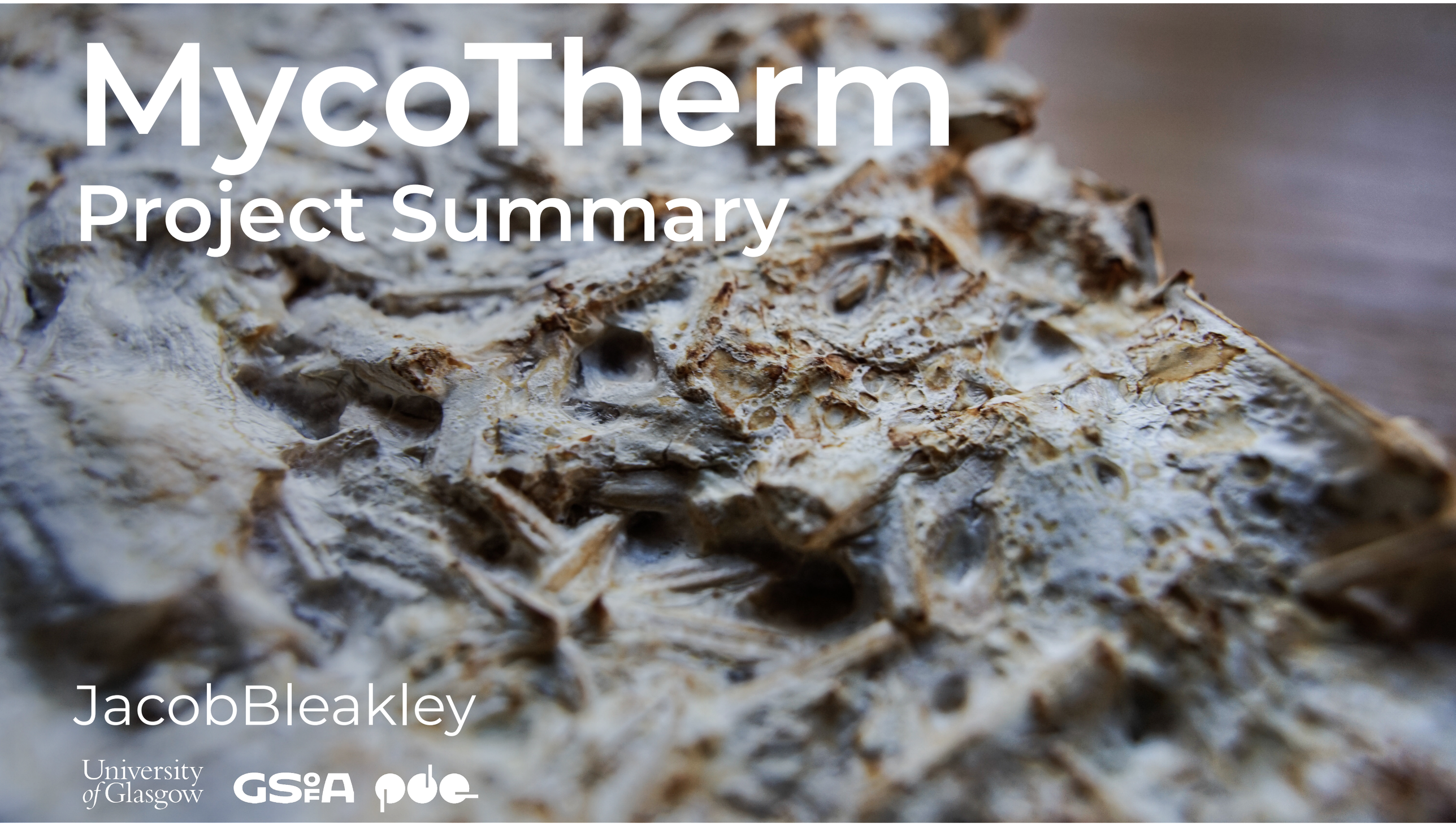
MycoTherm
Project Summary



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The Product

MycoTherm is a foam board insulation panel that is not just produced, but grown.

MycoTherm has been designed for pre-1930s buildings in Scotland that have been built with sandstone or limestone walls. These buildings were made in such a way that ventilation was not needed to be additionally installed because the stone walls were naturally breathable, absorbing moisture in the wet months and releasing it in the dry months.

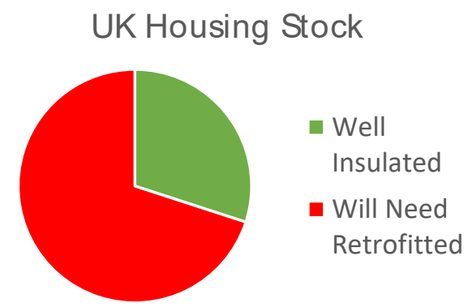
The product is installed much like rock wool insulation except that the boards have more rigidity and a more defined volume. This makes them suitable for spaces where gaps need to exist for ventilation such as underneath roof tiles.

To fit the material, a timber frame is built and secured to the wall, with a 60cm horizontal gap needed between wooden studs. The material will be manufactured to be 61cm so that when compressed, the outward force secures it in place. Another advantage to using a compression fit is that sealing tape is not necessary to cover the seals because the compression fit will close any gaps automatically.

At the end of life, the MycoTherm can be thrown in a compost heap and will be largely bio-degraded within 40 days.

The Problem

It is estimated that 70% of the UK housing stock will need to be retrofitted to meet the UK government's net zero carbon emissions target. With 260,000 of those estimated houses situated in Scotland alone, the retrofit sector is expected to be in high demand.



The largest portion of these buildings are pre-1930s sandstone and limestone buildings and therefore a breathable insulation is required. The default insulation for the companies I spoke to is rock wool. This causes issues because it irritates the hands, its fibres get lodged in human airways if PPE is not worn, and it is susceptible to becoming saturated with moisture in high relative humidity environments.

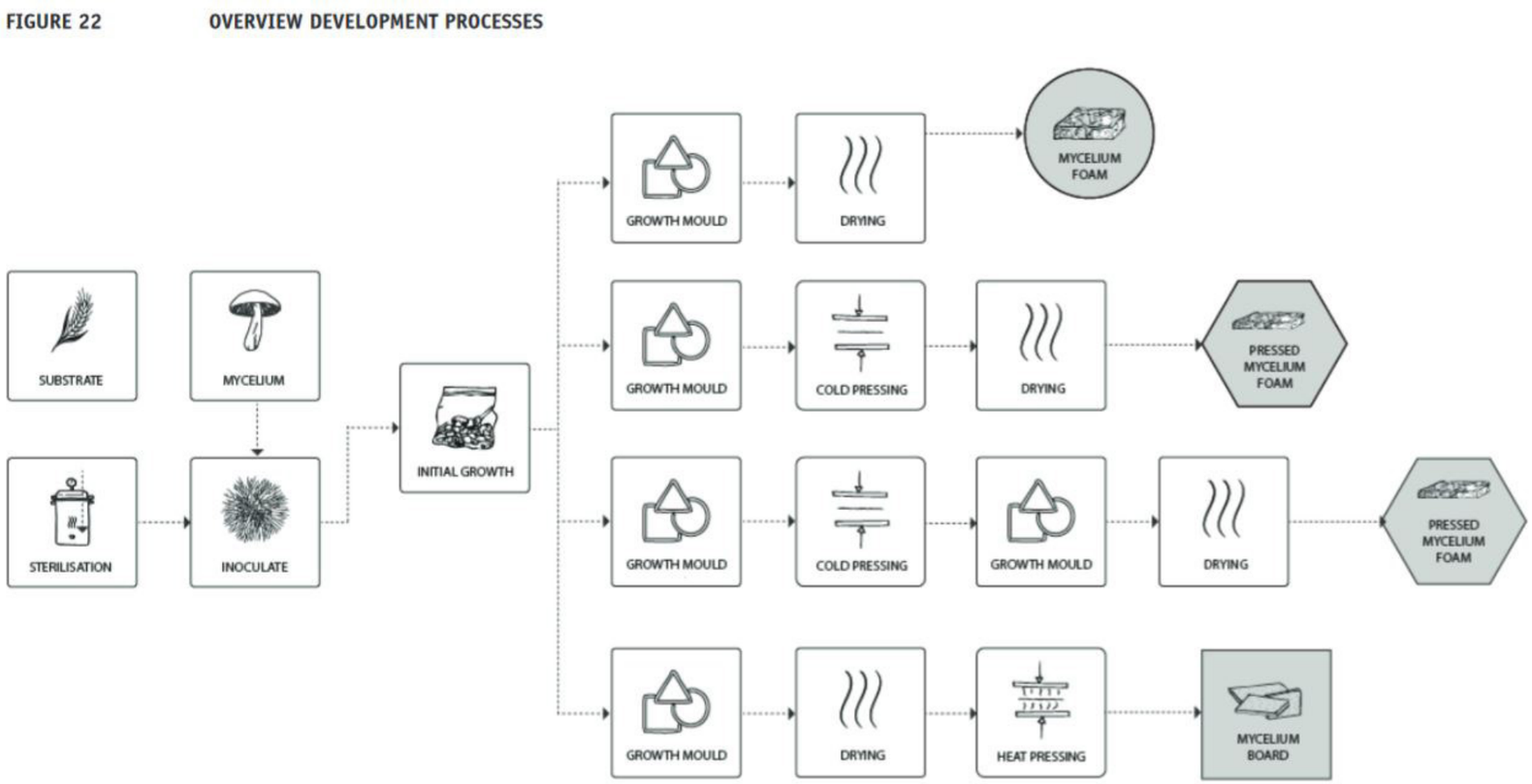
The other most common type of insulation is synthetic foam board insulation. This is not breathable and a vapour barrier must therefore be used to stop mold and decay. Because it is not breathable, natural ventilation of the building is limited and and mechanical ventilations therefore need to be installed. Other issues surrounding this type of insulation are:

- **Derived from petrochemicals**
- **Off-gases toxic volatile organic compounds (VOCs)**
- **Must be taped to prevent heat bridging**

The Material

While I have been proactive in learning about the system design of insulation, the majority of this project has been material research and development. I began by following the mushroom growing community online and reading as many relevant research papers as possible.

I found that different types of material can be created from mycelium, and this depends largely on how it has been processed.



The diagram above was taken from a study on mycelium by a Dutch water processing company called STOWA. The figure illustrates effectively how post treatment of the material can alter the type of material created.

I opted to refrain from pressing my samples and instead only heat them for an extended period of time in the oven to kill and dry the mycelium. While pressing or heat pressing the material makes it more homogeneous and stiff, it reduces the amount of air gaps inside the matrix which increases thermal conductivity, making it an inferior insulator.

Expert Insights

Underfloor Insulation Glasgow Director

- Rock wool insulation is horrible to work with because it irritates the skin. This means that many workers will not put it back in place properly after carrying out maintenance in the wall such as fixing an electrical problem.
- Lofts are the most difficult to insulate because there is limited space and a rigid board is needed to ensure a 50mm gap between the insulation and roof felt for ventilation.

EcoSave Sales Director

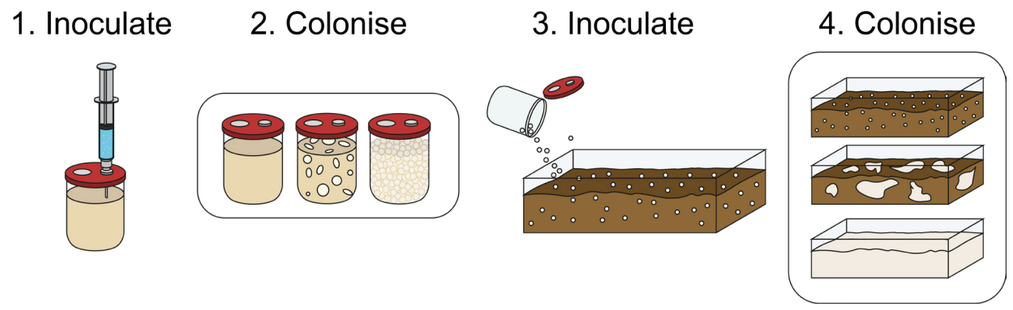
- Insulation goes hand in hand with ventilation. The type of insulation used depends entirely on what kind of building it is being installed on.
- Closed-cell insulation such as synthetic foam boards are not breathable and are therefore not suitable for old Scottish sandstone buildings.
- Rock wool is considered breathable but if exposed to high humidity it can become saturated, holding on to too much moisture, conducting more heat and therefore becoming useless.
- Sealing foam boards is time consuming and therefore costs money.
- Moisture content in wooden frame for insulations should not reach above 18%
- Compression fitting insulation is much more useful than needed to nail it in and tape it up such as with foam board.

MEARU Researcher

- A breathable building fabric must be implemented in old Scottish buildings to avoid mould growth.
- The mycelium should not be too thick so that the relative humidity between the wall and the insulation does not fall below the dew point. This will result in interstitial condensation, causing mold and decay.
- When asking for advice on my system design, she told me a moisture barrier was not needed and recommended fermocell and lime plaster to ensure the system design was breathable and sustainable.

Method

The growth of mycelium is most easily done in two stages. The first stage involves colonising a small volume of substrate by inoculating it with a mycelium liquid culture syringe and the second stage involves colonising a larger amount of substrate using the mycelium *spawn* to inoculate it. Each stage can be conducted with different substrates and additives depending on desired results. My tests were broken into spawn experiments and bulk experiments.



Sterilise Spawn Substrate

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Inoculate Spawn Substrate

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Wait for Spawn Substrate to Colonise

↓

Pasteurise Bulk Substrate

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Use Spawn Substrate to Inoculate a Larger Volume of Substrate

↓

Wait for Spawn Substrate to Colonise

↓

Kill and Dry Mycelium by Applying Heat

Experiments

Experiments throughout this project were designed to optimise the growth speed of mycelium with consideration for mass production, while also trying to achieve properties for a good insulation material.

- Comparison experiments were conducted as well as factorial experiments to explore how different additives, substrates and fungus species contributed to the growth speed and the quality of the finished material.

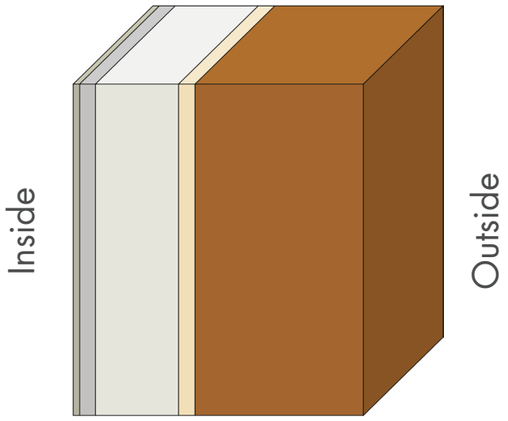
- Because of the eco-credentials, pest resistance, low thermal conductivity and sustainable farming, hemp was found to be the best substrate for MycoTherm. When testing fungus species, it was found that a species called Turkey Tail out-performed the others significantly leading me to believe that it is the best choice for commercial production.

- In spawn experiments I found that using rye grains as the substrate and adding gypsum significantly reduced the time until full colonisation.

- In Bulk experiments I found that the addition of sugar in the form of honey did not yield the fastest growth, but did contribute to increased thermal conductivity.

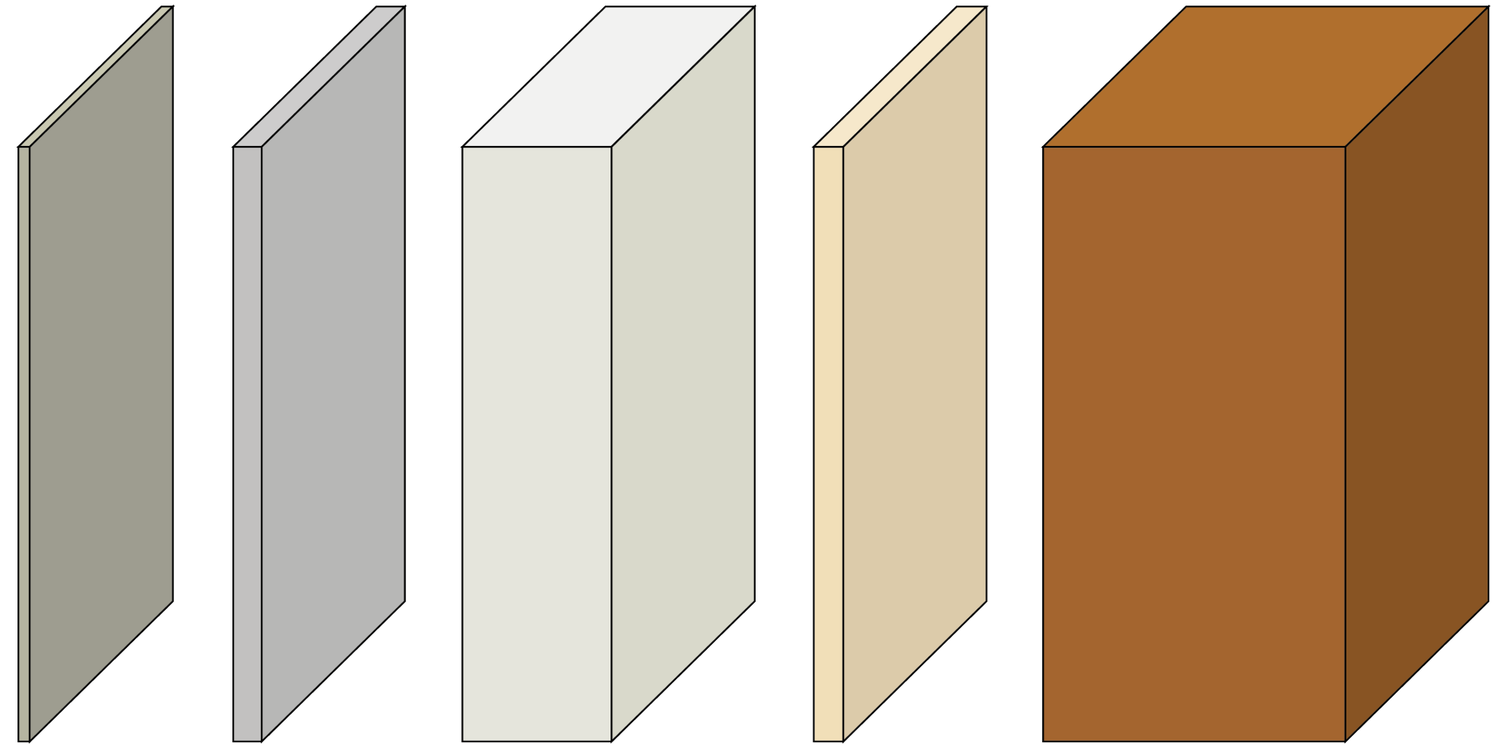
Because the aim of this project was focused around insulation, I wanted to obtain accurate thermal conductivity values of my grown samples. This was not possible because of no access to the special technology required. I was able to establish a relationship between the materials and the thermal conductivity, comparing samples with one another. However, for the purpose of calculating thickness for MycoTherm, I used a value of thermal conductivity achieved by a company currently developing and creating mycelium-based insulation solutions.

MycoTherm System Design



The MycoTherm system design is made entirely of natural materials and has been put together with sustainability in mind. The MycoTherm insulation panels work in tandem with other sustainable products to make a clean, warm, breathable section of wall.

Component	Thermal Conductivity	Thickness (mm)	U-Value
Fermocell	0.32	10	32
MycoTherm	0.024	65	0.37
Lime Plaster	0.73	6	121.7
Sandstone Wall	0.608	225	1.5



For new installation fits and retrofits, the current standard is to achieve a U-value below 0.3 $W/m^2 \cdot K$. Using data online and equations to derive the U-value from thickness and thermal conductivity, it was found that only 65mm of mycelium insulation is needed in this system design to achieve a U value of 0.29 $W/m^2 \cdot K$.

Large Scale Production

1. Sterilise a spawn bags with a large pressure cooker

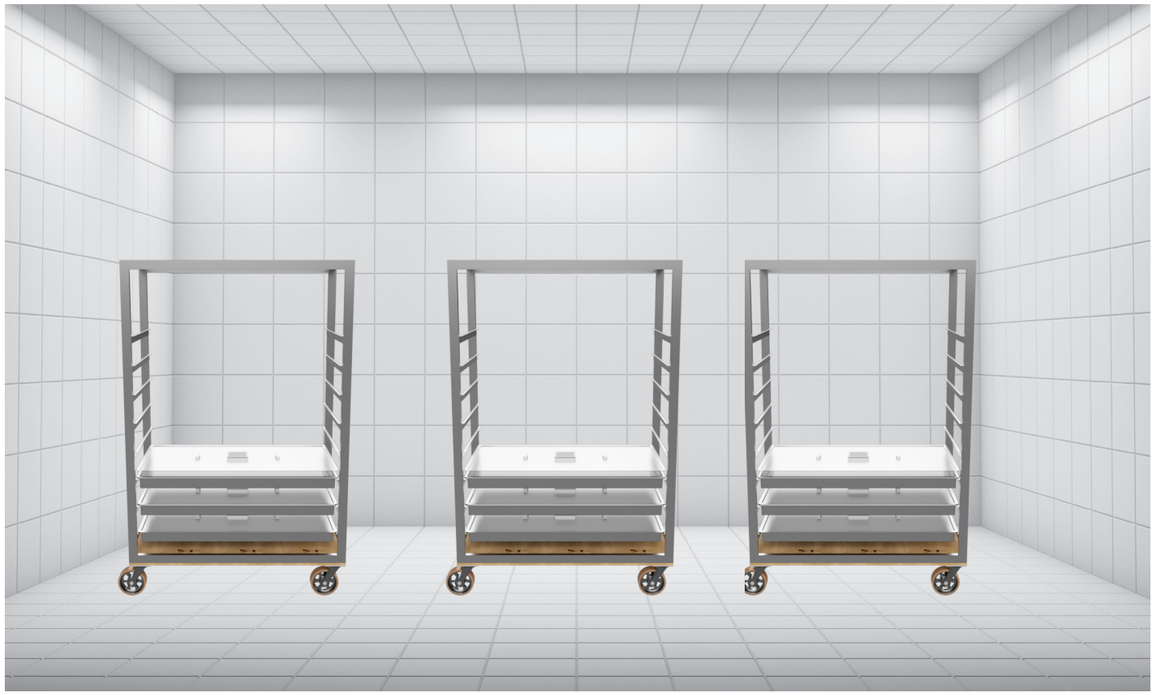
2. Using a laminar flow hood, inoculate the spawn with liquid solution

3. Once sterilised, place the grow bags in a grow room clean air flow, a steady humidity and temperature of around 27%, and wait for full colonisation

Large Scale Production

4. Place the bulk substrate in a porous bag such as a burlap sack.

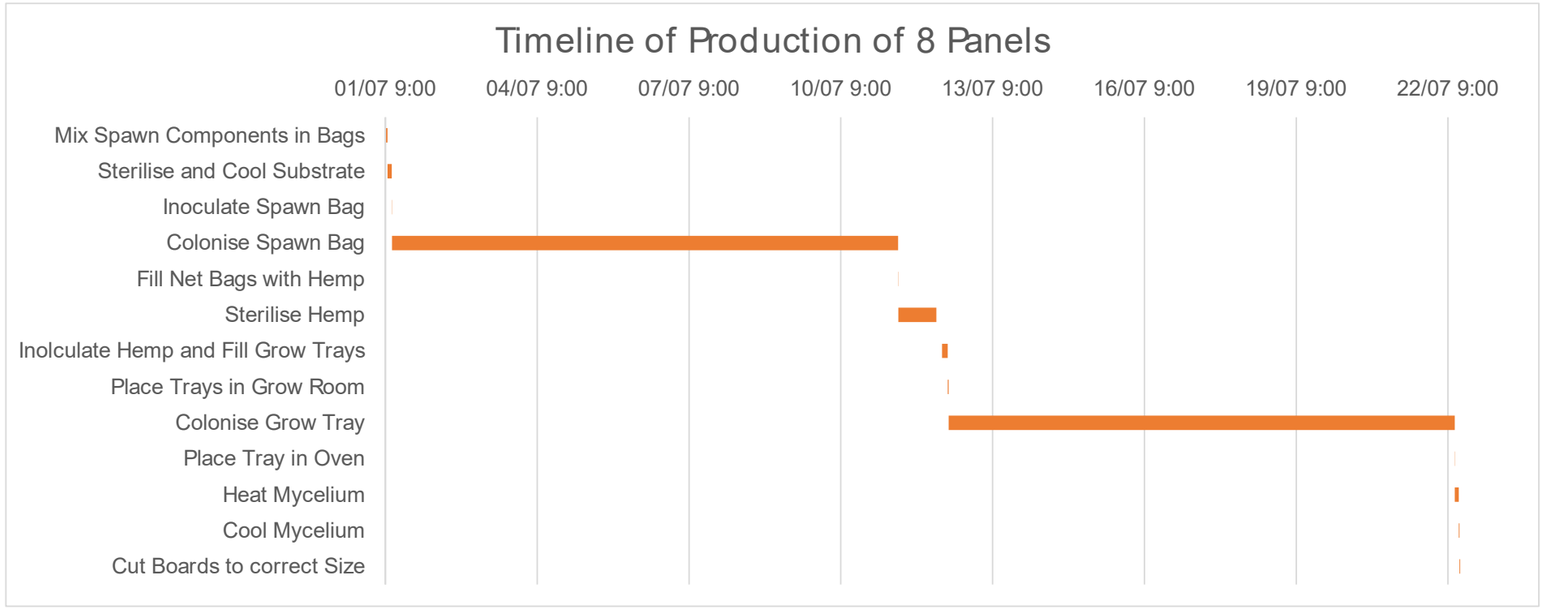
5. Pasteurise the substrate by leaving it soaked in a 0.2% lime solution. The high PH level kills unwanted microbes.



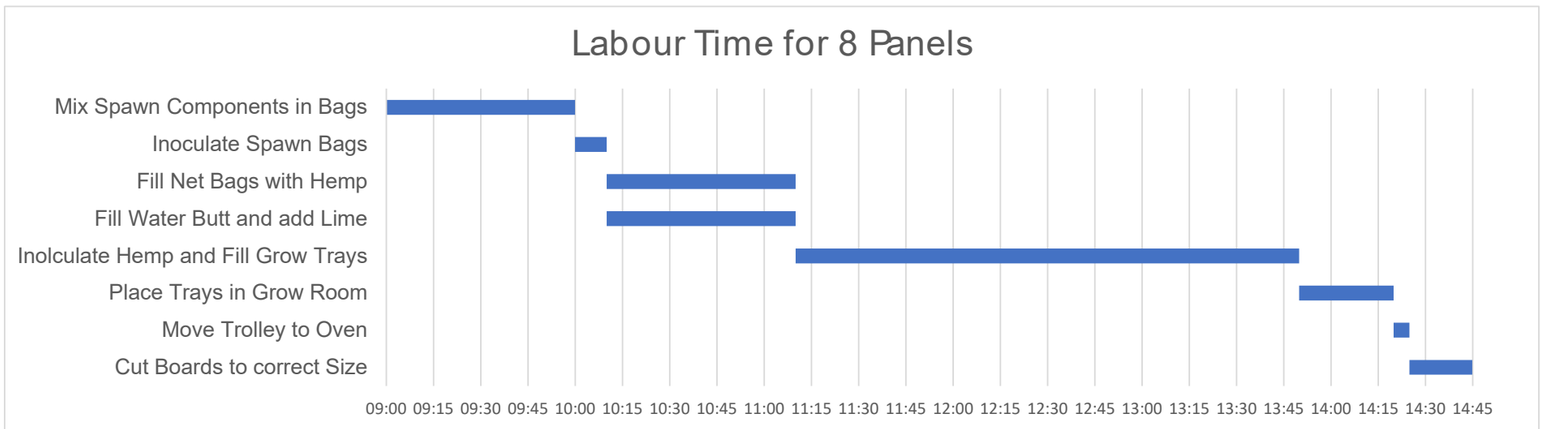
6. Mix the pateurised substrate with the spawn, fill the trays and place them on trolleys in a grow room using an electric pallet lifter.

7. Once fully colonised, place the mycelium in a drying oven to kill and dry the living organism.

Large Scale Production



The first figure shows the total production time for one trolley of 8 MycoTherm panels. The longest stages of production do not involve labour since there are long growth times.



The second figure shows only production stages requiring labour. I found that if one employee makes 8 panels concurrently, then the total labour should add up to around 6 hours.

If a worker is paid £10/hour, then the total labour cost going into each panel will be approximately £7.50.

Further Development

- To explore MycoTherm opportunities further, I would like to explore growth conditions such as carbon dioxide concentration, commercially available mushroom growing supplements and different sized hemps shivs.

- Investigating commercial waste streams would be beneficial, reducing costs and paving the way for circular economy business model. This could be cellulose from water treatment or coffee grounds from hospitality businesses.

- An avenue that I wish I had explored is to use spent mycelium from mushroom farms to create mycelium bio-materials. This would remove the need for the initial mycelium growing stage which takes 10+ days. If the spent mycelium is viable for further growth, then this might be a promising avenue for the myclelium material industry. This may also be beneficial for farmers who have limited resources to get rid of old mycelium.

- Due to the nature of how mycelium grows, another avenue that I would like to explore is the used of custom moulds to grow mycelium insulation for bespoke buildings with irregular shapes. The creation of these moulds could be done with relative ease, and would present new possibilities for what insulation could look like and possibly change our perception of insulation as something inherently practical to something that can also hold sculptural beauty.