ATTRACT ACADEMY

GUARDIAN AIR

STOPPING MOLD TAKING CONTROL OF YOUR HEALTH

DECEMBER 2023

CERN 23

Contents

Introduction:

Mold is a significant issue due to its adverse effects on both health and property. Mold produces airborne spores that, when inhaled, can cause respiratory problems and allergic reactions, particularly in individuals with allergies, asthma, or compromised immune systems. Beyond health concerns, mold can lead to structural damage by growing on surfaces like wood, weakening the integrity of buildings. The unpleasant odors associated with mold growth, the visual impact on aesthetics, and the worsened air quality due to mold further emphasize its negative consequences.

This problem is not only huge in terms of consequences, but also in the number of people suffering from it. In England alone, there are more than 1.000.000 households with mold.

The issue becomes even worse for people with pre-existing conditions or weakened immune systems, which is the case for people with a low income, who because of these limited financial resources suffer deal with many problems:

- Poor housing conditions, and therefore issues such as leaks, or poor ventilation, which can contribute to mold growth.

- Limited healthcare access, which can result in unavailability to be diagnosed, or delayed diagnosis and treatment

- Limited access to legal resources and consequently less awareness of their own rights. This can make it challenging for them to compel landlords to address mold issues, which is what we will discuss on the next slide

Mold growth intensifies with rising temperature and humidity, leading to potential health risks, including respiratory problems and in extreme cases cancer. Common symptoms observed include watery eyes and hoarseness among affected individuals.

For our project scope, we will focus on the UK. This is mainly due to the country facing issues in fighting mold in areas of poverty caused by but not limited to the UK's humid and damp weather, the difficulty in detecting mold early, the high cost of removing late-stage mold infestation, and tenants' awareness. Additionally, the UK faced a tragedy caused by this issue that led to the passing away of a two-year-old Awaab Ishak. To tackle the problem, the UK government agencies worked on fixing the issue by

introducing Awaab's Law for expediting reporting of apartments with mold issues to the government as well as raising more than £45 million to improve the quality of the social housing.

Patterns of behavior:

- **Aging Infrastructure:**

In regions with aging housing stock, deteriorating materials and inadequate maintenance can increase the risk of mold issues. Renovation and maintenance are crucial to mitigating this trend. One in six homes in England (15%) were built before 1900. Homes in England and Wales were most commonly built between 1930 and 1982 (46% in England) and only 7% were built in 2012 or later.

- **Indoor Air Quality Awareness:**

Growing awareness of the importance of indoor air quality has led to increased attention on mold as a potential health hazard. Homeowners are more likely to take proactive measures to prevent and address mold issues. The UK Government has established a cross-department working group and pledged to tackle aspects of indoor air quality in its 2019 Clean Air Strategy.

- **Link between Housing and Health:**

Housing conditions can impact physical and mental health in various ways. The impact of poor housing goes wider than the actual inhabitants as conditions incubated in unhealthy housing may spread, with costs ultimately borne by health and social care services. The Building Research Establishment (2021) estimates the cost to the NHS of treating those affected by poor housing as £1.4bn per year.

- **Insurance and Liability Considerations:**

Some home insurances depend on the provider and policy. Mold could be covered when it is developed as a result of incidents such as an escape from water, storm damage, or a flood. Mold is not covered when it's developed through a lack of property maintenance or certain home keeping habits.

- **Climate Change and Extreme Weather Events:**

Climate change can lead to more frequent and severe weather events, including heavy rains and flooding. These events can increase the risk of water intrusion and moisture problems in homes, creating ideal conditions for mold growth.

- **Green Building Practices:**

Green building standards often emphasize materials and practices that are resistant to mold and moisture. This trend can reduce the likelihood of mold growth in new constructions.

- **Smart Home Technology:**

Smart home devices, including humidity sensors and leak detectors, can help homeowners monitor and control indoor moisture levels, reducing the risk of mold development.

- **Increases in Fuel Prices:**

Increases in fuel prices had led tenants to prioritize securing food overheating their homes, leading to an increase in damp and cold conditions.

Mental Models:

Here are some mental models we need to take into consideration while thinking in a solution for mold and its unpliancy in health.

- "Mold is only a cosmetic issue." Some people believe that mold is merely a cosmetic problem and don't understand the health risks associated with exposure to mold. This misconception can lead to neglecting mold problems until they become severe.
- "Mold only grows in dirty homes." Some individuals think that only dirty or poorly maintained homes are susceptible to mold. In reality, mold can grow in clean and well-kept houses if there is excess moisture.
- "Bleach can solve all mold problems." Many people believe that using bleach is a universal solution for mold removal. While bleach can kill mold on non-porous surfaces, it's often ineffective on porous materials and may not address the underlying moisture issue.
- "Mold only grows in visible areas." This belief can lead to overlooking hidden mold problems, such as mold growth within walls, ceilings, or HVAC systems. Mold can thrive in concealed areas, making it harder to detect and remediate.

- "A dehumidifier/good ventilation will solve all moisture problems." While dehumidifiers and ventilation can help control indoor humidity levels, they may not address the root causes of moisture issues in a home, which could lead to ongoing mold growth.
- "Once mold is removed, the problem is solved." Removing visible mold is just one part of the solution. Without addressing the underlying moisture issue, mold is likely to return.
- "Professional help is unnecessary; I can handle it myself." Some people underestimate the severity of mold problems and attempt to remediate them without professional assistance, potentially making the problem worse or overlooking hidden issues.

Social Problems related to mold:

As explained in the introduction, mold is a huge issue with enormous impacts on our health... so the obvious question is... why isn't it properly solved when tenants find out they have mold in their houses? And why is it always so hard to tackle the problem? There are 2 possible solution approaches tenants take when they find mold in their homes:

- Trying to fix it by themselves with solutions such as bleach. The problem with this is that it tackles the symptoms and not the cause, so it won't get rid of mold, but simply gives a temporary improvement on the visuals of it. They will keep on trying to solve the problem the wrong way until, eventually, they give up, mold keeps growing, and they end up getting sick.

- The second possible solution tenants have is going to their landlords. This leads to a back-and-forth discussion over who is the blame and can end in the landlord fixing it, but also in eviction. It is a long, difficult, and risky path to take, where the power dynamics often lead to the landlord winning, as he has more resources.

Motivation:

We decided to create Guardian Air for all the previously explained problems related to mold. We think mold is a complex and dangerous problem with lethal implications for human health and an intrinsic social conflict that isn't being addressed. With Guardian Air, we aim to solve the whole problem once and for all and get rid of both the health and social issues related to mold. In the following sections, we will explain

the devices we developed, as well as give an in-depth explanation of the technology we chose to use, and why we chose it.

Technology:

Currently the most common method people use to detect mold in houses is visually. Residents realize they have mold in their house when they see it, which is not ideal because once you see it, it has been growing for a while, and it is already affecting your health. There are other more advanced methods like using moisture meters or thermal imaging to find the levels of humidity and temperature respectively. These are also not optimal methods because they lack many variables and won't give you accurate results on many occasions. Our prevention device implements multiple sensors and gives a mold growth probability having them all in mind, so it is more accurate in telling whether mold has grown or not. Besides the sensors, what adds the most value to our devices is the use of Attract EU technology PIPE 4.0 to find actual mold spores in the air, which will help find the mold source in the case of the detection device, and mold growth in general in the case of the prevention one. All of these topics will be further explained in the following sections.

Competitive Advantages

In contrast to methods that directly identify mold spores in collected samples, our device offers superior speed. Unlike other options that require samples to be transported to a laboratory for analysis, our device conducts real-time assessments in the room itself. Additionally, our solution is more efficient, as it eliminates the need for specialized personnel to process collected samples. Moreover, it promotes overall health by continuously monitoring the air for the presence of spores.

PIPE 4.0:

The PiPe 4.0 project aims to improve the monitoring of natural gas distribution infrastructure through advanced technologies. The initiative involves the application of photonics and nanotechnologies to develop sensors for measuring the composition and calorific value of natural gas. This technology uses laser Raman spectroscopy for fast and precise gas quality analysis.

We decided to use this technology because Raman spectroscopy would be an ideal tool to detect mold spores in the air and mold growth in the house. A spectroscopy also provides different spectra for everything it detects, so it would differentiate the types of molds.

The way we designed our detection device to classify the types of molds, and if it is mold or not, is the following: We have a database of all the types of molds and their corresponding spectra. When Raman Scattering provides us with the given spectra, we compare it to all of the database's spectra with a MSE (Minimum Squared Error) measure. If the MSE is bigger than a set threshold, it means there is no mold. If it is not, we choose the type of mold with the least MSE given, which will be the one with the most similar spectra.

While this technique has demonstrated effectiveness in controlled environments with exceptionally high concentrations of mold, further refinement and advancement of the technology are essential. Presently, Raman Spectroscopy excels in identifying molecules much smaller than mold spores. This feasibility arises from the reduced energy requirement for reliable identification through Raman Scattering as the size of the target decreases. However, a significant challenge lies in devising a mechanism for the device to capture any present spores and position them precisely where the laser can effectively interact with them.

Hyperspectral imaging on IR and SWIR applications:

As we know, visual identification of mold becomes possible only when it has reached an unhealthy level of proliferation. We have not investigated the reaction of low concentrations of mold to infrared (IR) or ultraviolet (UV) light. However, we anticipate that studying their responses could contribute significantly to mold detection. UV light, commonly employed in forensic applications to locate various organic compounds, holds particular promise as one of the most advantageous technologies for enhancing the detection rate of our device.

Guardian Air:

As mentioned before, the necessity to use Guardian Air is to solve the social conflicts related to mold as well as to fix the whole mold infestation problem, including its early detection and proper elimination. To achieve that, we have developed two technologies and an associated system to improve the social dynamics. They are the following:

Mold monitor:

This device acts in the prevention stage. It allows the user to know when mold growing conditions are met and is also able to detect actual mold spores in the air

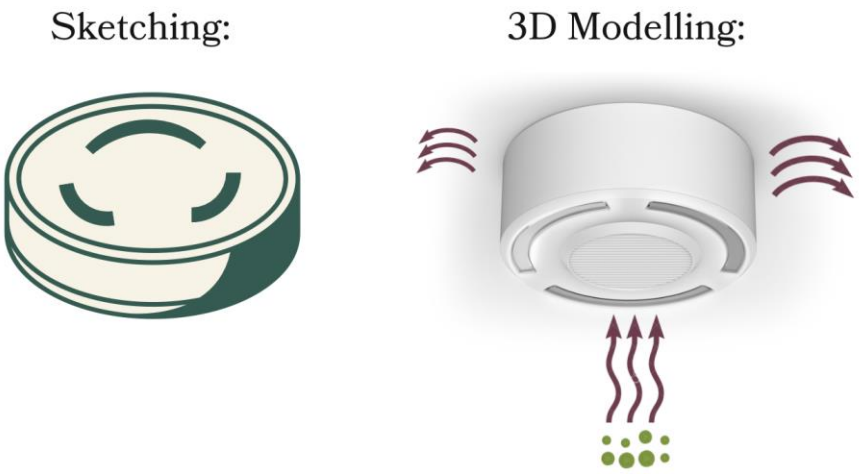


Figure 1: Mold monitor sketch and 3D model

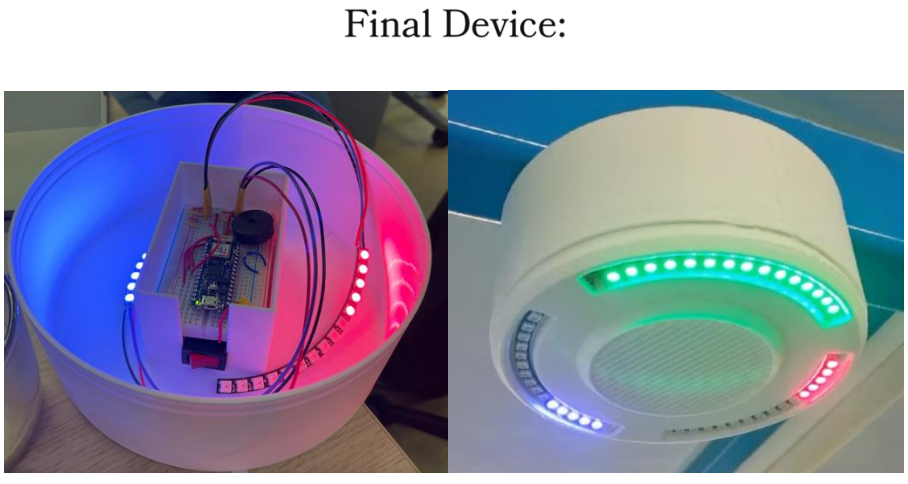


Figure 2: Mold monitor

Usage:

The device has 3 LED stripes, as shown in the following figure. One of them shows the temperature and another humidity read by the sensors.

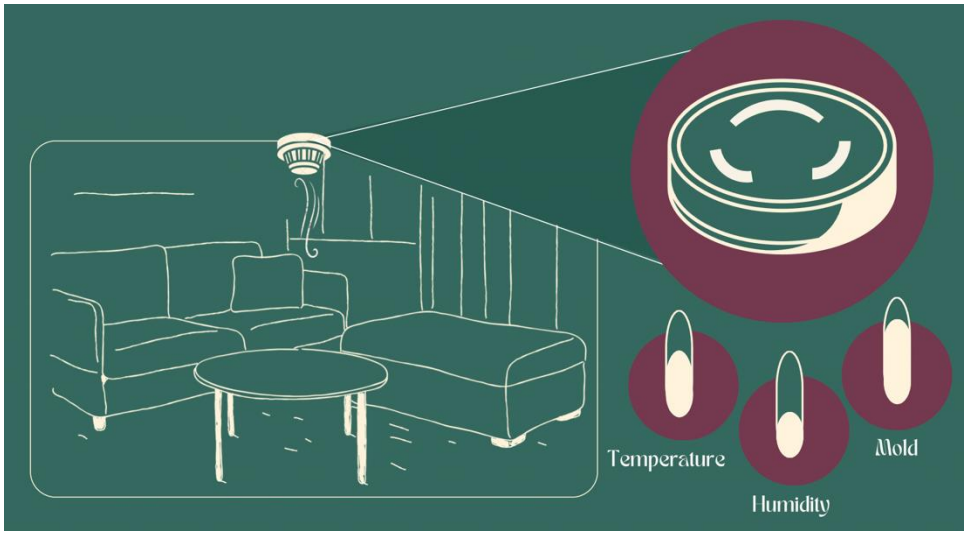


Figure 3: Mold Monitor Location

Regarding the third LED stripe: If the device detects either mold-growing conditions or mold spores, it automatically notifies the landlord so that he can fix the issue as soon as possible. This third stripe starts brightening the moment this happens and keeps on growing until the problem is solved. This stripe, therefore, keeps a history of how long the problem has been neglected, so it is to be used in case of a dispute over who is to blame for the problem. It can also be used to take legal action if needed.

Technology:

Since this device acts on the prevention part, its main objective is preventing mold from growing in the first place. That is done with multiple sensors: humidity, temperature, and an air quality sensor, all put together into a neural network to detect the probability of mold growth. Moreover, as early detection is also key, it also incorporates Raman spectroscopy to constantly look for mold spores, and we added a fan to increase the airflow, allowing for more particles to enter the device and increasing the chance of detecting mold spores if they are present.

The device will be non-invasive as it will have the shape of a smoke alarm, so residents will find it familiar and unnoticeable.

Portable Detector:

If mold is detected (detection stage), another device that Guardian Air offers is a “Portable Detector”. This device allows for locating the source of the early-stage mold to apply the necessary easy fix.

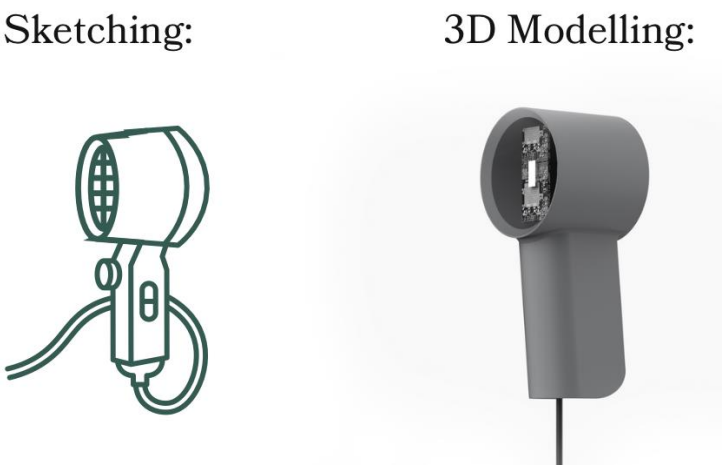


Figure 3: Portable Detector sketch and 3D model

Final Device:

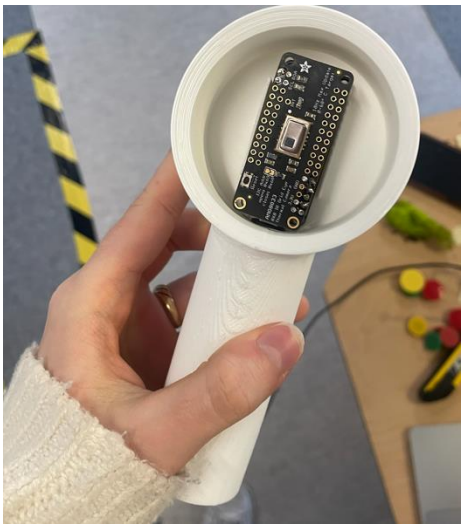


Figure 4: Portable Detector

The remarkable aspect of this portable detector in comparison to the readily available tools is that it can detect mold directly without the need for the use of proxies (e.g. moisture). Additionally, it provides real-time feedback on the type of mold detected in comparison to the test kits available in the market which necessitate the need to be sent for laboratory testing that requires at least a week. It should be noted that the portable detector would be sold to Non-Governmental Organizations (NGOs) to provide them with a tool that allows them to support the search for mold sources if detected in low-income houses. In addition to public establishments, such as schools, hospitals, and jails

Usage:

It is meant to be used by NGOs or Mold removal companies. They will bring the device to the house with mold growth, and to look for the source they will scan the room with the device.

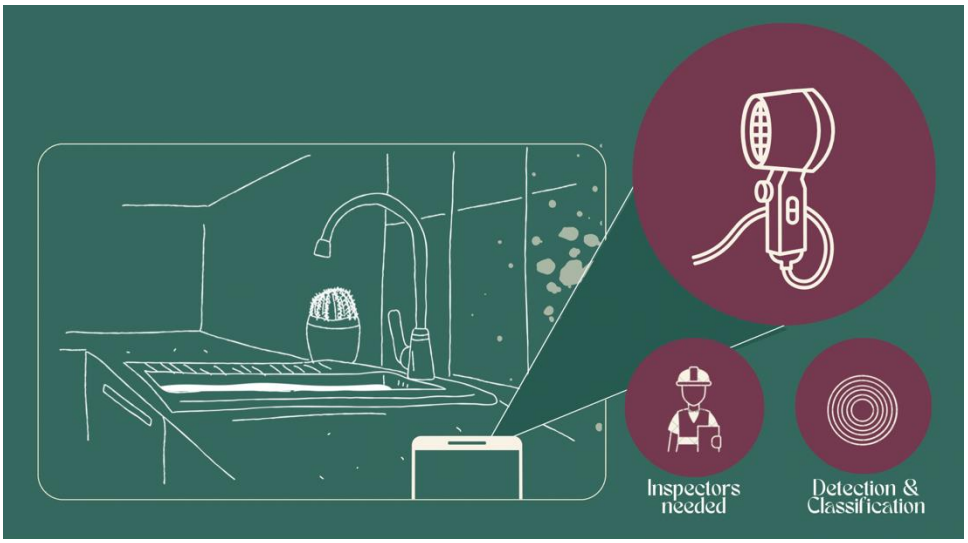


Figure 5: Portable Detector Features

It is a very complete device because it also provides the mold type (thanks to the MSE method explained earlier in the document) and its concrete effects on human health, as well as a precise solution for every type.

Technology:

Since this device acts on the detection part, its main objective is finding the mold source. That is done using the same Raman Spectroscopy technology implemented in the other device. Besides that, the Detector has some added user experience features such as a screen that shows a map of the area it is scanning and visually shows where the mold is located, or an added sound it makes every time mold is detected. This allows for a really comfortable experience, with an intuitive and easy to use device that everyone will understand:

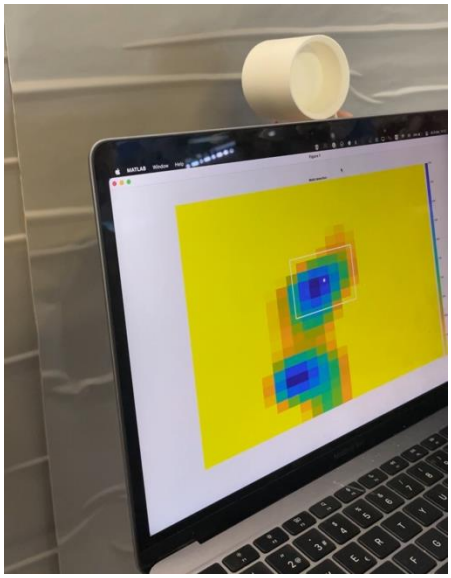


Figure 6: Portable Detector Usage

Impact:

The following are the impacted segments with their respective positive impact:

- **Landlords & Housing associations** that are leasing residents in areas of poverty that are subject to mold infestation in the UK.
    - **Significant decreases in mold removal remedy cost** due to tackling the issue in its early stage. An early detection leads to an expedited spot removal of the mold which costs $500 in comparison to late-stage removal which in some cases costs $30,000 for a 2,000-square-foot Whole-home mold remediation and removal is required.[1]

- **Tenants living in areas of poverty** that are subject to mold infestation in the UK, which include but are not limited to children, the elderly, and people with respiratory issues (e.g. asthma).

[1] Gerhardt, N. (2023, August 21). How much does mold remediation and removal cost? Forbes Home. https://www.forbes.com/home-improvement/home/mold-remediation-removal-costs/

  - In the UK more than 1.6 million children are living in moldy residences[2]. This is alarming due to the major health issues caused by mold, especially the development of asthma, a life-long illness that can develop with long exposure of mold.[3]
- **The UK government**, due to its requirement of regulating the living standard in the housing market as well as resolving landlords-tenants' conflicts.

Market Analysis:

The **smart home devices** market for indoor air quality in the UK is expanding, driven by a growing awareness of health concerns related to poor indoor air and the need for cost-effective solutions. **Tenants** are concerned about their family's health at home, but despite the increased acceptance of smart home devices, they would only accept non-invasive solutions. On the other hand, **Landlords** now face the challenge to provide better housing conditions. After the implementation of Awaab's law in 2022, governments efforts to regulate increased significantly, putting extra pressure on them to provide solutions.

Guardian Air is a unique offering, focusing on preventing mold growth and enhancing air quality in low-income households. Landlords can benefit with cost removal savings, as the early detection system results cost-efficient. Guardian Air also allows for property value enhancement by providing traceability of their properties. Tenants can also feel taken care of as the data collection will allow the government to enforce protective measures in their favor and improve their power relationship with their landlords.

Business Model Canvas:

Customer segment:

- **Landlords & Housing associations**, especially the G15, which is an organization of the largest housing associations in London that collectively are responsible for managing more than 600 thousand homes. This customer segment is used for supplying tenants in poverty with our devices to tackle the mold issue.
- **Financially Capable Tenants**, Guardian Air protects all types of tenants from mold. Therefore, financially capable tenants can be a customer base for our product.

[2] Bancroft, H. (2023, February 25). Revealed: Over 1.6 million children living in moldy damp rental homes. The Independent. https://www.independent.co.uk/news/uk/home-news/mold-damp-homes-awaab-ishak-renting-b2285720.html

[3] Suni, E., & Suni, E. (2023, November 8). Mold in the bedroom. Sleep Foundation. https://www.sleepfoundation.org/bedroom-environment/mold-in-the-bedroom

Value Proposition:

- **Tenants:** Guardian Air allows tenants to detect mold early, leading to faster and easier removal of mold if detected, leading to a significant increase in quality of life through avoiding associated mold health implications, especially to the critical inhabitants which consist of children, elderly, and people with asthma. These health implications include but are not limited to memory loss, poor mental health, fatigue, lung issues, and worst-case scenario death.
- **Landlords & Housing associations:** Guardian Air allows landlords being able to detect mold early, leading to inexpensive and easier removal requirements of mold if detected. Additionally, in the case the mold was detected, the product allows users to locate the mold source. This helps landlords avoid expansive avoidable resident maintenance, especially structural damage, caused by late-stage mold damage.
- **Government:** Guardian Air allows landlords & tenants the ability to document and verify the amount of time taken from which mold was detected till the sensors' s were recalibrated by the landlord. This allows the government agencies to have better and expedited landlords-tenants conflict resolution.

Key Activities:

To reach the aimed outcome value the following key activities need to be accomplished:

- The use of Guardian Air devices.
- Establishing a partnership with a manufacturer & a package delivery service provider.
- Establishing a good relationship with the housing NGOs to pressure landlords to adopt the technology.
- Forming the company and acquiring the necessary human and financial capital.

Key partnerships:

- **UK Government**
    - The Department for Levelling Up, Housing and Communities (DLUHC)
    - Non-Profit Organization
- **Non-Profit Organization**
    - The Joseph Rowntree Foundation
    - Shelter
    - National Housing Federation (NHF)
    - Citizens Advice

- Housing Justice

Revenue Streams:

- **Landlords & Housing Associations:** As the main customers for our products, through outbound selling, as communicating with landlords requires less visits and leads to bulk purchases, which is in contrast to directly visiting each tenant located in an area of poverty. This segment will be communicated through sales visits.
- **Financially capable tenants**: As potential customers for our products. Due to the significant resources required to reach this segment, the main strategy is to keep our products readily available in e-commerce stores (e.g. Amazon). It is worth mentioning that tenants in poverty would be reached mainly through landlords due to their limited financial capability

Cost structure:

- Our main cost driver is the upkeep required for the company staff, especially for the sales team as the yearly average for each salesperson requires €31,500 yearly.
- In terms of capital cost for manufacturing, we don't estimate a requirement allocated for manufacturing as it will be outsourced through a partnership to avoid the need of manufacturing know-how and the costs associated with running a plant. This would allow us to have our products of high quality and the ability to diversify the supply sources for risk mitigation and cost management.

Funding:

- The project is planned to be mainly funded by an investor.
- There is a possibility that the project can be subsidized as the UK government has raised more than £15 million[4] to tackle the mold issue through the Social Housing Quality Fund. Additionally, the UK Housing Secretary's, at the start of 2023, announced a £30 million[5] for Greater Manchester and the West Midlands to improve the quality of social housing in their region.
- Non-profit NGOs can support funding the project as well.

[4] Authority, G. M. C. (n.d.). £15m fund to open for social housing improvements to tackle damp and mold. Greater Manchester Combined Authority. https://www.greatermanchester-ca.gov.uk/news/15m-fund-to-open-for-social-housing-improvements-to-tackle-damp-and-mold/

[5] Department for Levelling Up, Housing and Communities. (2023, January 25). Levelling Up Secretary's speech to the Convention of the North. GOV.UK. https://www.gov.uk/government/speeches/levelling-up-secretarys-speech-to-the-convention-of-the-north#:~:text=So%20today%20we%20are%20going,course%2C%20one%20of%20multiple%20missions.

Prototype:

For the prototyping process, we followed an iterative approach, considering the insights given by the coaches. At the first stage, we performed a hybrid-brainstorming to come up with the largest possible number of solutions to the mold problem for our target users.

To refine and converge our ideas to better tackle the challenge, we clearly identified the “must have” and “nice to have” features, allowing us to simplify and combine our ideas.

Figure 7: Ideation process.

This allowed us to experiment with better-refined versions through a “build-break-fix” exercise, where all the team members contributed to the first version of our two solutions. This was complemented by the use of generative AI tools to better represent the perspective and materials of our proposed solutions.

Figure 8: Home detector and screen for tenant instructions.

Figure 9: Scanning Gun

After having visualized a first solution, we created an assumption map, clearly indicating what things needed to happen in order for the prototypes to succeed. The aim of this process was to clarify what to validate with the relevant stakeholders during showcase interviews.

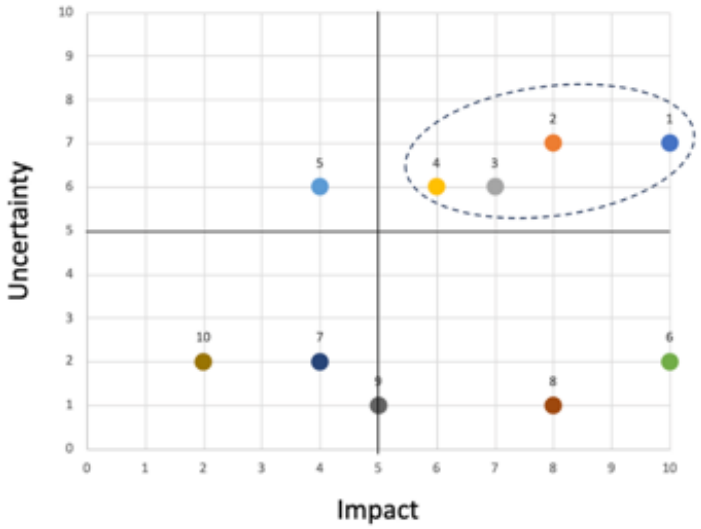


Figure 10: Assumption Map

After receiving feedback and validating our assumptions we learned that some of the initial assumptions were incorrect. First, the “real-time” monitoring of the home device was felt as intrusive, giving pushback from the tenants in its adoption. Second, the screen with “user friendly” indications on how to prevent the mold growth failed to shift the balance of power, putting extra pressure and responsibility on the tenant. As they have busy and hectic lifestyles, they should not be the ones responsible for the prevention of mold. However, the sound feedback of the device still is perceived as positive feedback of the correct working of the device. Third, despite we explored the potential combination of both devices, the at home and the searching gun, we discovered that this was not feasible due to the increased cost associated with precision Raman spectroscopy and the possibility of tempering the scanning by removing the device from the assigned home.

1. **Mold Monitor:** A tool for mold early detection, through installing sensors in the residence that evaluate the rooms' temperature and humidity if the mold cultivating environment was reached. In the case that a room had a high probability of mold being detected, the tenants would be alerted through a flashing light, and a simple fixed solution would be presented on the portable screen to amend the current room environment.

2. **Portable Detector:** A tool for locating the mold source, if mold was detected, to apply the necessary fix to the mold source. The tool will utilize the Raman scattering technology used in Pipe 4.0 which will be used for locating the source by assessing the area with the highest concentration of mold as well as the mold type.

Proof of concept:

To showcase the practical utility of our planned devices, we have created two mock-ups. Our aim is to offer a hands-on experience of how these devices will be utilized. To fulfill this objective, we meticulously designed them specifically for demonstration purposes.

1. Mold Monitor

The purpose of this device is to provide continuous information about the environmental conditions of the location. That's why it features three LED strips that illuminate with different colors depending on whether the conditions are unfavorable or not. The device is programmed with a simulation that can be remotely executed from a computer. This simulation demonstrates how the LEDs would behave in two different scenarios:

- Favorable Conditions for Mold Growth:

  The LED strips indicating these conditions would light up in more aggressive colors.

  The alarm LED would flash in orange until the conditions return to normal.

- Simulation of Mold Spore Detection:

  In the case of detecting a mold spore, the alarm LED would flash in intense red.

  When both conditions are restored to a healthy state, the alarm LED turns green.

Inside, an Arduino is opening a telnet server for communication via Wi-Fi. It controls 3 Adressable Neo Pixel LED Stripes. Code is annexed.

2. Portable Detector

The case is made with 3D printing to get the desired shape. For the user experience features a microcontroller was added to the device to act as a thermometer. The demonstration of how the device would work is done hiding a heat-delivering resistor behind a fake wall connected to a battery. The device with the embedded thermometer would then scan the wall and its temperature. We created a code so that

the read values are shown on a map. The resistor would show up on the map acting as if it was the mold. Code is annexed.

Reflection of Learning:

- Some ideas might not be executable in the current time frame due to some limitations. Nevertheless, being prepared for technological advances allows us to find their respective use applications.
- Whenever one is designing a tool to be used by people, it should be non-invasive, comfortable and easy to use, and it should align seamlessly with the user's daily routine.
- To ensure project progress in a multidisciplinary team, each member should provide their unique perspective in accordance with their expertise. The time given to each member should be respected, as otherwise members might go out of the project scope which might lead to delays.
- Some consideration should be taken in order to implement the technologies in public spaces, such as public housing, jails, schools or hospitals, so as to help the most vulnerable communities.

Thank You!

We really appreciate your coaching and passion

- Team 4

ANNEX

Mold Monitor Code:

```
#include <Adafruit_NeoPixel.h>
#include "globals.h"
#include "buzzer.h"
#include "comm.h"
```

```
Adafruit_NeoPixel humPixels = Adafruit_NeoPixel(15, 3, NEO_GRB +
NEO_KHZ800);
Adafruit_NeoPixel tempPixels = Adafruit_NeoPixel(15, 4, NEO_GRB +
NEO_KHZ800);
Adafruit_NeoPixel moldPixels = Adafruit_NeoPixel(15, 5, NEO_GRB +
NEO_KHZ800);

int32_t tl = tempPixels.Color(255,10,10);
int32_t tm = tempPixels.Color(255,5,5);
int32_t th = tempPixels.Color(255,0,0);
int32_t temp_color[15] = {tl,tl,tl,tl,tl,tl,tl,tl,tl,tm,tm,th,th,th,th};
int32_t hl = humPixels.Color(80,80,255);
int32_t hm = humPixels.Color(30,30,255);
int32_t hh = humPixels.Color(0,0,255);
int32_t hum_color[15] = {hl,hl,hl,hl,hl,hl,hl,hl,hl,hm,hm,hh,hh,hh,hh};
int32_t mold_color = moldPixels.Color(255, 160, 0);
int32_t green_color = moldPixels.Color(0, 255, 0);
int32_t red_color = moldPixels.Color(255, 0, 0);
int32_t no_color = moldPixels.Color(0, 0, 0);
bool buzzing = false;
String commandd = "";

void setup() {
  Serial.begin(9600);
  humPixels.begin();
  tempPixels.begin();
  moldPixels.begin();

  tempPixels.clear();
  for(int pixel=0; pixel<5; pixel++){tempPixels.setPixelColor(pixel,
temp_color[pixel]);}
  tempPixels.show();
  humPixels.clear();
  for(int pixel=0; pixel<5; pixel++){humPixels.setPixelColor(pixel,
hum_color[pixel]);}
  humPixels.show();
  setup_buzzer();
  setup_comm();
  alarm_freq(3000, 100);
}
  void loop() {
  delay(100);
  commandd = rcv_command();
  if (commandd == "cond") {
    Serial.print("Command received: ");
    Serial.println(commandd);
    theatre_cond();
```

```
  }
  if (commandd == "mold") {
    Serial.print("Command received: ");
    Serial.println(commandd);
    theatre_mold();
  }
  commandd = "";
}
void theatre_cond(){
  tempPixels.begin();
  humPixels.begin();
  tempPixels.clear();
  for(int pixel=0; pixel<5; pixel++){tempPixels.setPixelColor(pixel,
temp_color[pixel]);}
  tempPixels.show();
  humPixels.clear();
  for(int pixel=0; pixel<5; pixel++){humPixels.setPixelColor(pixel,
hum_color[pixel]);}
  humPixels.show();
  Serial.println("Rising temp");
  for(int pixel=4; pixel<13; pixel++){
    tempPixels.setPixelColor(pixel, temp_color[pixel]);
    tempPixels.show();
    delay(int(1000));
  }
  Serial.println("Rising hum");
  for(int pixel=4; pixel<13; pixel++){
    humPixels.setPixelColor(pixel, hum_color[pixel]);
    humPixels.show();
    delay(int(1000));
  }

  Serial.println("Buzzing");
  moldPixels.begin();
  while(rcv_command() != "stop"){
    moldPixels.fill(mold_color, 0, 15);
    moldPixels.show();
    alarm_freq(1200, 200);
    moldPixels.clear();
    moldPixels.show();
    delay(200);
  }
  moldPixels.fill(mold_color, 0, 15);
  moldPixels.show();
  Serial.println("Lowering temp");
  for(int pixel=13; pixel>4; pixel--){
    tempPixels.setPixelColor(pixel, no_color);
    tempPixels.show();
```

```
    delay(int(1000));
  }
  Serial.println("Lowering hum");
  for(int pixel=13; pixel>4; pixel--){
    humPixels.setPixelColor(pixel, no_color);
    humPixels.show();
    delay(int(1000));
  }
  moldPixels.clear();
  moldPixels.show();
  alarm_freq(2000, 200);
  moldPixels.fill(green_color, 0, 15);
  moldPixels.show();
  delay(200);
  moldPixels.clear();
  moldPixels.show();
  alarm_freq(2000, 200);
  moldPixels.fill(green_color, 0, 15);
  moldPixels.show();
  delay(200);
  moldPixels.clear();
  moldPixels.show();
  alarm_freq(2000, 200);
}

void theatre_mold(){
  moldPixels.begin();
  while(rcv_command() != "stop"){
    moldPixels.fill(red_color, 0, 15);
    moldPixels.show();
    delay(200);
    moldPixels.clear();
    moldPixels.show();
    delay(200);
  }
  moldPixels.clear();
  moldPixels.show();
  alarm_freq(2000, 200);
  moldPixels.fill(green_color, 0, 15);
  moldPixels.show();
  delay(200);
  moldPixels.clear();
  moldPixels.show();
  alarm_freq(2000, 200);
  moldPixels.fill(green_color, 0, 15);
  moldPixels.show();
  delay(200);
  moldPixels.clear();
```

```
  moldPixels.show();
  alarm_freq(2000, 200);
}
```

```
#include <SPI.h>
#include <WiFiNINA.h>
#include <Adafruit_NeoPixel.h>
#include <iostream>
#include <cctype>

// Commands
#define NONE 0
#define H_TEMP 1
#define H_HUM 2
#define REC_TEMP 3
#define REC_HUM 4
#define CLEAN 5

// Wifi conf
int status = WL_IDLE_STATUS;
int ledState = LOW;                          //ledState used to set the LED
unsigned long previousMillisInfo = 0;        //will store last time Wi-Fi
information was updated
unsigned long previousMillisLED = 0;         // will store the last time LED
was updated
const int intervalInfo = 5000;

char ssid[] = "CERN";                 // your network SSID (name)
char pass[] = "";                  // your network password (use for WPA, or
use as key for WEP)

WiFiServer server(23);
boolean alreadyConnected = false; // whether or not the client was
connected previously

String currentCommand = "";
String command = "";

void printWifiStatus() {
  Serial.print("SSID: ");
  Serial.println(WiFi.SSID());
  IPAddress ip = WiFi.localIP();
  Serial.print("IP Address: ");
  Serial.println(ip);
  long rssi = WiFi.RSSI();
  Serial.print("signal strength (RSSI):");
  Serial.print(rssi);
  Serial.println(" dBm");
```

```
}


void setup_comm() {
  if (WiFi.status() == WL_NO_MODULE) {
    Serial.println("Communication with WiFi module failed!");
    while (true);
  }

  if (WiFi.firmwareVersion() < WIFI_FIRMWARE_LATEST_VERSION)
{Serial.println("Please upgrade the firmware");}

  while (status != WL_CONNECTED) {
    Serial.print("Attempting to connect to SSID: ");
    Serial.println(ssid);
    status = WiFi.begin(ssid);
    delay(5000);

  }
  server.begin();
  printWifiStatus();
}

String rcv_command(){
  WiFiClient client = server.available();
  if (client) {
    if (!alreadyConnected) {
      client.flush();
      Serial.println("We have a new client");
      client.println("Hello, Press Enter to start!");
      alreadyConnected = true;
    }

    if (client.available() > 0) {
      char thisChar = client.read();
      if (thisChar == '\n'){
        command = currentCommand;
        if(command.length()>1){
          command.remove(command.length()-1);
        }
        currentCommand = "";
        return command;
      }
      currentCommand += thisChar;
      //server.write(thisChar);
    }
  }
  return "";
```

```
}
#include <arduino.h>

void alarm_freq(int freq, int delays){
  tone(8, freq, delays);
  delay(delays);
}

void setup_buzzer(){
  pinMode(8, OUTPUT);
  alarm_freq(1500, 100);
}
```

Portable Detector Code:

```
clear all;
delete(instrfindall); %% we delete old instances to avoid errors
serial_Port = serial('/dev/tty.usbmodem11101', 'terminator', ','); %%camera
connection
fopen(serial_Port);
position = 1;
closed = true;
sumCol = 0;
numIt = 10;
i = 0;
clims = [2500, 3000]; %% limits of temperature of the colour map (x100)
% Load a sound file
[ooo, Fs] =
audioread('/Users/marinapuigdemuntschmolling/Documents/mono.wav');
% Create a full-screen figure
hFig = figure('units','normalized','outerposition',[0 0 1 1]);
hAx = axes('Parent', hFig);
set(hFig, 'MenuBar', 'none', 'ToolBar', 'none');
while(1)
```

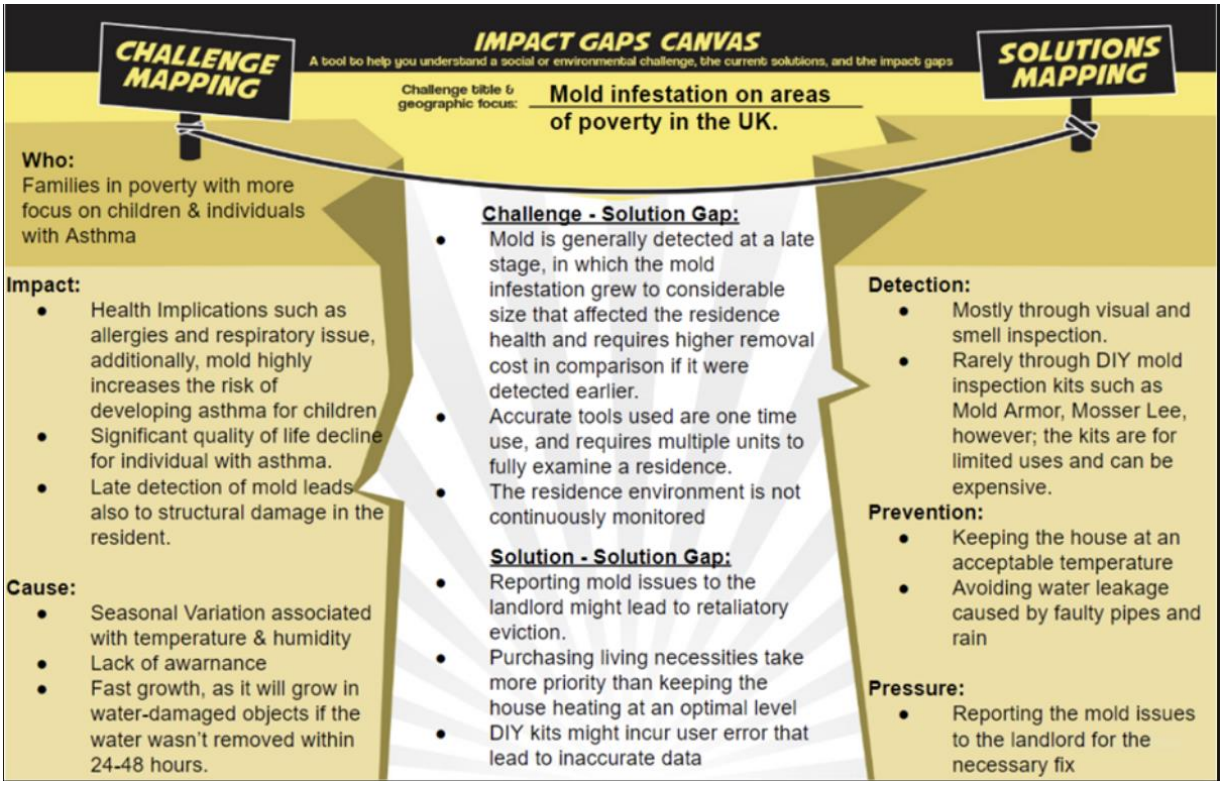
```
flushinput(serial_Port); %% we delete possible buffer samples
r = fscanf(serial_Port);
t = str2num(r);
si = size(t);
if(si(2) == 64) %% if the vector is well read
i = i + 1;
A = reshape(t,[], 8); %%Matrix-shape
```

```
A = imresize(A, 3); %%interpolation
h = [1 1 1; 1 2 1; 1 1 1]; %%filter to detect hot spots zone
y = conv2(A, h);
locations = ismember(y, max(max(y))); %% find the max spots
locations = locations(2:end-1, 2:end-1); %% remove the convolution edges
[row, col] = find(locations); %%find the row and col of the max spots
imagesc(flipud(rot90(A)), clims) %% plot the image
title('Mold detection')
colormap(flipud(parula)); % Set the colormap to parula and flip it
colorbar
shading interp
axis off
hold on
plot(col, row, 'w*', 'LineWidth', 2, 'MarkerSize', 10) %plot a star where the hot zone
max is.
sumCol = sumCol + col(1);
if i == numIt % average some samples to avoid noisy movements.
% Also to avoid sudden movements
if max(max(y)) > 26000 % empirical-found threshold
if ((sumCol/numIt > 14 && position == 2) || closed == true)
fprintf('position 1 ');
% Play the sound when the threshold is met
```

```
sound(ooo, Fs);
position = 1;
% Display the 'hello' message in full-screen
% Display message if condition is met
message = 'Stachybotrys chartarum found';
% Increase the font size
fontSize = 26;
% Display the message for 50 iterations
for i = 1:2
text(5, 8, message, 'FontSize', fontSize, 'Color', 'red');
pause(0.01); % Pause for a short duration between iterations
drawnow; % Update the figure
end
elseif sumCol/numIt < 8 && position == 1 && closed == false
fprintf('position 2 ');
% Play the sound when the threshold is met
sound(ooo, Fs);
position = 2;
% Display the 'hello' message in full-screen
% Display message if condition is met
message = 'Stachybotrys chartarum found';
% Increase the font size
fontSize = 26;
% Display the message for 50 iterations
for i = 1:20
text(5, 8, message, 'FontSize', fontSize, 'Color', 'red');
pause(0.01); % Pause for a short duration between iterations
drawnow; % Update the figure
end
end
```

```
closed = false;
else
closed = true;
end
i = 0;
sumCol = 0;
end
lengthRec = 6;
rectangle('Position',[col(1)-lengthRec/2 row(1)-lengthRec/2 lengthRec lengthRec],
'EdgeColor','w', 'LineWidth', 3) %we draw a rectangle centred in the hot spot to
better visualization
end
pause(0.01); %% let the computer breath
end
```

Impact GAP Analysis:



Impact Model Canvas: