoors is clear especially during high pollution events on 19th-20th of February. However, additional significant indoor sources elevated indoor concentrations above outdoor levels and accounted for around 70% of total indoor PM2.5 levels in this case. In other cases, outdoor PM accounted for over 50% of the total.

Evaluation / Reflection

Tenants were more hesitant than expected about accepting additional sensors and measurements of PM2.5 were therefore more limited, but we eventually managed to get access to the target number of properties. This highlights how important our information campaigns have been for our main environmental sensor programme e.g. local press articles, housing news which has helped people understand what is coming and why.

3 Stage 3: Translating the findings into tenant materials to help tenants ventilate better.

At stage 1 we identified that the building fabric of the homes in the study were acting as sponges or reservoirs for moisture and thus storing it up. This means that we need to think about moisture management year-round rather than only in autumn / winter.

Therefore, the first focus of our tenant materials needed to be on moisture management and whilst various options exist for tenant information, a video was landed on as the best way to relay this complex information and messaging in a visually appealing, informative, and light-hearted way. Through some joint working from the partners, we were able to re-allocate some budget towards a video.

We worked with an additional partner, to produce a 3-minute animated film explaining the conditions that can lead to black mould growth and poor indoor air quality and communicate several simple behaviour changes that can lead to improved indoor air quality, reduce mould risk, and improve health outcomes.

The content is suitable for use by West Dunbartonshire Council but also by other social housing providers because we understand this challenge to be widespread.

The video includes several characters including a robot (Figure 12) which we can then use across our other materials such as flyers and letters and online to create a consistent messaging. The video will be shared with tenants and tenant groups before sharing more widely online and on social media.

Figure 12: Snapshot from the 3-minute animated film explaining the conditions that can lead to black mould growth and poor indoor air quality. The aim of this film was to communicate several simple behavioural changes that can lead to im prove indoor air quality, reduce mould risk, and improve health outcomes.

Findings

The video has been distributed across social media platforms and the feedback from WDC staff has been that videos were well received because they can quickly convey a lot of information in a digestible format. Having characters and graphics we can use across a branding / marketing pack will also be beneficial.

Evaluation / Reflection

The project is delivering enhanced educational materials for tenants to improve ventilation practices and initially we thought this would be achieved by written materials only, but we are really pleased through some excellent joint working we have been able to deliver a video which will really improve our impact within WDC and beyond.

The findings from this project will need to be digested by WDC to inform broader strategies for addressing damp, mould, and air quality in our homes. The concept of the building fabric behaving like a "sponge" means we need to plan a year-round campaign of moisture management rather than focusing on the colder weather months / heating season. This is becoming more pressing with the new requirements for the Scottish Housing Regulator who will require us to report on our response to damp and mould complaints.

Stakeholder Feedback

Tenants valued the opportunity to participate in the project, noting increased understanding of how to balance ventilation with energy efficiency. Simple actions such as not drying clothes indoors, using pan lids when cooking, or filling baths with cold water before the hot water to reduce the amount of steam generated which in turn increases moisture in the air. The best times to ventilate rooms to ensure healthy CO2 levels and to keep moisture levels in check. In a few extreme cases it may be necessary to deploy dehumidifiers to remove moisture from the air and fabric of the building.

Key Considerations

Facilitators

- Strong partnership between social housing providers, academia, and private sector experts.
- Use of existing sensor infrastructure reduced costs and accelerated timelines.
- Good communications connectivity via 5G, quality broadband or similar connectivity.

Barriers

- Tenant hesitancy to participate due to perceived privacy concerns.
- Weather and seasonal factors limiting data collection opportunities.

Learnings

- Combining data-driven insights with tenant engagement is critical for successful intervention and encouraging behaviour change.
- Understanding outdoor pollution levels and using this information to inform smart ventilation strategies indoors.
- Addressing tenant concerns early builds trust and improves participation rates.

Conclusions

The **Healthy Homes** project demonstrates how data analytics, sensor technology, and tenant education can improve indoor air quality and well-being in social housing.

The initiative aligns with regional strategic goals and provides a scalable model for addressing air quality challenges.

Using enhanced connectivity such as broadband and 5G networks the collection, real time analysis and publication of data provides guidance to tenants on how best to ventilate their homes without being affected by the negative effects of outdoor pollution levels.

Next Steps

- Share findings and educational materials with other councils in the Glasgow City Region and beyond.
- Distribute the animated film produced by this project to all councils in the Glasgow City Region and adapt that for an even wider audience nationally.
- Further leverage a program currently in development within Vodafone Business studying black mould in homes to scale to other cities especially as there is increasing demand to improve the thermal performance of the building stock to achieve NetZero for climate benefits.
- Align our findings with another project funded by the Greater London Authority (GLA) studying the incidence of Asthma in children related to indoor and outdoor air quality within the London Borough of Southwark.
- Explore additional funding opportunities to expand external PM2.5 sensor deployment to create a network across the region, where if anyone has concerns about the air quality near them, they can check an interactive map which will tell them what it is near them and it could give them a score good time to ventilate v keep windows closed. This will give all council and landlords a resource to refer to when tenants or residents have concerns about pollution and ventilating.
- Advocate for policy adjustments to support smart ventilation practices in social housing.

Sustainability & Further Exploitation Plan

The project will result in long-term benefits, including improved tenant health, reduced heating costs, and enhanced property management strategies.

By aligning with the Social Housing Net Zero Standard, this initiative sets a precedent for scalable, sustainable air quality interventions across the region and beyond.

Our consortium has been approached by a London Borough who are facing similar problems with a view to leveraging the learnings from this project and creating a similar approach to the deployment of sensors to manage rental properties in the public and private housing sectors.

Acknowledgements

Special thanks to **West Dunbartonshire Council** and **Vodafone Business**, and the tenants who participated in the project for their invaluable contributions.

Thank you to **Glasgow City Region** and **DSIT** for funding and supporting the project.

Disclaimer

The findings presented in this case study reflect the independence of the project and the collaborative efforts of all stakeholders. No conflicts of interest have been identified.

Find out more about the project on the Glasgow City Region website.