



**Ag.**

**Lab.**

*On-farm production of building insulation  
from crop residues*

# Ag.Lab.

*On-farm production of building insulation  
from crop residues*



Loretta Bosence, Ben Bosence, Dr Caroline Nye,  
and Professor Matt Lobley

February 2026



Local Works Studio

<b>Contents</b>		<i>page</i>	<i>page</i>
<b>1. Introduction</b>	<b>4</b>	4.8 Economics and Diversification	30
<b>2. Research problem and objectives</b>	<b>6</b>	4.9 Education and Collaboration	32
<b>3. Research methods</b>	<b>8</b>	4.10 Change	34
3.1 Partnerships and Dialogue	8	4.11 Policy	36
3.2 Material and Block Prototyping	9		
3.3 Development of a Manufacturing System	10		
3.4 Legacy Considerations	10		
<b>4. Findings</b>	<b>11</b>	<b>5. Implications of research findings</b>	<b>38</b>
4.1 Growing Crops and Plant Material	11	5.1 Research problem	38
4.2 Harvesting and Machinery	12	5.2 Fitting into the farm Harvest	38
4.3 Drying, Shredding and Storage of Plant Material	15	5.3 Fitting into the farm Manufacturing	42
4.4 Material Testing	18	5.4 Fitting into the farm Labour	43
4.5 Fabrication	20	5.5 Knowledge and training	48
4.6 Recruitment, Labour and Mechanisation	23	5.6 Rural worker housing and building	49
4.6.1 Full-time farming staff	24	5.7 Economic viability	49
4.6.2 Seasonal workers	24	5.8 Unexpected findings and opportunities	50
4.6.3 Domestic workers	25	5.9 Limitations of research	51
4.6.4 The shift towards mechanisation	26	5.10 Recommendations for further research	52
4.6.5 Block making work	27		
4.6.6 'Good work' and conditions	28	<b>6. Summary of key findings</b>	<b>53</b>
4.7 Accommodation and buildings	28	<b>5. Conclusion</b>	<b>54</b>
		<b>6. References</b>	<b>56</b>
		<b>7. Acknowledgments and credits</b>	<b>57</b>

# Introduction



English country brick making - Nicholas Condry. 1847

'Farming and brick making have always gone together, very traditionally. A lot of farms made bricks [...] in the winter and then dried them through the summer' (F7)

Ag. Lab. was the abbreviation used to describe an Agricultural Labourer in the UK census record, first used in 1841. In the context of this project the term refers more broadly to the human efforts, of all kinds, involved in bringing crops to harvest, but also to the potential for agriculture to be a vital laboratory for innovation.

## 1.1. Context

The construction industry faces the impending challenge of how to reduce its reliance on high-carbon, resource-intensive materials such as concrete, steel and fired bricks, and to limit the destructive impacts of their extraction. This is the case not only in the UK and Europe but globally (Ahmad et al, 2025; Sangmesh et al, 2023). In response to the urgent need for sustainable alternatives, it is anticipated that attention will increasingly turn to agriculture (Göswein et al, 2022; Balador, 2024). Crops and agricultural by-products, which have historically been used as constituents in traditional building materials, in the contemporary climate, are becoming a viable sustainable substitute for high-energy mineral and petro-chemical insulation products. Insulating building blocks, panels and bulk aggregates made from plants have the potential to reduce environmental damage and embodied carbon associated with construction. Although plant-fibre insulation currently comprises just 1% of the market share for UK insulation (AMA Research, 2021), production in Europe is expanding rapidly.

## 1.2. Plant-based insulation

Plant-based insulation is a sustainable building material made from the natural fibres of plants, like hemp and straw. These materials are used to insulate buildings for thermal and acoustic purposes, providing a sustainable, non-toxic alternative to conventional insulation like Rockwool (mineral fiberglass) or Celotex (plastic PIR foam). Plant-based insulation offers benefits such as: low embodied energy; carbon sequestration; potential for local fabrication; non-toxic properties; (when combined with natural mineral binders) fire resistance; and improvement to end-of-building-life options in deconstruction. Plant-based insulation can be vapour permeable, which helps ensure moisture does not get trapped in the building fabric, reducing the risk of condensation, harmful moulds and structural damage. These materials can therefore help to regulate indoor humidity, without compromising their performance.

The most common forms of plant-based insulation materials are:

- Hempcrete - Fibres are mixed with a binder, such as lime, to create non-structural building blocks or cast walls.
- Straw – Baled and stacked, or compressed into pre-fab timber modules to form thick walls
- Wood fibre – Waste wood is processed and bound using synthetic or natural glues into thick, non-structural insulation batts.
- Cork – Renewable bark from cork oaks is chipped, heated and compressed into batts.



Typical new wall build up with PIR foam insulation boards

## 1.3. Sweetcorn insulation

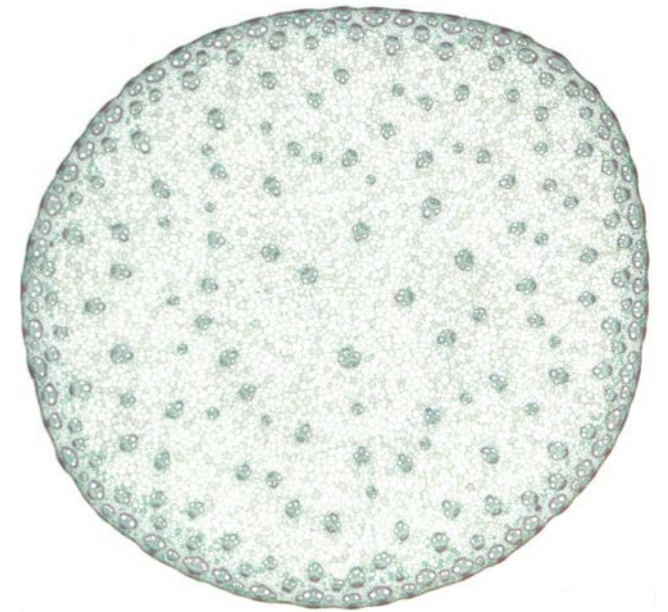
Sweetcorn *Zea mays convar. saccharata var. rugosa* originates from Central America, arising from a spontaneous mutation of the maize plant, cultivated by indigenous people and further hybridized in the 20th century. It is a rare C4 plant, fixing carbon dioxide and conserving water more efficiently, as well as being more productive, in warm conditions than the majority of other (C3) plants. It is adapted to cope with the high temperatures and seasonal drought of tropical grasslands and savannah's.

These adaptations to drought stress are reflected in the physiology of the Sweetcorn plant – with a pithy inner core of closely spaced vascular bundles and an alveolar structure 'similar to the structure of expanded polystyrene' (Mayer et. Al, 2017). This makes it perfect, when shredded and graded to the right size, as a biogenic aggregate for insulating materials.

Advances in plant breeding and a warming climate in the UK have made it possible to grow the crop successfully in the south-east of England, where it has been grown on farms since the 1970's.



Felix-Edouard Guerin - Botanical and zoological illustration



*Zea mays* stem. Photo: John Houseman and Matthew Ford

Maize growing for animal fodder in the UK has also increased exponentially in this period and is set to increase further as the plant has become a key feedstock used to create 'green' energy in anaerobic digesters (AD). The Soil Association (SA, 2015) raised concerns about intensive maize production, due to wide spacing between rows, and compaction associated with late-harvesting in wetter months, exposing soil to erosion and causing run-off pollution to waterways.

In 2023 Local Works Studio developed a prototype material, similar to Hempcrete, that uses the fibre by-product from growing sweetcorn cobs for food - the stalk and leaves - mixed with a blended binder of lime and clay, sourced as excavation waste close to the trial farm. The sweetcorn fibre consists of all of the plant material that is left in the field after the cobs have been harvested. Processing involves shredding the stem and leaves of the plant and grading the fibre to the correct aggregate size.



Prototype sweetcorn insulation block - Local Works Studio

## 2. Research problem and objectives

Large scale, centralised, industrial production of these bio-based materials, connected to national and global supply chains, will inevitably be integral to future procurement for retrofit and new housing developments at scale. However, this moment offers a unique opportunity to shape this nascent industry - to consider whether we must replicate industrial capitalist models of agriculture, production and global distribution in order to adopt these materials across the UK, or if we might also develop bio-regional and agroecological approaches to growing, processing and circulating materials, that more effectively tackle the multiple crises of climate, biodiversity, inequality and housing.

The Ag.Lab. project seeks to explore a complementary alternative to the traditional pathway for manufacturing and distribution of insulating building materials - a decentralised, “Harvest to House” approach. In this model, farms become small-scale producers, using residues from their existing crops and farmers’ versatile skills to manufacture low-carbon products for local use; and diversification into building material production is a seasonal counterpart, rather than competition, to existing food systems.

Such a distributed system could complement industrial-scale production by:

- reducing transport distances and associated emissions;
- allowing farmers to diversify their businesses and strengthen local economies;
- creating new, attractive forms of rural employment;
- and responding flexibly to regional building needs.

This vision faces obstacles. Farmers operate within tight financial and operational constraints, where food production takes priority. UK agriculture is in the grip of a labour crisis, with an ageing workforce, difficulties recruiting seasonal staff, and many local people unable or unwilling to take up farm jobs. For a farm-based building material system to succeed, it would need to fit seamlessly



Seasonal workers accommodation on farm

into existing infrastructure, align with seasonal workloads, and offer work that is both viable and rewarding. Even at a local level, products will compete in a market flooded with cheap, industrially produced alternatives and will need to meet building standards.

The overall question guiding this project was therefore:

*How could a small-scale, farm-based system for producing plant-based building materials function so that it is economically and operationally viable for farmers and attractive to workers?*

To address this, we looked in particular at:

- how production processes might fit into the seasonal, operational and labour demands of the farm; and how farm machinery and facilities might be adapted for fabrication;
- the skills and knowledge farmers and farm workers already possess; where they might need support or training; how fabrication processes can be simplified so that they are easy to learn and teach;



Young sweetcorn plants, late May



Sweetcorn harvester at the Trial farm

- what might make the tasks, working environment and rural work generally, more appealing and viable for workers;
- whether the insulating materials themselves could be used directly on farms, for example in worker housing or for retrofitting farm buildings;
- and the economic factors and policies that might effect the viability of on-farm production.

We chose to focus the research trials on the fabrication of a plant-based insulating block, equivalent in size to a standard concrete block, commonly used in UK construction. This block could easily be made by hand, would fit into existing construction systems and be familiar to tradespeople. We aimed to investigate and test the potential for use of existing crops, farm machinery and skills across all stages of the harvesting and block manufacturing system.

There is a large body of recent technical research, literature reviews and lab-based tests, centred on material innovation and routes to market for



Seasonal workers at the trial farm

plant-based insulating materials, including bio-concretes, bio-polymers and bio-composites, made from plants like hemp, straw, sugarcane, and even the cobs from sweetcorn. Research has also been undertaken in the UK to investigate the potential viability and application of plant-based building material production at a strategic, bio-regional level, for example Material Cultures’ 2021 report on Circular Bio-based Construction in the North East and Yorkshire. These studies have looked at the impacts and opportunities for industry stakeholders, construction workers and built environment professionals. However, none have addressed the practicalities of implementing these systems on farms, or have looked at the implications of their widespread adoption, for farmers, farm workers and other rural stakeholders.

Uniquely, the Ag.Lab. project aimed to examine the complex human, environmental, and operational barriers and opportunities for sustainable farm-based material production through collaborative dialogue with farmers and farm workers, and to test findings in an in-depth case study within a real-world context.



Hand-picking sweetcorn

### 3. Research methods

The project was structured as a participatory trial, combining: interviews; participant observation; farm surveys; prototype development; and collaborative action-research - testing systems and methods.

The aim of the research was to form a comprehensive picture of the opportunities and challenges that might be faced by farmers who want to produce insulating building materials and to use this understanding to develop a pilot manufacturing system on a trial farm. Over the course of the project our research methods were adapted to our growing understanding of conditions and constraints on the farm. The process of designing site-specific operations for block making, with farmers and workers, did not result in a successful manufacturing system that could be adopted more widely, but strongly informed the findings and conclusions of this research project.

The research team felt it was important to develop outputs from the project that would enable findings to be shared accessibly with a broad audience of stakeholders, in a readily accessible, easy to digest format that would suit time-pressed farmers and workers. Interviews and the co-design process have been recorded and will be shared (with consent) as a mini-series of audio podcasts, telling the story of the project. The physical processes and outcomes have been summarised in a short animation.

#### 3.1 Partnerships and Dialogue

Local Works Studio have a strong working relationship with a farm in East Sussex, having previously collaborated, harvesting plant material for early bio-based insulation tests. This 'trial farm' became the main site for the project.

Semi-structured interviews were carried out with the farmer and farm workers, as well as with other farmers, land managers and specialists from the wider area. We also reached out to several organisations, with experience of material research on farms, further afield in the UK. Interviews explored knowledge of machinery and materials, experiences of rural work, perspectives on diversification and what would make new kinds of work more appealing. We also asked participants about construction and potential applications



Interviewing participant on the farm

for insulating blocks on farms. Samples were made by Local Works Studio and taken to show other fabricators and developers for discussion. A breakdown of interviewee types can be seen in Table 1. below. In the following findings, participants will be referenced by the codes in this table.

Number	Codes	Interviewees
4	F1, F3, F4, F7	Farmer owner
2	F5, F6	Farm manager
3	FW1, FW5, FW6	Farm worker
2	FC4, FC5	Farm labour expert
2	FC2, FC3	Land manager
2	FB1, FB2	Plant-based construction material producer
3	FC1, F2, D1	Rural housing expert, or construction projects manager
<b>18</b>		

Table 1. Ag. Lab. interview participants, by role

The interviews were recorded (with consent) and transcribed. We used the qualitative analysis software, Nvivo (Version 14), (Lumivero, 2023) to code responses, looking for recurring themes such as labour challenges, crop growing and harvesting, barriers and opportunities to fabrication of blocks, and general stakeholder perceptions of construction-related tasks. These insights directly informed the design and testing stages.

We held several co-design workshops with farmers

and workers from the trial farm at Local Works Studio's workshop and on the farm itself. These sessions used dialogue and drawing to test and iterate solutions to specific operational questions that had arisen over the course of the project. We looked at: collection methods; drying systems; shredding; transport and storage.

#### 3.2 Material and Block Prototyping

Building on two previous harvests where plant material was collected and trialled, the team developed new block prototypes specifically for this project using plant waste collected across the research period. The aim was to create a simple, unfired insulating block that could be manufactured on-site and potentially used for farm-based construction needs.

A simple plywood 'slip mould' was designed for this project that made blocks at 440 x 215 x 100mm – the standard size for concrete blocks in the UK. The mould is filled, with gentle tamping of the plant insulation blend by hand and is immediately released from the mould for drying and curing on racks, then moved into stacks for storage before use or distribution. We also developed a new binder blend for this project using local clay, which reduced the lime content and therefore reduced the carbon content of the finished block.

Prototype insulation blocks were tested for compressive strength, fire resistance and thermal conductivity. The compressive strength test was done independently and meets current UK testing standards, and the fire and thermal conductivity tests were done in-house and were not intended to meet UK standards, but provided initial data into the performance of the material.

Local Works Studio met with testing organisations, including the BBA (British Board of Agrément) to discuss U-value testing (a measure of how effectively a material or building component insulates against heat loss). We obtained quotes for Sweetcorn insulation blocks to be lab tested for U-Values, however the cost and time frames were found to be out of the scope of this project. We chose instead to prioritise research into the viability and effectiveness of harvesting and manufacturing operations, to ascertain best options for production before investing in testing for specific products.



Material samples by Local Works Studio



Prototype blocks by Local Works Studio



Fabrication trial with farm workers

### 3.3 Development of a Manufacturing System

The focus of both interviews, initial material tests and co-design workshops was on the feasibility of developing a plant-based block manufacturing system that would incorporate established cropping and harvesting regimes and use existing or easily accessible equipment and infrastructure.

Initial research was centred on the type of plant by-products that might be harvested and testing numerous methods for drying these plant residues, including: Air drying of windrows in the field; Air drying of standing crops in the field; whole plants drying on a mesh stack made from fencing panels found on the farm; hanging in an open sided barn; shredded plants dried on a mesh in a closed barn.

Multiple methods were also tried for shredding and grading of wet and dry plants. Early iterations took place at Local Works Studio's workshop, allowing us to trial processes without interrupting the farm's harvest operations. Where necessary, small-scale specialist machinery was hired from Local Works Studio to simulate equipment that might be adapted or cheaply bought for farms.

Two half-days of block fabrication on the trial farm were completed in early July, with the farm workers, just before the harvest period. The fabrication area was set up in an open sided barn on the farm. LWS trialled a number of arrangements for making the blocks by hand with workers, including: mixing materials; mould filling; tamping; demoulding; stacking on drying racks; and subsequent removal for storage. Notes were collected on: set-up and making cycle times; ease of training and use; movement of people and materials through the process, resulting quality and density of blocks. In addition, the on-farm prototyping tested how the fabrication process could be easily communicated to workers without English language (or limited English)

### 3.4 Legacy Considerations

Throughout the project we evaluated potential "pathways forward":

- Could the trial farm adopt the system for on-site retrofits?
- Might local developers invest in or support such approaches?
- How might crop rotations and nutrient cycles be adapted to reduce biomass loss if scaled up?
- Might the material be suitable for machine block fabrication?
- Could the sweetcorn aggregate be spray applied to buildings as insulation without a lime binder?
- Might the ensiled storage of plant aggregates offer a better, scalable model?
- Could the material also become an insulating plaster?

These questions ensured that the work looked beyond immediate feasibility to longer-term opportunities.



Prototype insulation blocks in cold-store barn next to expanding foam insulation, for comparison

## 4. Findings

Our research revealed both opportunities and challenges in developing farm-based systems for producing plant-based building materials. Findings are grouped by theme. Results from farm surveys, practical tests and workshops conducted by Local Works Studio, are set out alongside findings drawn from experiences and reflections of participating farmers and workers, shared in interview.

### 4.1. Growing Crops and Plant Material

The farm where the research trial took place is one of only a handful of large-scale growers of Sweetcorn in the country and participants from this site had extensive knowledge of its production as a food crop. Several participants from other farms had experimented with growing a range of arable crops, including, most notably, maize and hemp.

Sweetcorn was described as having potential but requires a warm climate, only found in the south and east of England. "This is probably some of the better, more favourable climate in the UK. However, if you were to ask sweetcorn the question, where would you like to grow? It wouldn't be in the UK." (F1) Cultivation requires careful soil rotation and the crop is vulnerable to market swings and weather extremes. A poor spring or autumn storm could wipe out an entire crop (F1). Conversely, however, one participant mentioned that slightly warmer temperatures resulting from climate change might favour growing conditions. Soils in Sussex are very variable and growing arable crops is particularly challenging - a few interviewees questioned whether local clay soils were suitable for tilling at all (FC3).

In common with other food crops, sweetcorn has



Sweetcorn growing at the trial farm



Harvester emptying cobs into a trailer

been selected and hybridised so that the non-food part of the plant (the stem and leaves) has become smaller and less substantial, so more energy can go into the harvestable crop. Early varieties also grow to be less substantial because of cold weather during establishment. Still, a relatively small proportion - a single cob per plant - of each 1.8 metre sweetcorn plant is harvested.

While there was little experience among participants in relation to using plant material for construction purposes, the following were suggested as other potential crops worthy of investigation for fibre and plant aggregates: bean stems, straw, maize, mustards, radish, red clover, chicory, grass clippings, and even hedge trimmings.

Hemp was seen as promising but also risky. Some participants had abandoned it because it performed poorly in their damp, cold, heavy clay soils and on sites exposed to salty winds. In terms of accessibility of seed, one farmer reported having to drive to Germany to source it, highlighting the difficulty of obtaining reliable supplies. One team of farmers found the investment in specialist harvesting and processing machinery demanded by hemp made it uneconomical to grow at single field scale.

Break crops and green manures were widely recognised as underused resources. Grown on a rotation, they can rest, protect and improve soils, as well as potentially feeding them (legumes), drawing up nutrients and moisture with deep roots (hemp), with substantial benefits to subsequent crops. These plants are grown by many of the farmers we interviewed as part of the food growing cycle, allowing them to reduce fertilizer inputs and prevent soil degradation, flooding and sedimentation

in rivers. Break crops and cover crops were also eligible for public funding (via SFI scheme until March 2024, due to recommence in 2026). Prompt termination of these crops before the next cycle of food crops causes a problem for farmers with insufficient livestock to graze-off the crop in time, leading to use of herbicide (and extra cost). Climate warming also means there is less frost to break down plants for mechanical incorporation into soils. Many break crops are left to die and stand in the field, so are usually dry at harvest and several interviewees (FC3) and (F5) suggested they could be used for fibre in addition to food crop by-products.

Incorporating organic matter - left-over stalks, leaves and roots from food crops - back into the soil was seen as essential by several interviewees because of the benefits to the soil structure and improvements to soil fertility for future crops. As one participant explained, “all of that material is very valuable because we use it to put back into the soil to feed the soil biology” (F6). However, using all of the (above ground portion) of the plant is seen as worthwhile by many farmers we interviewed and is commonly done in both industrial and agroecological farming eg. wheat and leafy crops. If the farm is mixed arable and livestock then the use of organic matter from crops is less vital, as animal manure mixed with bedding also provides inputs. (F5)

There is very little surplus from crops, or land management, on farms. One participant stated that “I think there’s actually very little [...] spare material [in the South East]” (FC3). If farmers cannot use the harvested crop and its residues on the farm then it is sold on quickly to others. If they do not have a buyer in advance then the crop will often be ploughed in without harvesting, because contractor and fuel costs are so high. Very little material is stored without a plan for its future use.

Various actors already compete for crop residues, which are used for: bedding; animal feed; biogas from anaerobic digestion; and horticultural mulch. Despite these tensions, many participants saw opportunities to extract more value from underused material. Some farmers who grow a crop for more than one purpose eg. seed and hay (FB2) are prepared to sacrifice the quality or yield of one of these crops, for the increased value of two harvests from one plant, as well as better

biodiversity outcomes. One farmer describing it as a process of “looking at what’s the greatest value out of what we can use” (FB1). One farmer (F3) grows crops ‘to fail’ by planting 6-7 varieties at once in the same field, which has yielded good results in a challenging climate and he feels this ‘de-risks’ arable farming.

#### 4.2 Harvesting and machinery

For plants to be used as aggregates in insulation, they need to be cut, collected, shredded into small pieces and stored, for use, as and when they are needed in the manufacturing of products.

The trial farm has very specialised sweetcorn harvesting machinery which is optimised for gathering the crop in good condition. The use of the remaining 90% of the plant material is not considered in the machine design. As one participant put it: “The bit we’re guaranteed to get paid on, is a harvestable cob, so some of the questions you’ve got, we’ve never even thought of those.” The current mechanical sweetcorn harvesting processes causes significant damage to remaining stems and leaves, so only a relatively small proportion of the plants (less than 1/3) can actually be gathered for use as fibre after the food crop is harvested and the fibre and insulating qualities are compromised.



Cut stalks and plant waste left by the sweetcorn harvester



Harvesting sweetcorn cobs



The sweetcorn harvester crushes half of the remaining plants

This loss of biomass is due to: cutting stalks high above the ground; the sweetcorn harvester wheels crush half the crop into the ground as they cut the following rows.

Observing various stages of the current harvesting process we found the following by-products had potential for collection:

##### 1. Cut harvester waste:

Plant material left in the field, after the sweetcorn harvester has taken the cobs, could be raked into windrows by a tractor mounted rotary rake to enable natural drying and/or ease of picking up with a forage harvester machine.

Quantity (potential): Up to 1/3 of current crop

Viability: LWS tested this method by manually raking the plant material into windrows. This was difficult to do as the plant stem is thick and strong, and there was concern from drivers that in this method the rotary rake would not be strong enough to work efficiently and could be damaged.

##### 2. Left-over standing crop:

At the end of every harvest period there are often several unharvested fields, due to the reduced demand for sweetcorn in early Autumn and unfavourable seasonal weather conditions. At the end of the 2024 season the farmer left standing sweetcorn plants for LWS to collect by hand.

Quantity (potential): Up to 2-3 acres of unharvested sweetcorn. 2.5 acres = 40,000 plants

Viability: The best way to collect this material would be with a forage harvester, however the expense of hiring the contractor for a comparatively small area may not be cost effective.

##### 3. Waste from hand-picked crops:

If the sweetcorn harvester is not used, e.g. after wind events, when the harvester cannot cut lodged stems, and cobs are picked by hand (as they were until 15 years ago), then all of the standing plants could be collected and shredded (wet or dry) with a forage harvester.

Quantity (potential): Dependent on conditions and availability of labour to hand pick cobs. Hand-picking is twice as slow as machine (FW1), so a maximum of half the total acreage - 225 acres - could be harvested this way.

Viability: If there is sufficient labour to pick by hand and it is economically viable, this method enables the use of the majority (around 95%) of the remaining plant residues, and for some to be retained for soil improvement.



Harvesting sweetcorn by hand after the crop was bent over by wind



Seasonal workers set aside waste plants from the grading machine

4. *Harvester waste:*

Plant material that is picked up by the sweetcorn harvester along with the cobs. In the sorting barn, stem and leaf is separated from the good cobs by the farm workers and emptied into large crates. This waste is usually sent to local farms for cattle food.

Quantity: 1 x large wooden crate of waste plant stem can be collected in 2 days (crate = 2.2 m<sup>3</sup>)

Viability: The workers were happy to separate the stem, and it did not effect the efficiency of their process. This method could contribute a small proportion to the overall plant material collected.



Forage harvester loading shredded maize into trailer

We have made estimated calculations of crop by-product dry weight (below 15% moisture) and their potential transformation into hand-made blocks at the trial farm. This gives us a blocks-per-acre figure for 2 different harvesting methods.

There are more than 450 acres of sweetcorn grown every year:

- 4 plants per m<sup>2</sup>
- 16,188 plants per acre (1 acre = 4047 m<sup>2</sup>)
- 7,284,600 plants (at approximately 1.5 metres usable stem - including leaf material)
- 1 dry plant (below 15% moisture) = 40 grams (0.04kg)

If a sweetcorn harvester is used to collect cobs:

- Less than 33% of plant material can be collected from the field.  
= 97,128 kgs
- 1 standard block = 1 kg of plant aggregate (22 plants per block)
- 97,128 kgs = 97,128 blocks per 450 acres  
= 216 blocks per acre

If the sweetcorn cobs are picked by hand:

- 95% of plant material can be collected from the field  
= 291,384 kgs
- 1 standard block = 1 kg of plant aggregate (22 plants per block)
- 291,384 kgs = 291,384 blocks per 450 acres  
= 648 blocks per acre

A forage harvester is built to harvest and chop standing crops of maize, wheat or grass for silage. It can shred the plants in the field into pieces, at the optimal size for use as aggregates in insulation blocks or loose applications, with no need for additional equipment. It is thought that a forage harvester and wagon could pick up whole-plant waste from windrows (F1), but is not built to work efficiently with plants on the ground and there may be a high amount of waste and contamination from soil. Rotary rakes are designed to work mainly with grass and it is thought they may not be robust enough to deal with sweetcorn stems - though anecdotally both machines have been used to pick up heavy detritus from floods (FW6). The risk to machinery is also unknown and it was not possible to trial the use of them during this project due to

the prohibitively high cost of hiring machine and contractor for the day. Previous trials at other farms using expensive harvesting equipment on experimental trials for hemp resulted in damage and loss of confidence by contractors.(FC2).

**4.3 Drying, shredding and storage of plant material**

In the block making system being trialled in this project, plants residues need to be shredded and stored for onward use in the manufacturing process. The plant material must be dry for conventional shredding machinery to work and, most importantly, so that it can be stored without decomposition or contamination from mould. The problem of drying plant material was a significant challenge for the project team and has led to important findings and compelling avenues for future research.

We tested multiple methods for drying the waste sweetcorn plants:

1. *Mesh stack:*

Plant material was laid onto horizontal Heras fencing mesh panels from the farm, stacked outside, with a gap of 150mm between each lift, 7 layers high – providing 49 square metres of drying space. Corrugated roofing sheets were used to prevent rain ingress.

Trial quantity: 70kg of dry plants

Results: Plant material dried well over the course of 60 days, but rain blew into the side of the stack several times and the covering sheet blew off in high winds, delaying the process. This method is time consuming and inefficient to set up and manage, and too provisional at scale.



Dry sweetcorn stems in mesh rack. Note upper and lower levels were filled 15 days apart.

2. *Pallet bag:*

Stackable pallet bags are used by the farm to store and transport cobs. LWS filled 5 x 1m<sup>3</sup> bags with plants stacked vertically on-end. They were then stacked with a fork lift truck in a covered (and open-sided) barn for drying.

Quantity: 5m<sup>3</sup>

Results: Plant material dried well over 45 days. Drying times were fastest when the plastic mesh sides of the pallet were pushed down to allow more air flow. Works well for small to medium size scale but would be an inefficient use of valuable covered space for large scale production.



3. *Hanging under cover:*

Whole plants were hung in bundles of 10 hooked onto a rafter of an open-sided barn close to the roof.

Quantity trialled: 120 plants

Results: Plant material dried well over course of 35 days, but this method is too time consuming and provisional to be practical at scale. It also requires working at height which would potentially increase insurance premiums and risk to workers.



Hung sweetcorn plants drying in an open-sided barn



Raking windrows of sweetcorn stalks



Unharvested trial variety of sweetcorn beginning to dry in the field

#### 4. Field dry - Windrows:

Cut plants were gathered into windrows (linear heaps at widths to match forage harvester pick-up width) this allows cut material to dry naturally in sun and wind, in the same way grass and wheat stalks are dried for hay or straw. Tests were done by hand raking, but a rotary rake would be used in practice. Ideally windrows would be turned once and drying may take up to 3 weeks.

Results: Tests were done at the end of the season and impending bad weather meant windrows had to be rolled in and the field tilled before plants were dry. This illustrates the unpredictability and risk from weather associated with this method.

#### 5. Field dry - Standing:

Plants left unharvested at the end of the season, as well as plants from fields that had cobs harvested by hand - after strong winds, when the sweetcorn harvesting machine could not cut lodged stems - were left standing to dry naturally in the sun and wind in the field. Dry plants were collected afterwards by hand cutting, but a forage harvester would be used in practice.

Trial quantity: 1 double row of sweetcorn = 900 plants at 36 kg dry weight (below 15% moisture)

Results: Despite bad weather throughout the drying period, plants dried effectively in just a few weeks. This was by far the most efficient method we trialled, in terms of time, labour, energy and space required.

Sweetcorn plants have a thick stem with a tough outer skin and a sponge-like inner core that holds water. This protects them from drought, but also means they take a comparatively long time to dry compared to other crops.

Plants drilled later in the season have thicker stems because they get more sun than earlier plantings that start in the cold weather. (F1). This more substantial pithy core makes these later varieties better for insulation but more difficult to dry. Unpredictable weather conditions after the middle of the season (mid-august) also make these later crops more risky to leave to dry in the field.

Machines for forming windrows might not be robust enough to cope with maize and sweetcorn stalks as they are designed for grass. There is also a risk of windrows beginning to ferment and overheat in warm, damp conditions, which can compromise the integrity of the material. There are also concerns that windrows and post-harvest residues left in the field can be colonised by overwintering larvae of European Corn Borer moth, with negative consequences for subsequent crops.

Drying cut material on the farm in buildings is prohibitive in terms of space and energy. However, there is time pressure on fields used for drying later in the season, due to the need to plant following crops and to prepare the ground before soil becomes unworkable in autumn wet weather. If maize (and therefore sweetcorn) can be cut after the first frosts, it results in dryer material.

*"If you could harvest the maize stalks in November after they've had a frost, then the dry matter content is much lower and it basically goes through the forage harvester and starts blowing everywhere because it's so dry"* (F5)

Miscanthus, a perennial grass, is being used experimentally as plant aggregate in blocks and is harvested annually as a dead standing crop in early spring after winter frosts at 8% moisture content (FB2).

Once it is dry, plant material needs to be shredded and graded in size to an ideal particle length of 10-25mm long (Stanwix, 2014) for use as an aggregate. We tested the following shredding and grading methods in our workshop and on the trial farm:

#### Wood chipper:

A petrol-powered wood chipper was used to shred dry plant material. The machine has a grading mesh, so large material remains in the shredding area until it is small enough to pass through the mesh.

Quantity: 30kg of dry plant (approx 1 m<sup>3</sup>) takes 3 hours to shred.

Results: This method was slow, It could not shred wet plants as it clogged the machine. The plant aggregate size was good, and there was not much dust created. The material required grading to remove the largest particles. A larger machine would be required in practice

#### Hammer mill:

A large 3 phase electric machine for processing timber into wood chip. Very similar results to the above method.

#### Trommel grading:

A rotating sieve was used to remove plant aggregate over 25mm size. The remaining material (25mm down) was used to make the blocks.



Using a small trommel to test the grading process



Dry shredded sweetcorn plant - note the varied particles - the pithy insulating core and longer leaf fibres

A consistent theme in interviews was the lack of infrastructure to handle raw material at the farm scale (F1, F2, F4, F5, F6). One farmer explained: 'On the scale that we were at with the (hemp) trial that would have been disproportionately expensive to try and process on farm really' (F4). One fabricator noted that even in large warehouses, air circulation is insufficient for consistent drying, and dedicating valuable storage space to low-value stock creates difficult trade-offs. (FB2).

Many farms have some spare barn and yard space, enough to make blocks to use on the farm, especially out of the main cropping season, when barns are only used to store machinery. None believed they had space to make blocks (using a machine) and dry them at a scale for sale elsewhere. The smaller farms we spoke to do not have the covered space for any production at scale. None of the participants felt fully equipped to dry, shred, grade, store, or mix plant matter into usable building material. Drying was a particular concern, especially after August when damp weather makes it hard to process biomass.

To overcome the issues of drying, shredding and storage it was suggested by one participant (F1) that plants could be collected and shredded in the field by a forage harvester and ensiled, in a manner similar to forage maize - where anaerobic,



Maize fodder in silage clamp.

oxygen free clamps are built to preserve and store large volumes of shredded maize for 3-5 years as cattle fodder. This process, applied to insulation manufacturing, could use existing equipment and infrastructure to provide an alternative processing and storage method for plant residues. After accidentally ensiling hemp, a colleague of one interviewee tried using it to make insulation material, anecdotally, with some success, but trials were ad-hoc, limited in scale and with no evidenced results (FC3). Preliminary assessments and tests of ensiled maize were made by LWS for potential as an insulation material in response to the challenges of drying plants on the farm. Though this material research was beyond the scope of this project, initial results were promising.

The ensiling process is already used on many of the participating farms. One interviewee pointed out (FW6) that there are a number of redundant silage clamps in the area, on dairy farms that have gone out of business, that could be used where farmers they do not have their own clamps.

“Silage clamps almost litter the countryside”(F1).

#### 4.4 Material Testing

Participants anticipated that public understanding of bio-based blocks could present challenges. Concerns about durability, fire safety, and general unfamiliarity might limit immediate acceptance in residential settings. (F2)

Farm workers reported after the fabrication trials (see below) that it was difficult to ensure uniformity in block density and finish, and anticipated that it would be harder to maintain consistency with greater numbers and a higher turn-over of seasonal

workers (FW1). Fabricators pointed out that: “the expectation of conformity within the industry is pretty stringent.” (FB1,FB2).

Developers stressed that without recognised data and warranties, contractors would add risk premiums to projects, raising costs and slowing uptake (D1).

Certification, fire testing, and meeting building control requirements were identified as potential barriers to wider adoption. Low tolerance for deviation from standard of plant-based materials - affected by seasonal and natural variation - was seen as being especially problematic. However, producers working with other natural inert mineral materials, said that variation between batches is tolerated and accommodated by standards and this approach could be applied to plant-based materials. In the case of sand: “You don’t get individual approval for each aggregate you’re using. You have a standard grading that you can use it to and it sort of complies to a standard”(FB2).

We developed a bespoke material for this project that reflects the geology and available materials on the trial farms. The mix is shown below, but further testing is required to refine the blend and possibly reduce the lime content:

Mix for 1 block:

- 1kg of sweetcorn aggregate
- 1.5 litres of clay slip
- 1.5 litres lime
- Sweetcorn aggregate was measured in weight as the volume changes depending on density.
- Clay and lime were measured in volume as the clay was wet

The materials were tested at our workshop for strength, resistance to fire and thermal conductivity. This gives a basic understanding of the performance of the material as a building insulator.

We obtained three quotes for testing U-Values, which were between £5,000 and £25,000, and found that they were beyond the available budget of this project.

Overall results showed that the sweetcorn material was stronger than hempcrete, and had the equivalent resistance to fire as hempcrete.

#### Compressive strength

The compressive strength of the sweetcorn blocks were tested by crushing 100mm cubes of the material to failure using testing method British Standard: BS EN 12390-3:2019.

Results

Age of test blocks: 92 days

Mass in Air: 654.0 g

Density (Volume by calculation) BS EN 12390-7:2019: 650 kg/m<sup>3</sup>

Maximum load applied: 38.3 kN

Cube Compressive Strength BS EN 12390-3: varied from 2.2 - 3.8 N/mm<sup>2</sup>

For comparison, Hempcrete has a lower compressive strength, typically ranging from 0.3 to 1 N/mm<sup>2</sup>.

#### Fire test

Local Works Studio conducted a fire test using one of the insulation blocks made by the farm workers at the Trial farm.

- The block was fully cured and dry at 120 days
- The flame from a blowtorch was directed at the material, so the tip of the flame touched the block
- The test lasted for 1.5 hours
- The temperature on the surface of the block was measured at 600C
- There was no ignition or re-ignition
- There was no visible smoke
- After 1.5 hours the area of damage from the flame was cleaned and measured at 45mm diameter and 30mm deep
- The rest of the block was unaltered



Damage to a sweetcorn block from a 90 minute fire test at 600C

For comparison:

*Hempcrete*

Hempcrete is suitable for applications where fire resistance of 60 minutes is required, and this might easily be increased to 90 or 120 minutes fire resistance with alterations in the specification. Testing undertaken by the French manufacturer Isochanvre produced results that indicated that Hempcrete is a “non-flammable material”, with fire-resistance performance improving over time as the lime binder continues to carbonate.

*Celotex*

Celotex insulation is not inherently fire resistant as it is a combustible material, and Celotex’s parent company, Saint Gobain, has research showing that Celotex insulation releases toxic smoke, when burning, that contains hydrogen cyanide and carbon monoxide. (Fire Industry Association, 2023)

*Rockwall*

Rockwall is highly fire resistant and is classified as non-combustible. Unlike other materials, it does not produce significant amounts of toxic smoke or gases during a fire. The organic binder used to hold the fibers together is combustible, but its percentage is very low (less than 2 %), so it does not affect the material’s non-combustible classification according to standard fire tests.

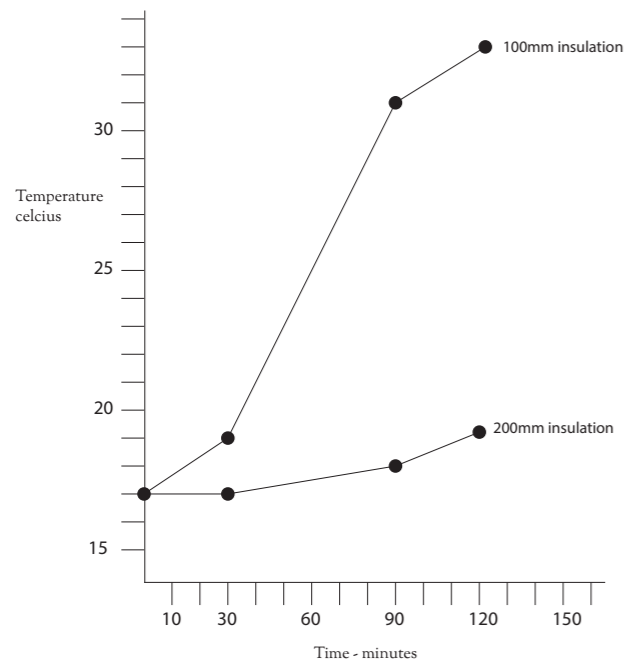
#### Thermal performance

Local Works Studio conducted a test to see how quickly heat was transferred through the sweetcorn blocks.

- 2 sweetcorn blocks made by the farm workers at the trial farm were used



Thermal conductivity test



Graph showing thermal performance of sweetcorn block at 2 different thicknesses over 120 minutes. Heat source is 600C

- The blocks were fully cured and dry at 120 days
- The heat source was a blowtorch that gave a surface temperature on the block of 600C
- The first thermometer was set at 100mm distance from the heat source
- The second thermometer was set at 200mm from the heat source
- Both thermometers started at 17C

#### 4.5 Fabrication

A simple plywood 'slip mould' was designed for this project that made blocks at 440 x 215 x 100mm - the standard UK size for concrete blocks. LWS trialled a number of arrangements for making these blocks by hand with farm workers, including: mixing materials; mould filling; tamping; de-moulding; stacking on drying racks; and subsequent removal for storage.

The 2 trial fabrication sessions took place in the first week of July 2025. The sweetcorn harvest had not started, and seasonal workers were on the farm to prepare for the work. 2 seasonal workers and the farm work manager were involved in the trial, and they each had a work station and block mould. Training involved a run-through of the process with LWS, highlighting the essential weighing and compaction pressure of the material into the mould.

Process for a single block – undertaken by trained

farm workers (unless indicated otherwise):

1. Dry shredded sweetcorn collected from the 2024 harvest was graded to (20mm down) in a mechanised trommel (rotating sieve). This removes the largest particles, which are not suitable for adding to the trial block size.
2. Lime and clay binder was blended (by an experienced technician) with the sweetcorn aggregate in a standard cement mixer.
3. Sufficient blended material for 1 block was collected and weighed.
4. Farm workers filled the block moulds with the mix, and were taught how to tamp the material to the correct consistency to ensure correct strength and insulation properties.
5. Blocks were immediately removed from the moulds and set to cure on a rack.

This process was continuous with raw materials being fed into the production line as needed during 2 sessions of 2hrs.

Notes were collected on: set-up and making cycle times; ease of training and use; movement of people and materials through the process and resulting quality and density of blocks.



Fabrication trial

Block drying methods

1. Natural drying: Blocks were left to cure for 1 week before being moved outside, in good weather, for final curing.
2. Air movement drying: Blocks were left to cure for 1 week before moving to enclosed barn with gentle air movement from an electric fan.

#### Results

Seasonal workers who took part in the block making trial enjoyed the work and the change from usual harvesting tasks. They found it to be comparatively easy (compared to other jobs on the farm) and sociable (FWS). They felt the process still



Fabrication trial

needed refining but that it was promising from their point of view. The farm worker manager (FW1) felt that seasonal workers would need to be encouraged to improve quality over quantity (to avoid rushing due to the competition often seen between workers on harvest operations) and that the speed of the process could be improved. During the trial it was noted that 1 worker can make 12 blocks per hour = 5 minutes per block.

The farm worker manager (FW1) predicted that with more workers, blocks could become very variable in quality. He said that a more skilled worker, perhaps experienced in construction, would be required to oversee the operation, to do the mixing and quality control. It was hard to achieve consistent quality when hand-making blocks with seasonal workers because: there was only a short time to learn the craft at the end of a long season; workers had variable skills and abilities; some workers did not speak English so took longer to learn the process and quality required.

There is a question of standardisation and what density and size tolerances there could be on blocks to meet standards. Weighing the blend for each block ensured that the density would remain constant if all the material was used within the mould.

Hand-made blocks take a relatively long time to make, even with skilled and experienced workers. One participant (F1) said that block making at a small scale, for use on the farm, would be too fiddly to retain his interest. The more blocks need to be handled (moved around racking etc) the more expensive they are to produce.



Cured blocks



Prototype insulation blocks in farm workers common room



Prototype insulation block against facade of bunk houses

During the trial fabrication process the weather was very warm and dry (max.28 degrees). This meant that the blocks stiffened quickly on the drying shelves, over a 3 - 4 day period. The blocks were then transferred to pallets within an open-sided barn for a further 10 days, they were then moved to LWS workshop for final curing. The blocks were dry after 4 weeks from the fabrication date.

An adapted concrete block making machine was used by fabricators we interviewed (FB1, FB2) and reduces the number of steps to manufacture a plant-based block. Using a mechanised block press would require far fewer people, with 3 skilled workers to make a maximum of 1000 blocks a day, but would require substantially more covered hard surface. A team of 3 semi-skilled workers making blocks by hand could only make around 150 blocks per day. Buying a machine like this is a significant capital outlay, even second hand, and would require investment of funds and time to master the process.

The operations of drying and logistics of storage and distribution of blocks are considered harder than the block making itself, (FB2) which is considered by most to be relatively simple and easy to do on farms. Most participants felt farmers would need to be supported by dedicated fabricators and specialist consultants if they wanted to become suppliers to industry.



Adapted concrete block making machine currently used for hemp

Several interviewees favoured the development of modular prefab cassettes that could be filled with bulk insulating plant aggregates, as an alternative to blocks (F1, F6) – from a logistical, fabrication and construction perspective. Though one local developer said that traditional block sizes would work well with existing trade knowledge on smaller residential projects (D1). The idea of using ensiled materials that could be stored and used in bulk from an existing silage clamp was favoured by the trial farmer (F1).

Turning residual plant fibres into insulating blocks was widely seen as both exciting and challenging by all interviewed stakeholders. Participants acknowledged that producing blocks on farms could open up new opportunities, but also highlighted the practical hurdles involved in achieving consistent quality, finding space for processing and drying, and accessing machinery.

Farm workers also saw potential in the possibility of blocks made from plant materials, but wider issues were reported in terms of sourcing reliable labour to conduct the work.

#### 4.6. Recruitment, labour and mechanisation

Labour shortages were a recurring theme and repeatedly identified as a limiting factor. Recruiting, training, and retaining workers in rural areas is already difficult and has been a problem for many decades - but this issue has been highlighted more in recent years due to extreme circumstances such as the COVID-19 pandemic and Brexit (Nye and Lobley, 2021, Nye 2021; Nye et al, 2022). Health and safety obligations were seen as another burden, and some farmers felt reluctant to take on more responsibilities as employers.

*“If most farms are struggling financially, this is another wage, and National Insurance, and accommodation for young people is a big problem and you know that means you’ve got to have 30,000 spare in your income every year. To host that person, even on a like 18,000 a year type entry job that’s a big chunk of money. People haven’t got it” (FC3)*



#### 4.6.1. Full-time farming staff

Within full-time farming teams there is little capacity for extra work. With full-time farmers insisting that they cannot become too distracted from the main work of growing crops. “A small team of 5 farmers, farming 1000 acres really do need to get on and go farming” (F2) Out of season, or in slower periods, farmers work maintaining, repairing and preparing for the next season. “What do you do out of the season? Prepare for the season!” (F2) Many farmers have other jobs, or contracts, off the farm that bring in extra income in the winter (FC3). Shorter daylight hours are a welcome opportunity to rest and recuperate, as summer brings very long working hours and few rest days.

*“If you’re running a small outfit and you’re doing most of the work yourself then you sort of need that recovery time in the winter” (FC3).*

It is thought that there is more scope to employ Seasonal Workers’s in plant-based fabrication and processing on farms at the end of the harvest season, with occasional days during the season, if harvest work is interrupted (though horticultural visas do not currently allow for this – see below). Growers on smaller farms said that they might appreciate having alternative extra work for workers in the winter months (F6).

#### 4.6.2. Seasonal workers

The application process for the 43,000 Seasonal Workers visas available every year in the UK is increasingly competitive and the scheme is oversubscribed. (FC4) The majority of seasonal workers now come from Central Asia and other countries outside the EU. If the season goes well, the money workers earn, in the 6 months they are allowed to stay, can be life changing for them and their families (FC5). Farms are obligated to

provide 32 hours of work a week for people on the Seasonal Workers visa scheme and the work must be restricted to harvesting and sorting crops. Farm workers rely on this guaranteed income to pay off costs associated with obtaining the visa and travelling to the UK, and most hope to pick up longer shifts where possible (FW1). Weather and orders can fluctuate, occasionally leaving workers short of work, or farmers paying for workers when there is little for them to do. The size and diversity of larger farm businesses means suitable work of some kind can usually be found, but labour experts thought that current visa conditions would prevent workers from doing any plant-based fabrication or construction jobs on the farm (FC5). It is believed a need for extra workers beyond the UK market would need to be demonstrated to government in order for the Seasonal Worker visa to be changed to include plant-based fabrication or other jobs on the farm (FC4). A request for clarification on whether migrant seasonal workers would legally be permitted to carry out block fabrication as part of their contracted farm work was sent to the Home Office, but no response was received.

Many workers who come from beyond the EU do not speak English. Where workers’ English language is limited, visual aids and sign language are helpful. One participant who supervises



*Hand-picking sweetcorn on the trial farm*

Seasonal Workers pointed out that the higher the expectation of English language, the more limited the options for recruitment, therefore tasks need to be simple and easily communicable (FW1).

Many Seasonal Workers’s come to the UK to develop new skills. Some seasonal workers also have construction experience in their home countries and in the UK. Labour providers try to recruit from rural areas to ensure that workers are familiar with the conditions and type of work being offered on UK farms (FC4). Some of the workers we spoke to had first-hand experience of vernacular building methods, using plant waste (including sweetcorn) and earth as material.

Many workers have other trades, skills and businesses at home which they are aiming to fund through the money they earn in one season in the UK. Labour experts said that a well-run scheme can enable workers from developing countries to use and share skills they have learned in the UK when they return home.

*“What you see, in a number of countries, is the ability of these individuals to access funding in their own countries, to develop and implement programmes in these countries which take the skills that they’ve learned, whilst on this temporary migration programme and implement them, back in their own country” (FC4).*

In terms of the work itself, workers expressed mixed views. Some found block making enjoyable, a change of pace from repetitive farm tasks, and even described it as ‘the future.’ Others valued the work but emphasised their main goal was to earn quickly and return home. The research team and participants initially imagined fabrication as

seasonal work, complementing farming rhythms. However, it quickly became clear that storing fibre for year-round processing would require a more stable labour model.

#### 4.6.3. Domestic workers

Farmers and labour providers alike described ongoing recruitment challenges, particularly in rural areas where local people are reluctant to take on farm jobs. Only domestic (UK citizen) seasonal workers, EU status workers and Ukrainians with BRP status have the freedom to work in any part of the farm business and there are far less EU workers coming to the UK since Brexit. Domestic workers are much harder to recruit into farming – they have comparatively higher expectations for conditions, pay and regular hours and often seek permanent positions. Hand picking and sorting, that allows full use of crops and their residues, is difficult and unpredictable to fulfil locally. Seasonal worker posts are often advertised in job centres, but there is very little uptake of positions from the domestic market (FC5). Even where local recruitment was attempted, farmers described exercising “*extreme caution*” (F2), due to high costs, training needs, and the risks of delegating responsibility in safety-critical roles (e.g. entrusting inexperienced teenagers with heavy machinery).

However, farmers we interviewed from mixed farms and smaller organic farms say they find it comparatively easy to recruit from the local labour market, but still find it a challenge to find workers who understand the need for speed and efficiency.

*“You hear that a lot. When it’s sort of more conventional agriculture, hear a lot of people say, ‘Well, you can’t get people, no one wants to do it in this country, and blah, blah, blah’. But yeah, we kind of find the opposite in a way. The hard thing is, like I said, finding the right people.” F6*



*Loading pallets of cobs at the trial farm*

One participant said that candidates applying for jobs on their organic farm sometimes have romantic ideas about the work that do not match the reality. Many interviewees reported that new recruits (both domestic and seasonal visa workers) often struggle with the physical nature of the work (FW1).

*“In theory those people are there, whether they can withstand the actual working conditions, I don’t know, it’s becoming now a lifestyle for which you have to be brought up, because it’s so far removed from where everybody else works.”* FC3

Farmers we interviewed expressed sadness and concern that numbers of people working on farms and on the land in rural areas have drastically reduced in the last 40 years (F1, F2, F3, F4, FWS). Many felt a desire and responsibility to try to revive rural life and provide more employment on farms where possible. Some farmers we interviewed enjoy employing people and try to create jobs that bring new energy and ideas to farm community or estate.

*“My grandfather employed 40 people on 300 acres. I now employ 5 on 3.5 thousand acres and the system’s flawed. So unless we can inspire people to come back and want to get involved in landscape, we’re dead ducks, we’re kidding ourselves.”* (F3)

#### 4.6.4. The Shift Towards Mechanisation

Rising cost of wages and national insurance, as well as admin associated with managing and caring for seasonal workers, reduces the productivity of the ‘farm per labour unit’ (2,200 hrs per year) – the conventional measure of a farms profitability and efficiency. This leads conventional farms including



Seasonal workers on the grading machine

the trial farm to mechanise as many processes as possible. Investment in machines, though often more costly overall, and requiring a large initial outlay, is seen as preferable and less of a risk, because repayments are predictable. It is also seen as less stressful and represents less work for the farmer.

*“Where we used to have labour we now have finance agreements” [...]“We’re having to pay for labour and national insurance and everything else now, that has just gone stratospheric out the roof...actually a finance agreement over 5 years on a machine, at least the payments stay the same for 5 years”* (F1).

When the harvester and grader (the machine that allows workers to sort sweetcorn cobs by size and quality on the trial farm) are combined, they allow the farm to process sweetcorn at twice the speed and avoid the loss of large fields of same-age crops due to over-ripening, because a manual picking system cannot keep up.



Collecting crates from hand-picking requires more trips



Hand picking after a wind event

However, people are still seen as essential for some tasks requiring manual dexterity, and at times when machines are unable to work efficiently after weather events – flooding or wind.

*“A manual labour unit is really quite valuable, somebody’s eyes and ears and touch, there isn’t really a machine yet that is as adept as a human at making a multi-factor decision.”* (F1)

Seasonal workers said that work in the fields goes faster and is less boring, but is physically harder. An experienced worker compared hand-picking favourably with standing sorting at the grading machine: *“We half season pick by hand. It’s everyday picking. We are not, of course productive like machine. Was funny in the field to say in the fields time go fast, faster than here. Here is more monotonous boring.”* (FWS)

Hand-picking is an adaptable process, where quality is controlled in the field and mechanical damage limited, and can more than double the remaining plant that can be harvested for other uses. However, hand-picking also requires substantial numbers of workers to pick large volumes and areas. In many cases the costs of labour mean that it is not economically viable to pick (F1), or weed by hand (F6).

One participant said that the burden of providing infrastructure (eg. accommodation) for large numbers of workers is prohibitive and a huge amount of extra work for the farmer (F1). Hand-collection also requires many more vehicle movements and logistical infrastructure (eg. crates), but vehicles are smaller and do not compact the ground to the same extent, especially in wet weather.

#### 4.6.5. Block making work

Block making would require some manual labour at a small scale and more mechanical skills at a larger scale, or to produce bulk material. The trial farmer (F1) favours maintaining simplified job roles for any new fabrication work in line with current horticultural workers practices. One participant (F2) anticipated that recruitment of skilled workers, or processes that require more skill, would make blocks or other products more expensive. While many farmers already possess relevant skills - mechanical repair, operating machinery, problem-



Farmers have transferable mechanical skills for fabrication



Workers have valuable manual and perceptual skills

solving - participants stressed that running a block press is a specialist task requiring a combination of practical ability, perseverance, and ownership of the process. Even small oversights in cleaning or maintenance can ruin large batches of blocks (FB2). Both manual and mechanised production would require knowledge, judgement and ‘feel’ for materials on the part of the workers and supervisors to ensure consistency and quality using variable plant materials.

Workers on the trial felt that block making was a welcome change from working on the sweetcorn grading machine, less arduous than tasks like weeding and that it was simple, interesting and fun to do (FWS). It was felt by the workers’ manager that as long as it paid the same, most workers would be happy to do it (FW1). Most participants believed that the bulk of the work was not technically complex, meaning it could be taken on by farm workers with minimal formal training. Volunteers and younger workers were said to be particularly enthusiastic, especially when the work felt purposeful and connected to sustainable futures. *“There’s people who*

really want to work with their hands and really want to do something they feel is worthwhile” noted one young fabricator (FB2), suggesting a niche but growing interest.

#### 4.6.6. ‘Good work’ and conditions

Migrant workers are often employed on minimum-wage, zero-hour contracts - conditions that one labour expert argued do not constitute ‘good work’(FC4). Generally farm labour in horticulture has been reduced to simple, low-skill, repetitive tasks, performed under time pressure, in uncomfortable conditions, with little autonomy or opportunity for social interaction. It falls short of government targets for good work in terms of security, well-being, autonomy and voice (Department for Business, Energy and Industrial Strategy, 2018). By contrast workers we spoke to on mixed and small organic farms appreciated the variety of working mainly by hand and take pride in the work and the skill required.

Despite economic pressures, many farmers we spoke to go to great lengths to provide decent conditions, progression, autonomy and good housing for their staff.

*“I guess, it’s another thing we’re quite sort of proud about is...giving people in the local community, meaningful employment, ’cos I think that’s something we feel quite strongly about, and I feel very lucky personally to do a job that I really... love and feel very passionately about and gives me a sense of purpose and I think that’s what a lot of people that work here feel is that on the whole I think people feel like we’re doing something that’s worthwhile and it’s a nice working environment” (F6)*



Vegetable growing outside farm workers accommodation



New rural housing, built with plastic insulation - rarely affordable

#### 4.7. Accommodation and building

Most of the farms we spoke to had existing farm buildings, residential accommodation or industrial buildings, in their estate that need retrofitting to provide thermal comfort for employees, tenants etc. Accommodation was repeatedly highlighted as central to recruitment and retention.

*“In terms of the farm we’ve never had, touch wood, but we’ve not ever had any problems with recruiting people, but I think because we provide good houses” (F5)*

Historically many of the dwellings around farms would have been designed and built for land workers. However affordable accommodation has since disappeared from countryside with historical rural to urban migration of the workforce over time.

*“We’ve spent 200 years telling people ‘you’ll be poor cold and dirty if you work on a farm’. Why would you do? The publicity’s not been that great, it’s driven people away from it, so the accommodation’s gone with it”...in general there’s a shortage of housing for people on rural incomes”. (FC3)*

Workers and some farmers rely on cheap, subsidised accommodation tied to their jobs on farms and cannot escape them if they want to continue to live in the countryside (F5). Other workers live in local towns and commute into the countryside to work on farms. Some are still living with their families as rent is too expensive on low farm wages.(F6)



Accommodation for nine seasonal workers

*“It was very difficult to get planning permission for me to live here. But everybody else that works here comes from sort of a long way around. And yet the something like 8 cottages that surround the nursery were all built by the nursery in 18 whatever and now have been sort of extended and turned into plush residences that nobody at the nursery can possibly afford to live in” (F7)*

It is felt that government support and attention is mainly focused on large developments in urban areas and low-cost rural housing is not a priority (FC1).

Farmers prefer to have workers living on the farm to ensure consistent availability throughout the season.

*“It’s kind of transpired the best way to do it is to get people over, house them on site. They literally live at the farm. When they wake up, they’re at work, they go to sleep, they’ve just finish work” (F2).*

Like other farms, seasonal worker accommodation on the trial farm is in multi-occupancy static caravans, bunk houses and chalets, Workers have rent deducted from their wages - legally capped at around £75 per week (Barbulescu et al.,2023) - and they accept the limitations and low standard housing because they do not want to pay more. Seasonal Worker accommodation is usually only required in the summer months, so it is not deemed necessary by labour providers or farmers to insulate. Workers we spoke to report overheating in summer and feeling cold toward the end of the season.

*“Oh, we live in caravans. Everything is good. Just insulation is no good, and when it’s hot, it’s inside, is very hot” (FWS)*

Farmers have high operational costs associated with temporary accommodation because workers use electric heaters to reduce cold and to dry clothes, at the same time as leaving windows open to alleviate damp and condensation (FC4).

Several farmers saw potential in producing insulation blocks to improve on-site housing but noted that retrofitting caravans would be difficult because of their size. One labour expert explained that farmers rely on cheap caravans to be able to continue business, saying that a necessity to provide more permanent accommodation and the difficulty of gaining planning permission could be a potential “industry killer” (FC5).

Improvement to barns, such as: packhouses where people stand still for long periods in cold weather; animal shelters; and building bunkhouses, were identified as being more feasible opportunities.

There was a strong interest from all interviewees in using more sustainable construction materials on farms. Many were supportive of the idea of growing material, processing and making on the farm, even if it was more expensive in terms of labour. Many participants had experience of constructing new housing and farm buildings and use a lot of conventional petrochemical based insulating materials.

*“With our other hat on, where we do tend to build things, there is always an interest in using materials other than Kingspan and concrete blocks. New materials need to be developed and showcased. They use insulating materials on their industrial estate” (F1).*

Some had already invested in sustainable plant-based products. Several participants thought that the ability to use their own time or labour from the farm, would offset the potentially higher costs of building with more sustainable plant-based materials.

*“In the last 10 years, we’ve converted, probably 10 dwellings from old bull pens or stables [...] And if you could use your own material, that would be amazing [...] if you can insulate it using material you’ve grown and on the estate it be would be fantastic” (F5).*

One farmer built his home using prefabricated cassettes filled with hempcrete and had considered using his own crops as a substitute (F7). They found that employing engineering consultants to ensure dwellings with these materials met building regulations was a significant cost.

Historically there has been a strong connection between agriculture and construction, with farm workers moving between trades seasonally and materials being dug or grown locally. Some seasonal workers and those settled here from the EU have experience of building and living in homes made using plants and food crop by-products, including sweetcorn, where it has, or had, multiple uses within rural buildings – including thatch, wall and roof insulation and cob blocks.

*“My grandfather used to do this and put yellow dirt on top[...]and he will have also[...]mud bricks the one they turn, yellow from shit from horse manure [...] with straw [...] he used to just turn them from the sun”* (FW1).

#### 4.8. Economics and Diversification

Farmers repeatedly highlighted how dependent both crops and markets are on weather. Market demand also fluctuated with the weather, for instance, sales of sweetcorn increased during hot summers when more people barbecued. In relation to labour, one participant described how:

*“The weather impacts their work, and the weather impacts the orders [...] really the amount of work they might have on the sweetcorn is, to an extent, uncontrollable”* (F2).

Most farmers grow to order and have contracts with large food producers or supermarkets. They are also tied into large, long-term repayment contracts for machinery, which leaves them vulnerable if they lose their single or biggest customers, or if they the crop fails. Most food crops are undervalued and as primary commodities are affected by fluctuations in wider markets. Farm businesses are price-takers and must accept the prevailing market price for its products or services. Input costs, especially fossil fuels and fertilizers have been very volatile post Covid, Brexit and Ukraine war. Farmers (especially smaller to medium sized) operate on very tight margins without spare time or finances that might enable them to invest in new ventures. Even larger

farms operate on the basis of selling crops in order to pay for inputs for next year. *“We’re just living hand to mouth, just on a bit of a bigger scale”* (F1).

New enterprises and diversification that fit into conventional farming practices of the core business are thought by farmers as most likely to be adopted and succeed (F5). Several farmers felt that UK farming businesses were forced to rely on diversification and that food is hugely undervalued.

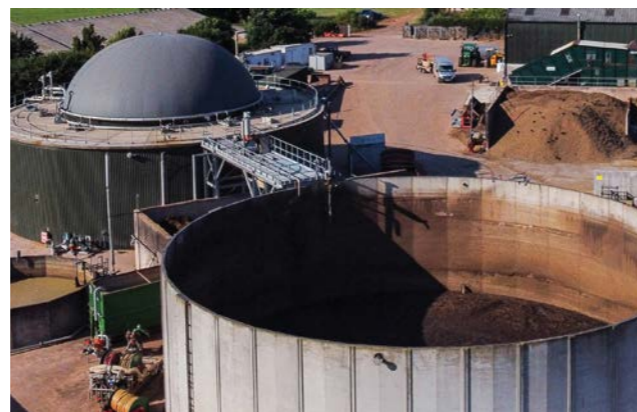
*“It’s not like people aren’t driving the systems hard enough to get the product off, it’s that the value that they get back is really low.”* FC3

Farmers suggest that harvesting is expensive and it is not worth harvesting anything that you are not going to use. The possibility of using the byproduct of an existing crop was seen as particularly attractive by many participants, because the existing crop pays for any additional, ‘experimental’ harvesting processes.

Most farms said they are open to growing non-food crops. One participant thought that it would broaden their appeal to other markets and that the yield of conventional agriculture had improved sufficiently to support it (F1). They pointed out that historically, farms used 1/3 of their arable area to grow oats as fuel for horses and there was a legal mandate to grow hemp and flax for the navy.

*“The last thing we get asked to do with our land is grow food on it, its solar panels, its housing, its roads, its reservoirs. Anything but food”* (F2).

There is pressure on farms and land from other sectors, in particular, infrastructure; Biodiversity Net Gain; and for maize, as feedstock for AD plants.



Anaerobic Digestion (AD) plant on a farm © Emily Fleur

One farmer told us that the energy market had distorted and inflated the price of foraged maize which potentially makes fibre crops more expensive to buy in for production of plant-based insulation. One developer said that they had been met with arguments against use of plant-based materials for construction, because of the use of productive land for non-food crops.

Most farmers say they would need the market to be tested first before committing to investment in non-food crops and on-farm production. Experimentation with new crops or processing ventures was seen as financially precarious. One farmer observed: *“Most people don’t want that level of risk [...] it’s something most people aren’t ready to entertain”* (F7). Uptake would hinge on clear evidence of profitability. As another participant explained: *“Farmers would need to actually see that there was a comparable profitable return from growing it”* (F4).

It is considered essential by many participants that there is a secure regional demand (or even contracts) for the plant fibre or insulation product to warrant investment by farmers and contractors in specialist machinery and infrastructure, but also to mitigate the risk the growing of it at scale, especially for the first time.

Conversely, developers, builders and product makers require a guaranteed supply of materials. One developer we spoke to was wary of delays and uncertainties linked to agricultural cycles:

*“If you’re innovating a product with an agricultural output pattern, then the contractor will panic and add a massive risk factor to their cost [...] None of this is a no [...] they’re just cautionary factors we have to look at seriously”* (D1)

They predicted that large building contractors would add substantial extra cost to mitigate the perceived risk - both for warranties on less-tested products and impacts on construction timelines - of using a new, locally produced materials, or may refuse to use them altogether.

A participant with extensive experience in local economic development observed that products need to drive growth of new crops on farms



Observing on-farm production of plant-based building materials

(FC1). They gave examples of a mattress factory in Yorkshire, and historically, the rope and sail making industry in Bridport, driving local hemp growing.

The basic insulation block production process is simple and manageable on a small scale, in principle, but in practice, at a scale worth investing in, the associated infrastructure is considerable. Pallets, storage areas, clean-down facilities, and reliable presses quickly accumulate costs. One fabricator described how, at one point, their entire stock of pallets, worth several thousand pounds, was tied up simply drying blocks (FB2). Even in small-scale production some investment would be needed to buy in additives like binders in bulk to keep costs down. These ‘hidden’ requirements often tipped the balance from feasible to prohibitive.

*“Making blocks has a few more complexities [...] It’s all those bits. It’s the pallets to stack them on. It’s the clean-down machinery [...] It’s the other £30,000 that you need to actually make it work”* (FB1)

Fabricators we spoke to were frustrated by a lack of time and freedom to apply their skills and experience to research in an experimental way, which they felt would lead to quicker innovation. They find it extremely difficult to compete in a market flooded with cheap products produced on a vast scale. Fabricators also stressed that scale is crucial. Small-scale production, hundreds of blocks a day, was seen as uneconomical. From their perspective, a viable enterprise would need to reach 20,000–25,000 blocks a day to ensure it was an affordable material for use in standard construction, rather than a ‘luxury good’ (FB2). However, many farmers and developers said they pay higher prices for sustainable materials produced locally, or on

their own farms, or would be willing to effectively subsidise the process with their own labour or 'sweat equity'.

Growers and makers had witnessed the decline of local construction material industries and the loss of local networks of markets for crops, as well as a culture of eating and building with local products. However, smaller farms, running box schemes and selling direct to customers felt their businesses were more resilient to crop failures and market turbulence than farmers growing monocultural crops at scale to supply wholesale buyers (F6). They also were able to profit by processing and distributing diverse crops themselves.



Loading pallets of sweetcorn cobs

Maize silage (and crops like it, inc hemp) is prohibitively expensive to transport beyond 5 miles (according to several interviewees) because it is so bulky and wet. Farmers felt that production for construction at scale would need to be moved closer to towns and be situated off a bigger road. If farms are particularly remote they find it harder and are less keen to diversify into businesses that require frequent transport or public access.

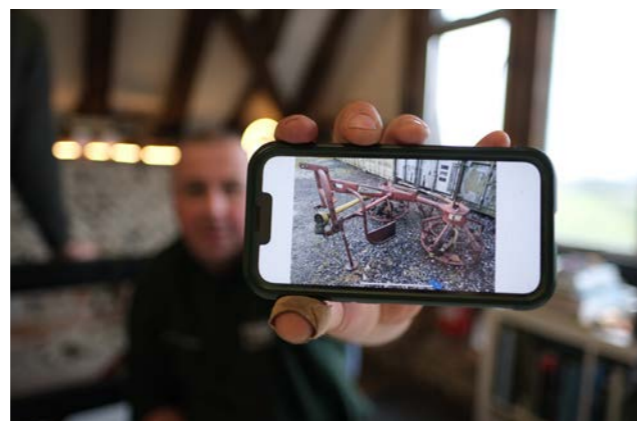
Participants were enthusiastic about the principle of making blocks close to where plant fibres are grown, rather than transporting bulky biomass long distances. As one fabricator put it:

*"I love the fact that concrete blocks for the most part are made near quarries. That's a success story in my eyes. And I fundamentally believe that is how blocks utilising natural fibre should be made, close to the source. It makes no sense shipping fibre around the country"* (F1)

#### 4.9. Education and Collaboration

There was strong recognition from all participants that new forms of training and land access would be needed to facilitate a transition to production with plant waste on farms. Several participants highlighted a skills gap in both farming and natural material production, alongside the challenge of high land prices preventing new entrants from experimenting.

*"We're beginning to talk about diversity in nature, in soil, maybe, that's become better understood. But I think we also need to talk about diversity within ourselves so we train ourselves to be more than just one thing. So that we can be an artist, a shepherd, an influencer, whatever"* (F3).



Sharing ideas at an Ag.Lab. co-design workshop

Many farmers are good at fabricating equipment, especially machinery with good welding skills, and they save themselves a lot of money this way. Seasonal Workers can often bring hidden skills and experience to the farm workforce.

*"When they think about farming, especially in this country, they sort of view it as unskilled labour, but I have a real problem with that because... It's not unskilled and even to harvest a crop and bag it up, there's a certain skill"* (F6).

Young people are seen as crucial to the adoption of new non-traditional crops and practices. The awareness and provision of new skills required in farming are lacking in the education system and it is seen as route for non-academic students.

*"The one problem that we became aware of, quite a few years ago, was the fact that basically students at, say, our local comprehensive [...] then it was a case of, oh, well, he doesn't seem as though he's capable of much else, he can*

*try farming. And I think you know the careers teachers ought to be more aware of the skills that actually are needed in agriculture these days."* (F4)

One participant stated that the "community of sweet corn growers is small and it's getting smaller" (F1) and related this decrease in growers to there being a smaller pool of knowledge, and fewer people with whom to discuss successes and failures.

There is some co-operation between farmers in the UK, but this is limited "Most farms survive on the network of favours that they trade with everybody else"(FC3). Farmers enjoy helping each other out, but stop short of joint business ventures. It is thought this is because business models (and crops and geographical contexts) are very diverse even within a single region, and are hard to match together (FC3). There is also a culture of independence and some rivalry between farms.

*"Inherently, UK farmers are not good at cooperating. They tend to be too competitive with one another, unfortunately, and they're too good at looking over the fence at what their neighbours doing, saying 'that won't work' and willing you to fail!"*(F4)

Machinery rings in the UK are seen as having potential but many said they tend to fail when trust has broken down due to misuse of machines or poor communication.

*"You always hope that machinery rings will come to fruition and they rarely do, and often the reason is if it's a specialist piece of equipment, they all want it on exactly the same day because the conditions are right for using that kit, that day, or someone will use it and not return it in quite the shape that's required"* (F3).



Exmoor Pony grazing initiative supported by local farmers



Interviews for the podcast

Machinery sharing sometimes works well with complementary (rather than the same) farming practices, where machinery is required at different times of the year, avoiding conflict.

Farmers will also occasionally share the cost of a contractor (F5). One farmer leads a buying co-op but says all their mutual activities focus on inputs, rather on what they could produce and sell together (F4). However, financial pressures and isolation are driving farmers to consider working together more, as one participant described collaboration as 'the future', they explained:

*"There's not many farmers left around here. There's only really three of us in the three parishes locally that are still actively farming. And it just makes absolute sense to not each of us go out and buy a combine or a big new cultivator or a drill or whatever. We just need to share it. And we are talking much more than we ever have done about all of those things."* (F5)

Good relationships and trust are seen as essential prior to committing to joint ventures. Several interviewees have found that starting unique landscape scale projects (eg. Exmoor pony grazing and locally sourced school meals) can link farms together and build alliances and trust (F3, FC1). Once scepticism and initial problems are overcome, people start to see the benefits. One interviewee felt that scale was important – projects need to be big enough to be a good example, but small enough to measure impacts.

*"If you get 4 or 5 farms...5 farmers working together, from Lewes to Eastbourne, that's more than enough, in order that you can make some real change."* (F3)

Farmers were also mindful that a single farm could become too large and impact future generations, who may need to break up the estate as part of succession arrangements, so advocated getting more from their land, collaborating between estates rather than expanding. Collaboration across generations and aligning visions for the farm was sometimes difficult, with older farmers being less inclined to adopt new methods and younger farmers being judged harshly and discouraged from adopting experimental practices. As one farmer recalled: *“It comes with challenges, I’ve got the bruises [...] the best one is ‘If that’s the best you can do. I want no more to do with this farm’. Yeah. That one really hurt.”* (F3).

Many farmers felt that small-scale on-farm processing was unrealistic on its own, but they were open to the idea of shared or regional facilities. A local processing and production hub that could enable farmers to pool resources with less risk was suggested by several interviewees. A group of farmers and community land managers in Dorset had been talking to a French flax farmers co-operative to see if this was a model they could replicate in the UK (FC2). A consultant who has worked with farmers across their region for over 30 years had had previous success in bringing farmers together for a school meals project:

*“Our experience was that, as soon as we set up Local Food Links which does the school meals, our relationship with the farmers kind of changed because that grew quite rapidly and then we could have contracts with farmers direct to say, you know, we need veg or we need meat or whatever. And it sort of felt that farmers could cope with that.”*(FC1)

They felt that there is scope for co-ops, but that it would need to be led by producers or multiple



Local Food Links - school dinners. South West UK

stakeholders, rather than farmers, at first – with farmers being invited to join as members.

#### 4.10. Change

It was widely felt by participants that it is difficult to make changes on farms, with only 30 seasonal opportunities to ‘get it right’ in one farmer’s career (F1). Historically farmers have been encouraged by government to specialise and discouraged from splitting work across multiple outputs, a trend which is difficult to reverse (FC3). Agricultural businesses in the UK are very diverse in their outputs, methods and business models – this makes it hard to innovate in a uniform way across farming. The variability of farming, with unpredictable seasons and economic climate, hefty financial agreements for machinery and contracts with suppliers, means the risks are high and there is a tendency to stick with what works. With slim financial margins there is little room for experimentation as one participant put it: *“You experiment when you feel you’ve got it in you”* (F1).

There was also recognition of lengthy timelines for change in farming. As one participant put it: *“It takes time for people to go [...] ‘I’d have to do this, which means winding down the number of sheep’ [...] So, there are long lead times for changes in working practices”* (F3). Making space for block production might require adjustments to growing and farm systems, such as freeing up barns or changing crop rotations, years in advance.

It was felt by several interviewees that scale of change was important and that the ability to generate and see a positive impact on biodiversity on their own land was a priority and a fundamental to motivation for them and their workers. Farmers we worked with are independent, pioneering and skilled – priding themselves on being able to adapt and innovate and enjoy experimentation. *“We have a really good philosophy on the farm, or you know, the way that we work and say, ‘Right, I’ve got an idea. Let’s get it out there’. The first idea is a crap idea, so we’ll just take that to pieces and then we’re onto something”* (F1). Older farmers talked about wanting to try new things to bring interest to the routine of farming (F4). One participant explained that farmers are naturally opportunistic: *“People are always up for a trial of something if they think they would make money out of it”*. F3



Interviewing fabricators in rural Wales

Providing sustainable environmental solutions and outcomes was important to the majority of participants:

*“I think our focus is much more on the environment than it ever has been. And I think that’s probably common with most of the farmers I know”* (F5).

However, farming is a traditional sector. If new ideas are introduced in a system of succession, or when new managers come to farms still owned by retired farmers, there can be resistance to change from existing practices. People at the end of their farming careers prefer to stick with what they know as there is too little time left to learn and put into practice new skills. Participants said they had found that the building trades could also be reluctant to adopt new methods and materials and had experienced resistance to using plant based or non-standard materials. *“A lot of the builders are of a certain age, they’re just ‘I’m too old now to learn new stuff, I’m just going to carry on, cause it nearly only 5-10 years’ [...] so the focus has to be on those younger people coming into the building trade and into farming, who are much more open to the idea of non-traditional crops”* (F4). There is also some resistance to change from planners and the public, who favour ‘traditional’ looking buildings and practices. One fabricator said they worked around this by *“recreating the tradition of today”* in buildings, where use of materials is transparent, as it would have been in the past (FB1).

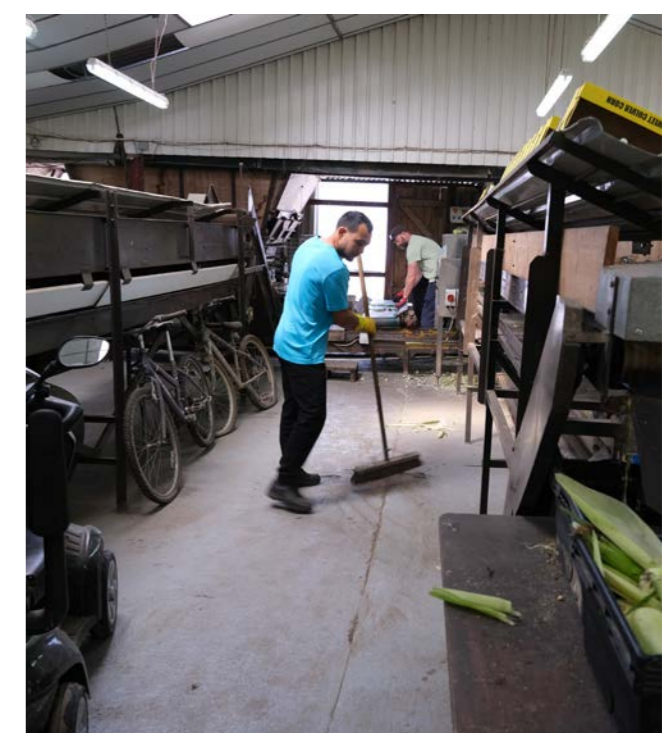
*“I just find it very strange how a lot of this (construction) industry looks back for direction from the past rather than looking at where we are now and saying we need to make that change and that there’s a fantastic honesty and progression to how you’re sourcing materials”* (FB1).

Young people are seen as crucial to the adoption of new non-traditional crops and practices. The high cost of land makes it difficult to take risks or for young new entrants to get a foothold. One participant suggested that county farms (owned and let by local authorities), many of which have been sold off in recent years, could be revived as spaces for innovation, training, and demonstration in natural building materials (FC2).

Seasonal farm workers coming from low-income countries said they had more immediate financial priorities to attend to than the wider problem of climate change, but were supportive of the concept of producing sustainable materials on farms, especially after being involved in the project. One participant explained his relationship to the notion of sustainability:

*“I’ve never been that type of guy. I think I was more the type of guy, what I was, I need to make my money and I had other focus on my mind. I have to be honest with you, I never pay too much attention to that [...] now that I’ve seen how this process is, yeah, I think there’s something very important”* (FW1).

They believed that it could offer a cheaper way to build in their home countries, if done by hand with waste products from farms, where this practice already existed and was common in the recent past (FW5).



#### 4.11. Policy

Several participants emphasised broader systemic barriers. Government policy incentives and initiatives to support change in farming and construction were seen as critical. Many participants highlighted that there is a need in the UK for new policy, tax and regulations around embodied carbon (similar to those in the EU) to drive the market for bio-based products and incentivise builders to use locally produced plant-based building materials. One participant suggested that if flax and hemp growing could be incorporated into the Sustainable Farming Incentive Scheme or a similar ecosystem payment scheme (potentially connecting it to carbon credits) that it would drive uptake among farmers (FC2). Brexit has affected the availability of labour and added pressure to arable farms who previously received EU subsidies. However, one farmer said that they prefer to go without government help, instead preferring to build an independent sustainable farming business that is not vulnerable to frequent changes in policy and funding (F5). Smaller farms said they would benefit from more support as they currently do not have access to the same funding or finance as larger farm businesses, so are less able to invest in new machinery or experimental practices (F6).

Issues around gaining planning permission for sustainably built workers' accommodation, using materials grown on farms, were raised by several participants. Even with this proof of adherence to building standards, farm estate managers, fabricators and developers we interviewed felt that there may still be fear of risk and resistance to the use of unknown materials from building control officers, insurers and house buyers. Several participants suggested that there was a need to go beyond financial incentives, with regulation having an important part to play in change (FB1, D1).

*"You know, you have to put pressure on those people to actually make that change [...] The carrot and the stick, isn't it? [...] That's how industries like the building industry move. They don't do it for the love, they do it because they have to."* (D1).

The expectation for conformity and low tolerance for deviation from standard materials is prohibitive to the development of plant-based materials. One fabricator said that it should not be the



responsibility of each farm to continuously test individual batches, but that the industry needs to work towards a standard with reasonable tolerance for seasonal and natural variation (FB2).

Even if things have begun to change in relation to policy and building regulations, the perception of farmers is still that 'we don't live in that world yet' and that sustainable materials are too expensive to be profitable to produce. One farm felt it was important to provide data and measurements of success relating to other values and costs, like carbon, access, water and well-being, to overcome scepticism and increase confidence in new sustainable methods of farming and production.

Labour experts highlighted the importance of well-run temporary migration programmes, properly integrated into labour ministries operations in developing countries, to enable seasonal workers to access funding for international knowledge exchange and implementation of sustainable methods and skills more widely.



## 5. Implications of research findings

### 5.1. Research problem

A decentralised 'Harvest to House' approach, where insulation materials are grown, processed and manufactured on the farm, was set out at the beginning of this report as a complementary alternative to the traditional pathway for manufacturing and distribution of building products. This vision faces many obstacles, including: tight financial and operational constraints on farms; an agricultural labour crisis; a need to align with existing infrastructure and seasonal workloads; competition from cheaper building products; and a need to meet building standards.

The Ag. Lab research project has been focused on the question:

*How could a small-scale, farm-based system for producing plant-based building materials function so that it is economically and operationally viable for farmers and attractive to workers?*

We aimed to investigate and test the potential for use of existing crops, farm machinery and skills across all stages of a harvesting and insulation block manufacturing system, and to examine the complex human, environmental, and operational barriers and opportunities for sustainable farm-based material production.

In answer to the research question:

*There is currently no viable single solution for harvest and manufacture of blocks on the trial farm with existing infrastructure and labour.* However, most elements of the process and regime were tested and demonstrated to have potential. With adaption to machinery, harvesting methods and recruitment, it would be possible to make insulating materials on the trial farm and generate income from their sale. Diagram 1. (page 40) shows the potential routes to harvest. Diagram 2. (page 44) illustrates the potential block manufacturing processes possible from these harvesting options. The discussion below examines the findings from the research and sets out the barriers and opportunities for making plant-based insulation on farms.

### 5.2. Fitting into the farm – Harvest

*Sweetcorn is good insulating material and performs like hemp:* Testing of materials created in the course of this project, including for compressive strength, resistance to fire and thermal conductivity, have shown that performance of a sweetcorn aggregate, when combined with a lime-clay binder, is comparable to that of hempcrete and other commercially available insulating plant-based blocks. Whilst this gives a basic understanding of performance and the material potential, further independent testing would be required for detailed comparison and certification purposes. Sweetcorn varieties are smaller and less diverse than they were 20 years ago, but they be bred in the future to satisfy two different needs from one plant. Potentially optimising the length and thickness of the stem for insulation, whilst retaining the value and properties of the food crop. Some farmers have indicated that they are willing to sacrifice some of the yield of a food crop if the value of two harvests combined makes it profitable.

*Current machinery compromises plant material quality and limits harvestable volumes:* Current harvest machinery compromises the quality of more than half of the potential crop of plant fibre and makes collection very challenging. Efficient mechanised harvesting of a dual crop, in the absence of manual labour, to harvest the sweetcorn cobs, would require a new specialist 'combine' harvester, as current machinery options (forage harvester and rotary rake) are not fit for purpose. This machinery does not yet exist and in the event, would likely be prohibitively expensive for small to medium scale farms, unless harvested by a shared specialist contractor. However, a combine harvester, capable of picking cobs (or other crops) and preserving the rest of the plant in good condition, might be an answer for wealthier farms in the future.



*Crop damage from sweetcorn harvester*

*Hand-picking would allow use of the full plant and reduce soil compaction:* When the sweetcorn is hand-picked, 95% of the plant remains and can be harvested efficiently by a for-age harvester. This dual harvest is a much more efficient use of biomass. However, the re-introduction of hand picking would prove difficult for farmers who have deliberately reduced labour inputs over time and invested in specialist harvesting machinery, optimised for collecting the food crop in good condition. Recruitment challenges, provision of accommodation, as well as associated admin, logistics and wage costs for extra workers would be a disincentive to farmers. The speed of harvest and the slow speed of hand-harvesting would also limit potential. However, the income from significant volumes of plant material, especially if value is added by processing on the farm, could make the proposal attractive to some farmers. Or they may consider a combined approach, where a portion of the crop is picked by hand and another harvested by machine.

*Using crop by-products for fibre is a more efficient use of good quality agricultural land and plant material:* In theory, the value of the food crop could pay for, or at least subsidise, the high cost of harvesting a plant by-product for construction fibre, and could allow the farmer to trial new ventures with less risk. Long lead times for changing crop rotations, to accommodate stand-alone fibre crops would also be avoided, where farms can continue to grow existing crops. Though with tight margins from current crops, there is still some associated risk, especially in a bad weather year. Arguments against the use of plant-based materials for construction and narratives about 'diverting land from food' are faced by farmers and developers alike, and the use of by-products from existing crops offers an ideal solution.

*Forage Harvesting is the most efficient way to shred plant material:* A forage harvester can quickly shred all plants in the field, into pieces at the optimal size for use as aggregates in insulation blocks or loose applications, with no need for additional equipment. This is a great example of efficient and cost saving use of existing agricultural equipment, as it removes a step in the manufacturing process, adding value to the product for the farmer.

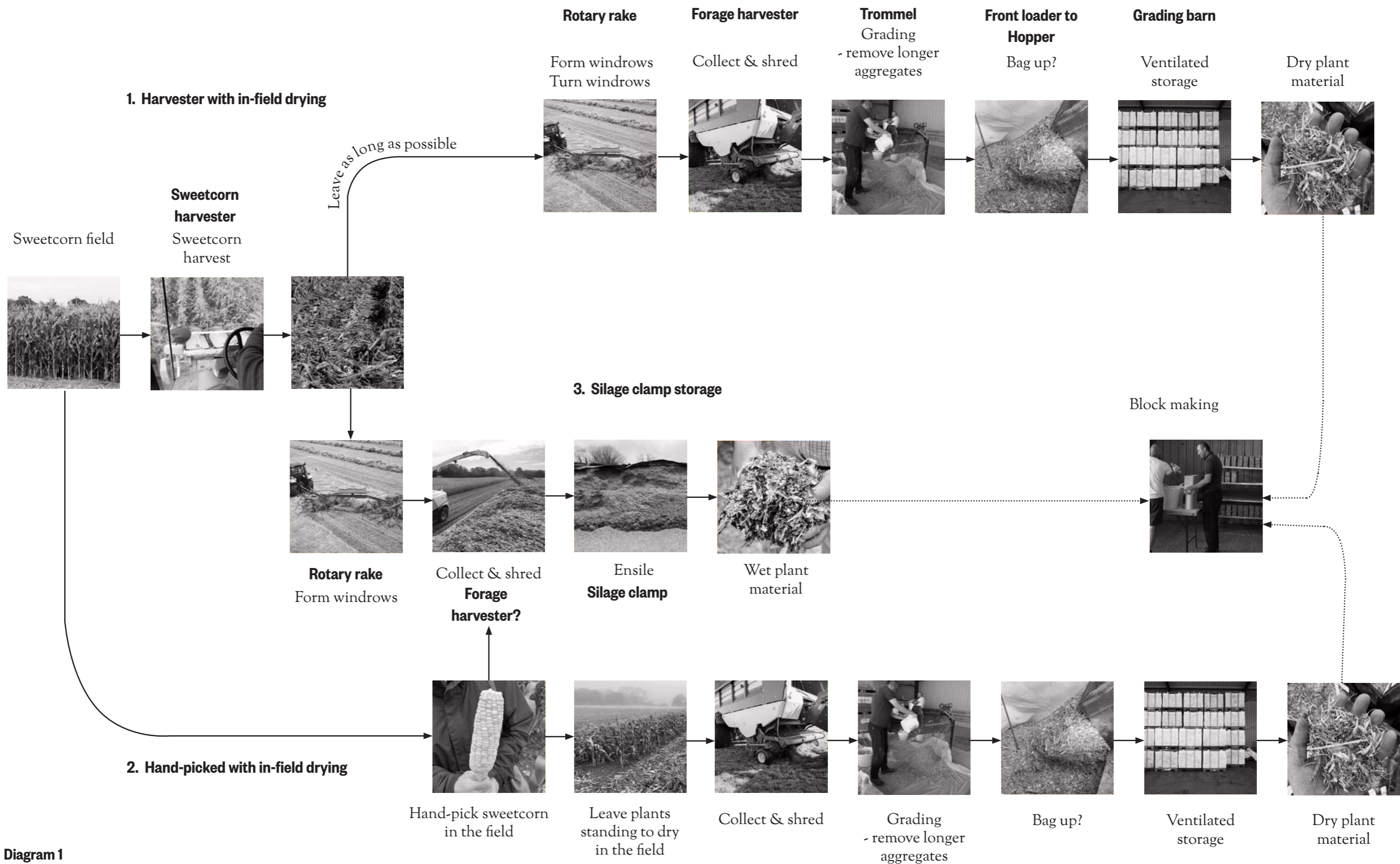
*Extraction of biomass must be balanced so that soils do not decline in health over time:* The research trial farm follows a relatively conventional agricultural system, growing monocultural crops on short rotation and currently incorporate at least half of the plants back into the soil, with some artificial fertiliser inputs. Organic and agroecological systems, that may offer more resilience in the future, rely on closed systems where biomass from crop residues feed the soil. On mixed farms arable farming can rely more on animal inputs. A system that makes efficient use of the land, to get the most from a given crop, must be finely balanced to ensure soil health, fertility and yield is not diminished over time by extracting too great a proportion of the biomass grown. Any design for future use of plant materials in the construction industry need to be adaptable to more sustainable farming practices to avoid perpetuating environmental problems associated with industrial agriculture.

*Sweetcorn is not a panacea and must be combined with other plants to meet construction material needs:* Whilst sweetcorn has potential to be a good alternative to other plant aggregates, it is limited by climate and is being grown at the limit of its range in the UK. With seasons increasingly variable, it is a risk to farmers tied into contracts, and to house builders who might rely on their supplies, to invest all energies into one species of fibre plant, across diverse soil types and regions. Monocultural agricultural solutions put additional strain on ecological systems, therefore more diverse approaches must be considered to mitigate risk to investors and natural systems.

*Drying plants after harvest requires energy and space that the farm does not have:* Drying the plant residues after the food crop has been harvested in the field, and storage of dried material at the farm, has proved to be very challenging, requiring multiple processes,



*Silage clamp with shredded Maize for cattle fodder. Processed by a Forage Harvester*



**Diagram 1**  
Potential routes to harvest

vehicle movements and extra energy. This limits the possibilities for use of these materials as part of the current regime on the trial farm, however, thinking about the problem with the farmer and workers has led to identifying unique solutions and compelling avenues for future research (See unexpected findings below).

### 5.3 Fitting into the farm – Manufacturing

The idea of creating local, seasonal products was widely supported in principle. Yet this enthusiasm was tempered by a strong sense of realism about the difficulties of actually setting up and running such systems.

*“The initial reaction to your project is, wow, that’s everything I believe in [...] And then a really cynical part of me just starts thinking about the process of actually doing it [...] But that’s why it’s important to work through it and see what is possible” (F1)*

Participants raised concerns about scale - for small projects, such as retrofitting a farmhouse, sourcing material from a single site might be feasible. But for housing developments of hundreds of units, larger and more secure supply chains would be essential. Farm size and type appeared to shape perceptions of feasibility. Larger arable farms, which run with less labour overall, might also find it easier to add a parallel enterprise.

*Block making is accessible, but complexity of process limits its potential on farms:* Mixing a plant-material with binder, pressing it into a mould and stacking is a simple skill to learn and teach. However, block making by hand requires multiple processing and handling steps and some skill to deliver consistency. This complexity adds time and cost, requiring semi-skilled labour to implement and experienced staff to supervise, with multiple small opportunities for variation from standard. A block making machine reduces some of this time and inconsistency, but is a significant outlay and still requires skilled labour and logistical infrastructure, like moulds, making areas, shelving, pallets and clean down equipment. Diagram 2. Illustrates the block making process trialled in this project.

*Block drying is challenging – using valuable space and energy:*  
Both methods of block making require large

amounts of space to dry blocks consistently. An adapted concrete block making machine requires large areas of hard surface to operate. To avoid the addition of cement binders, this space also needs to be protected from the weather. Whilst hand-making blocks could be a viable option on a small scale for on-farm use, smaller farms often have less space to spare, especially undercover.

*Blocks have potential for small projects and on-farm use:* Smaller, more adaptive farms, where some work is already done by hand, saw advantages in flexibility. These farms could benefit from small scale block making by hand, that uses spare moments in the season or winter months for fabrication – making and drying blocks incrementally, adding to a stored stock over time, or slowly working on a farm building project. Local single dwelling developments may also benefit from the accessible size and form of blocks that are familiar to building trades. Tactical use of farm labour, or ‘Sweat equity’, would enable small farms to insulate, low-carbon accommodation and workspaces at a reduced cost.

*Bulk is best for on-farm production with existing infrastructure:* The easiest way for plant-based



Filling a block mould

insulation to be made using existing farm infrastructure and the current skills of the farm workforce, would be to produce aggregates in bulk. With investment in a large tractor mounted, or standalone mixer, and hopper (where the farm does not already own it), a simple ready-mix batch plant could produce bulk material for spraying into building frames. There may also be opportunities for partnerships with makers of prefabricated cassettes, which could be filled with bulk material, are preferred by industry, and are more economical to make than blocks. This production could be slotted neatly into existing farming systems without adaptation, but less processing means less opportunities for farmers to add value, shorten the supply chain and get a better return for the crop.

*Production needs to be reasonably accessible to roads and close to development sites:* It was widely felt by farmers, fabricators and developers that fabrication at a central site, close to main roads and local housing development sites would be essential for production to be logistically viable at scale. More remote farms may conversely benefit from producing their own materials for use on the farm estate, avoiding the cost of transport to the farm.

*There are a range of potential outputs according to the size of farm:* There are several options for scale of production that vary according to the capacity and size of the farm. Illustrated in Table 2. (page 46) are potential options for production and fabrication modelled on some of the participating farms.

### 5.4 Fitting into the farm - Labour

*Full-time farming teams don’t have time for insulation production without substitution of activities:* For all scales of farm, the seasonal timing of fabrication was a concern. While the idea of spreading work across quieter periods was attractive in theory, in practice many doubted whether there was genuine ‘slack’ to make it work. Lack of time and resources makes further allocation of tasks to other initiatives a risk, though growers on smaller farms said that they might appreciate having alternative extra work for workers reduced to part-time hours in the winter months. Any new business would entail sacrificing time currently dedicated to other farming activities and would need to be demonstrably profitable. Given the demands on full time farmers fabrication may need to be implemented by a combination of

dedicated, seasonal and part-time staff.

*Seasonal Workers visas are an unresolved barrier to on-farm production:* One unresolved issue is whether migrant seasonal workers, who were identified as having capacity to fabricate during or at the end of the season, would legally be permitted to carry out block fabrication as part of their contracted farm work. We were unable to obtain clarification from the Home Office and without a clear policy position, farms and labour providers may be reluctant to involve migrant workers in fabrication, limiting the available workforce. Seasonal workers have an interest not only in the extra work and earning potential in fabrication, but also in developing new skills and potential improvements to accommodation.

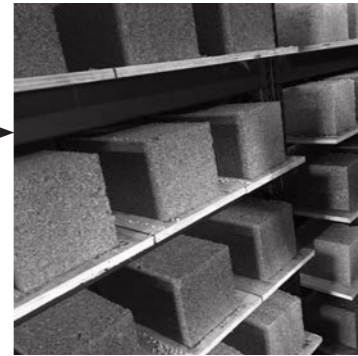
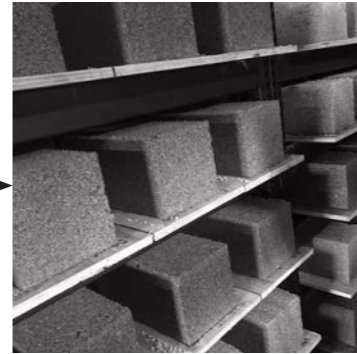
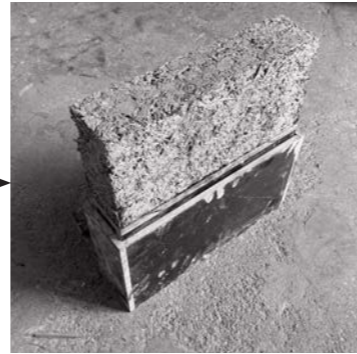
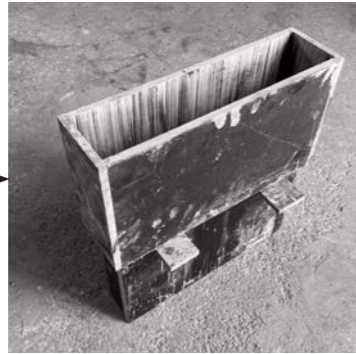
*Communication of future agricultural roles could help recruitment from domestic workforce:* Misunderstanding of the nature of work available on farms appears to contribute to recruitment difficulties, where workers fail to understand or meet requirements of the farm. Negative perceptions of agricultural also need to be overcome and there is a wider national agricultural labour crisis that fabrication alone cannot solve. However, new ventures like insulation production, with carefully designed labour models that balance productivity with fairness, offer an opportunity to attract domestic workforce with ‘good work’. The creation of new skilled job roles on farms could be attractive to domestic workers if offered as part of a varied repertoire of tasks. New roles would need to be clearly communicated to educational institutions and the wider public to maximise the opportunity for change.



Packing sweetcorn for local market

**Blend**  
materials in a  
forced-action  
mixer with  
water

Covered barn,  
water and  
electricity supply



**Prepare**  
slip mould

**Tamp**  
the material  
lightly into the  
mould

**De-mould**  
the block  
immediately,  
transfer carefully  
to drying rack

**Cure**  
the blocks  
initially  
for 10 days  
with no heat

**Dry (option 2 - preferred)**  
the blocks  
for 2 weeks in dry, warm  
weather

April - October only  
Open sided barn

**Store**  
the blocks  
on pallets in a dry,  
covered space



**Machine fabrication**

Artificial drying

**Dry (option 1)**

the blocks  
artificially with warm air  
movement for 1 week  
November - March

**Diagram 2**  
Potential block manufacturing processes

	<b>Small Farm</b> <i>Arable</i> 16 acres 8 FT Staff	<b>Medium Farm</b> <i>Mixed</i> 200 acres 60 acres arable 3 FT Staff	<b>Large Farm</b> <i>Arable</i> 500 acres 5 FT Staff 12 Seasonal Staff	<b>Very Large Farm</b> <i>Mixed</i> 2500 acres 800 arable 14 FT Staff	<b>Very Large Farm</b> <i>Mixed</i> 3500 acres 1800 arable 3 FT Staff	<b>Co-op Hub</b> <i>Mixed</i> 3-6 Large 6-12 Small - Med Farms
<b>On-farm</b> <i>Retrofit dwelling</i>	<i>Bulk aggregate (Small building)</i>	<i>Bulk aggregate</i>	<i>Bulk aggregate</i>	<i>Bulk aggregate</i>	<i>Bulk aggregate</i>	
<b>On-farm</b> <i>New dwelling</i>	<i>Blocks Bulk aggregate (Small building)</i>	<i>Bulk aggregate</i>	<i>Blocks Pre-fab modules Bulk aggregate</i>	<i>Blocks Pre-fab modules Bulk aggregate</i>	<i>Pre-fab modules Bulk aggregate</i>	
<b>On-farm</b> <i>Industrial unit</i>	<i>Blocks Bulk aggregate (Small building)</i>	<i>Bulk aggregate</i>	<i>Blocks Pre-fab modules Bulk aggregate</i>	<i>Blocks Pre-fab modules Bulk aggregate</i>	<i>Pre-fab modules Bulk aggregate</i>	
<b>Exemplar off-site</b> <i>New private dwelling</i>		<i>Bulk aggregate</i>	<i>Pre-fab modules Bulk aggregate</i>	<i>Blocks Pre-fab modules Bulk aggregate</i>	<i>Pre-fab modules Bulk aggregate</i>	<i>Blocks Pre-fab modules Bulk aggregate</i>
<b>Exemplar off-site</b> <i>Public building</i>			<i>Pre-fab modules Bulk aggregate</i>	<i>Blocks Pre-fab modules Bulk aggregate</i>	<i>Pre-fab modules Bulk aggregate</i>	<i>Blocks Pre-fab modules Bulk aggregate</i>
<b>Local Housing</b> <i>Retrofit</i>			<i>Bulk aggregate (1-10 Dwellings)</i>	<i>Bulk aggregate (11-25 Dwellings)</i>	<i>Bulk aggregate (26-50 Dwellings)</i>	<i>Blocks Pre-fab modules Bulk aggregate (50+ Dwellings)</i>
<b>Local Housing</b> <i>New development</i>			<i>Bulk aggregate (1-10 Dwellings)</i>	<i>Bulk aggregate (11-25 Dwellings)</i>	<i>Bulk aggregate (26-50 Dwellings)</i>	<i>Blocks Pre-fab modules Bulk aggregate (50+ Dwellings)</i>
<b>Supply to industry</b>						<i>Blocks Pre-fab modules Bulk aggregate</i>

**Table 2**  
**Production options**

*New entrants interested in sustainable ventures need a foothold:* Despite these issues around recruitment there was optimism about younger workers and people from farming and non-farming backgrounds being drawn to meaningful, hands-on block making. 'There's people who really want to work with their hands and really want to do something they feel is worthwhile,' suggesting a niche but growing interest. However, farmers highlighted limited opportunities to access land. (See Unexpected Findings and Opportunities, below).

*Young workers want 'good work':* It was considered by some participants that work on farms does not always meet ambitions for 'good work' set by government and that this is a disincentive for young people with higher expectations than older generations. In order for fabrication work to appeal to domestic and EU workers it needs to be more varied, intrinsically rewarding and offer opportunities for autonomy. Roles for workers in new sustainable industries must appeal to young people who are more aligned with this type of work. They need support to enable them to develop skills and experience necessary, as well as opportunity.

*Strategic use of machines is essential, but some manual labour can lead to better outcomes:* Agricultural machines, methods and systems are optimised to reduce risks associated with variability in weather, environment, and in economic and labour markets. Tactical use of machines and fuel at optimum times is used by farms at all scales. There are moments in agriculture when strategic use of large, expensive, shared (contracted) machinery is indispensable to avoid spoilage and get the harvest in. At other times, some slower, careful hand picking can be beneficial in terms of efficient use of resources (low waste) and preservation of the valuable properties of materials, soil and food. In the creation of new roles farmers will need to ensure that the intrinsic reward and opportunities for nature connection that make farming and land-based occupations worthwhile are retained and not entirely substituted by mechanisation in pursuit of efficiency.

### 5.5 Knowledge and training

*Farmers need support in new material ventures from skilled supervisors and experienced consultants:* Farmers and workers have hidden skills and a work ethic that could be valuable in the manufacturing process.

They would, nevertheless, need to be supported in any new building materials enterprise by skilled, experienced and knowledgeable consultants and staff who could supervise and organise production on the farm.

*Opportunities for international exchange of sustainable practices:* Many Seasonal Workers come to the UK to develop skills and could take home new experience and knowledge. Labour providers say there is potential for knowledge exchange that could help disseminate sustainable building and farming practices and improve economies of developing countries. Some Seasonal Workers have existing knowledge and experience of low-carbon building practices that could help them in their work and add value to new plant-based construction material businesses in the UK. Labour providers and ministries in the UK and abroad could have a role to play in promoting this exchange; incentivising suitable recruitment with funding; and supporting policy change to allow more flexible work on UK farms.

*Education needs to encompass new technology, sustainable production and diversified roles in farming:* It was widely reported that young people were not being fully prepared for future roles in farming by educational institutions and that this exacerbated recruitment issues. There is an opportunity for colleges to combine expertise in construction and agriculture and prepare students for new roles, including growing for construction fibre and material processing on farms.

*Farmers must work together to thrive and embrace new opportunities:* In the recent past farming would have been at the centre of village life, with hundreds of stakeholders and dependants on the land.



*Learning together and making alliances at Groundswell*

Farming is still a social occupation, but farmers are increasingly working alone, or in small teams across huge swathes of land. The farm social ecosystem these days is less complex, less diverse and more vulnerable when faced with dramatic change. Pools of localised knowledge and experience are shrinking. Farmers will need to support each other now more than ever, despite a culture of independence, to embrace new challenges and opportunities, such as providing building materials as well as food. In a context of increasing isolation for farmers, community building appears to be key and new ventures could help support this by providing structure and another financial incentive for pooling resources and know-how (See Unexpected Findings and Opportunities, below).

### 5.6 Rural worker housing and building

*Finding good housing is a limiting factor for recruitment:* Where farms already provided good housing and subsidised rents, they found it far easier to attract and keep staff. In contrast, farms with poor accommodation and poorer conditions struggled, even when offering similar pay. This suggests that the value of insulation blocks could extend beyond commercial sales, contributing directly to worker welfare and recruitment.

*Workers and farms need insulation:* Workers across a range of farm scales reported issues with finding well-insulated affordable accommodation near to their workplace. Seasonal and domestic workers living on farms often have problems with thermal comfort in their housing and working buildings because of the nature of temporary accommodation provided. Farm estates frequently need to retrofit older buildings for housing and business use, suggesting that an efficient and flexible solution for growing and making their own insulation materials could be worth the investment.

*New accessible certification and standards are needed for variable plant aggregates:*

The building industry is risk averse and requires reassurance on the quality of farm grown materials. To conform with building regulations for dwellings, blocks need to have certified data that demonstrates they conform to current standards for U-Values, fire resistance, weight, damp, ventilation and mould. The expectation for conformity and low tolerance for deviation from standard materials is prohibitive



*Prototype blocks stacked outside seasonal workers accommodation*

to the development of plant-based materials that are affected by seasonal and natural variability. The cost and administrative burden of independent testing and certification for individual batches and products is out of reach for most farming businesses and will likely slow uptake. Testing, certification and new grading standards therefore need to be developed that provide safe control, but also have a reasonable tolerance for variation, like those applied to other inert natural materials such as sand.

*Demonstrator buildings are needed to increase confidence in new methods:* Even with proof of adherence to building standards, farm estate managers, fabricators and developers we interviewed felt that there may still be resistance to the use of unknown materials from building control officers, insurers and house buyers. More funding is needed for demonstrator projects to support confidence within industry and the public, as well as supportive planning policies. Even with changes in industry and government directives, the perception of farmers is still that 'we don't live in that world yet', so change would need to be supported by public information aimed at potential alternative producers. Demonstrator retrofit and new building projects in lower risk non-residential applications like industrial units, farm buildings and animal shelters, could provide valuable evidence, data and feasibility studies, helping to build confidence before expanding into the worker accommodation or local housing.

### 5.7 Economic viability

*Cross-sector collaboration and funding is needed to underwrite the risk of trials on both farms and buildings sites:* Funding and a government (DEFRA)

supported program is needed to underwrite the risks assumed by farmers when trialling new crops and methods and to encourage developers to build more with plant-based materials. There also needs to be funding for cross-industry research and experimentation by organisations and companies who are experienced and aware of the opportunities and challenges faced in both construction and agricultural sectors. Sustainable materials and systems need to be developed, tested and applied in real world projects and settings.

*Carbon costs and externalities of material production need to be recognised to prevent unfair competition:* The price of building materials and products does not reflect the externalities of their procurement - the cost or benefits embodied in their extraction and processing. Many farmers felt that 'good' sustainable materials, like those with potential to be made from crop waste on farms, cannot compete in the current market and this economic conundrum is currently impossible to solve. However, one developer was optimistic about costs coming down in the near future and the cost of non bio-based construction going up 'because people attach a cost to carbon'. There is a need in the UK for new policy and regulations around embodied carbon (as in the EU) to drive the market for bio-based products and incentivise builders to use locally produced plant-based building materials.

*Competition from other markets such as biogas complicate economic models:* The energy market has distorted and inflated the price of foraged maize, increasingly used as feedstock for Anaerobic Digester (AD) plants, which potentially makes fibre crops more expensive to buy in for construction. This would likely raise the cost of block or bulk



Medium to large scale building material processing at a fabrication company in the UK

insulation materials bought for insulation and adds complication to any predictions of economic viability. This will be a consideration when looking to alternative production methods identified by this research, like the use of silage (See Unexpected Findings and Opportunities, below).

*Plant-based insulation blocks are currently perceived as an extravagance:*

*"My experience has been slightly disillusioned, of thinking about natural materials and their role in construction over the last few years and not seeing it shift...builders saying they're going to use standard products, 'we've got to keep it low cost' and not thinking to even introduce the idea of natural materials, which is sad I think" (FC2).* Several participants raised concerns about whether small-scale production could ever be economically viable. As one fabricator explained, unless thousands of blocks can be produced per day, the costs may render them a 'luxury' rather than a practical, affordable material. This tension between small, decentralised production and the demands of the construction industry is a critical issue for future trials.

### 5.8 Unexpected findings and opportunities

*Ensiling could offer the most practical storage method for construction plant fibre:* Farmers suggested that the difficulties of drying and storing plant-aggregates can be overcome by considering anaerobic 'clamping' of materials. This method works within existing farming systems without adaptation and makes use of redundant infrastructure. The damp storage method would allow efficient harvesting and shredding of plant material by forage harvester immediately after the cobs are collected and would avoid risks associated with drying material. Ensiling is a good storage alternative well known to farmers. The silage clamp can be added to incrementally and provides a simple on-farm bank of material for use when needed, with little wastage. Though the material is perishable long-term, it can be kept for between 3-5 years, if necessary. Ensiling could also open the door to the use of mixed plant species, including commonly grown break and cover crops that have ecological benefits and are currently eligible for funding. Any future silage system for construction fibres would need to be carefully designed to minimise associated methane emissions of silage and maximise quality of the material. Preliminary tests of ensiled maize in insulation

blocks were made by Local Works Studio using a wet mix. There are currently no available products or materials made using this method and further research will be needed to assess properties and performance of the material over time. Though this material research is beyond the scope of this project, initial results were promising.

*Local processing hubs and farmers cooperatives could mitigate risks of production on farms and build supportive networks:* A co-operative led by producers, with farmer owner-members alongside other stakeholders could allow farmers to get better returns from crops and produce plant fibre insulation at a scale that suits local development. A processing hub, sited on a farm close to bigger road networks could mitigate risk and enable purchase of any specialist equipment and shared machinery. Supply of building materials is potentially more consistent and flexible if a stock of materials can be gradually built up in storage before sale, enabling year-round fabrication, construction and retrofit. It was suggested by a group of farmers and community land managers that, to begin with, bigger producers could generate demand, which would stimulate more confidence and supply at a regional level. Later, regional import substitution could allow smaller local processing plants to supply local development. In this case, processors could work with farmers to generate reliable supply. A cooperative processing hub could, therefore, make production more efficient, spread costs, and help smaller farms access new markets.

*County farms could become test sites for crop and production run by new entrants:* It was suggested by participants that county farms (owned and let by local authorities), could be revived as spaces for innovation, training, and demonstration in natural building materials. This could give younger farmers and those interested in sustainability a way into the sector and help bridge the gap between farming and construction. Crop trials and affordable on-site housing built by farm residents could provide valuable data and experience.

### 5.9 Limitations of research

The Ag. Lab. research project was originally planned to run for one year, however, it was extended to accommodate two harvests on the farm. The project team found that practical research on

farms requires more than one year to gain sufficient understanding and to provide opportunities for tests across the multiple seasons.

The scale of machinery on the farm, and cost of contracted machinery, meant that not all mechanical harvesting and processing options could be tested. Where possible a manual or small-scale substitute activity was trialled in the place of large machinery like the forage harvester, rotary rake, industrial forced action mixer, and tree surgeons' shredder. Where this was not possible, or comparable, we interviewed farmers with sufficient experience in these processes to assess their potential for use in the manufacturing system.

Because the research period fell awkwardly across the year, and the trial was on a working farm, it was not possible to test the whole harvest and manufacturing system at once, but elements of the system were tested individually, asynchronously. This underlines the gap between proof-of-concept prototypes and a fully viable system of manufacture.

Within the expertise of the project team it was not possible to make a full assessment of financial feasibility of the fabrication options, especially with so many potential options and within the context of an unpredictable climate and market.

Though testing was done to British Standards in the workshop, with one independent test, the cost of further independent testing, including U-Value tests, was found to be prohibitive and beyond the budget of the project.

A wide range of interviewees participated in the research, but there were some missing perspectives, particularly of younger people and new entrants.



Different blends of insulation for testing. Local Works Studio

Interviewing seasonal workers proved to be challenging as the project period and short harvest season did not allow enough time to build trust with migrant workers and very few workers had sufficient English to give consent and participate in interviews.

The trial was run on a relatively conventional farm and it will also be important to understand how the harvesting and manufacturing of crop by-products for fibre might work on in alternative more sustainable farming systems.

### 5.10 Recommendations for further research

- *Ensiled storage of plant fibre for construction:* Feasibility study into silage storage of harvest by-products for construction. Including operational and material testing.
- *Multi-species plant aggregates:* Investigating blends of other crop by-products (break crops etc.), for use as construction insulation.
- *Forms of housing for workers using farm materials:* Investigating the retrofit and new-build of farm housing, using outcomes such as: bulk plant aggregate for plasters; structural/insulated cassettes and insulation blocks.
- *Feasibility study to compare insulation outcomes:* Desk-based study into the operational process, economies of scale and economic variables of on-farm production. This 'proof-of-concept' could help to give confidence and encourage farmers into diversifying into crops for building materials.

- *Develop standards for variable plant materials:* Provide testing data and measurements of success relating to variable plant aggregates for insulation materials. Referencing existing variable standards in sands and aggregates for construction. To overcome scepticism and increase confidence in new sustainable methods of farming and production.
- *Agroecological farm model:* Investigating a holistic alternative to industrial, conventional agriculture with cross-disciplinary research, combining expertise in sustainable construction and agriculture.
- *Plant breeding for food crop and fibre:* Growing trials to develop cultivars for maximum volume of plant fibre plus a food crop.



A maize clump, with silage, currently used for cattle feed



UK fabricated insulation blocks made using Miscanthus fibre

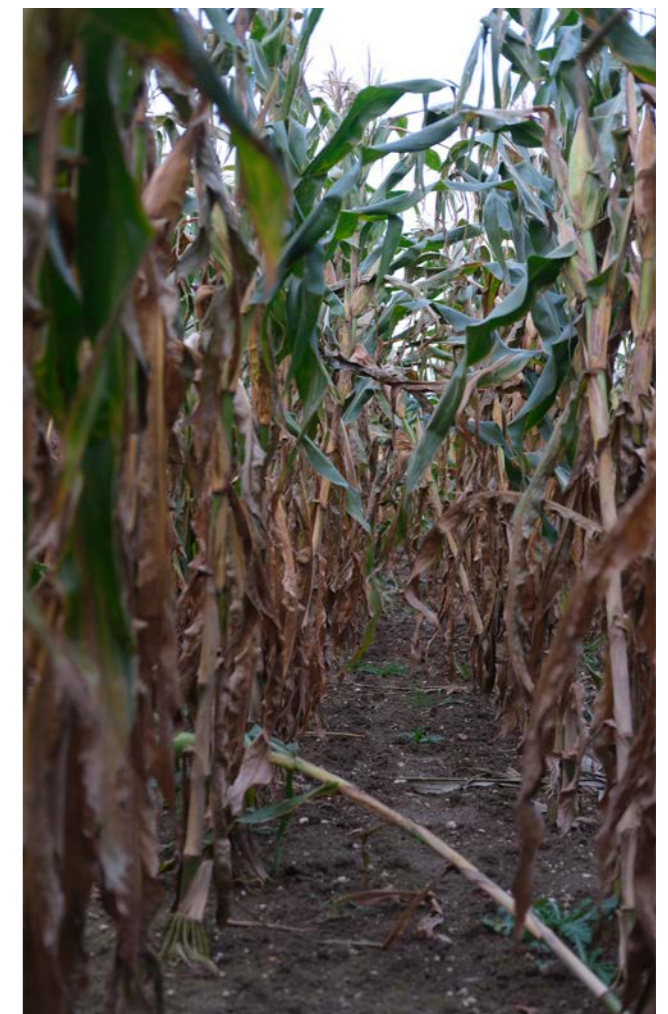


Farm buildings and worker's caravans in need of insulation

## 6. Summary of key findings

- Sweetcorn aggregates - when combined with a binder - make a good insulating material and perform in a very similar way to hempcrete
- Hand-picking sweetcorn cobs would allow the use of the full undamaged plant for fibre, and reduce soil compaction
- Extraction of biomass for use in construction must be balanced so that soils do not decline in health over time
- Block making is accessible, but complexity of the process limits its potential on farms
- Insulation blocks have potential for small projects and on-farm use
- There are opportunities for international exchange of sustainable construction practices
- Education needs to encompass new technology, sustainable production and diversified roles in farming
- New accessible certification and standards are needed for variable plant aggregates within construction
- Cross-sector funding is needed to underwrite the risk of trials on both farms and buildings sites
- Farm workers accommodation and other farm infrastructure requires insulation - preferably sustainable and breathable insulation, made from plant by-products
- Demonstrator buildings are needed to increase confidence in new methods
- Using food crop by-products for fibre is a more efficient use of good quality agricultural land and plant material
- Ensiling could offer the most practical storage method for construction plant fibre

- Local processing hubs and farmers cooperatives could mitigate risks of production on farms and build supportive networks
- County farms could become test sites for crop and production run by new entrants



## 7. Conclusion

*“It was sweetcorn at first, it’s a bigger, bigger, bigger picture than that, sweetcorn is a lovely part of the story, and that’s why we’re all sitting here, but it’s a way more sprawling beast than that.” (Fi)*

There is an urgent need in the UK for new plant-based building materials that are sustainably grown, made and distributed. The aim of our research was to investigate the opportunities for a decentralised, ‘harvest to house’ approach to the manufacture of construction materials, using the waste from existing food crops, processed on the farm.

Every farm and landscape is unique and there is no off-the-peg solution that will work in all contexts. Any national solutions to the intersecting crises of climate, biodiversity and housing must be adaptable to the environmental and social particularities of every region and ecosystem. The Ag. Lab. project was based on just one farm for one year, but the issues it revealed and the solutions it offers are larger than the sum of its parts.

The research demonstrated the complexity and difficulty of trying to produce a consistent product in inconsistent conditions. It was found that, instead of a single system that could be rolled out and adapted to every suitable small or medium farm in the country, there are a range of viable approaches to producing insulating materials from crop residues, that vary in scale and form according to the capacity of the farm. The project has confirmed that such work holds appeal for farmers, workers, and developers alike, providing it can be adopted without significant disruption to already stretched farm systems.

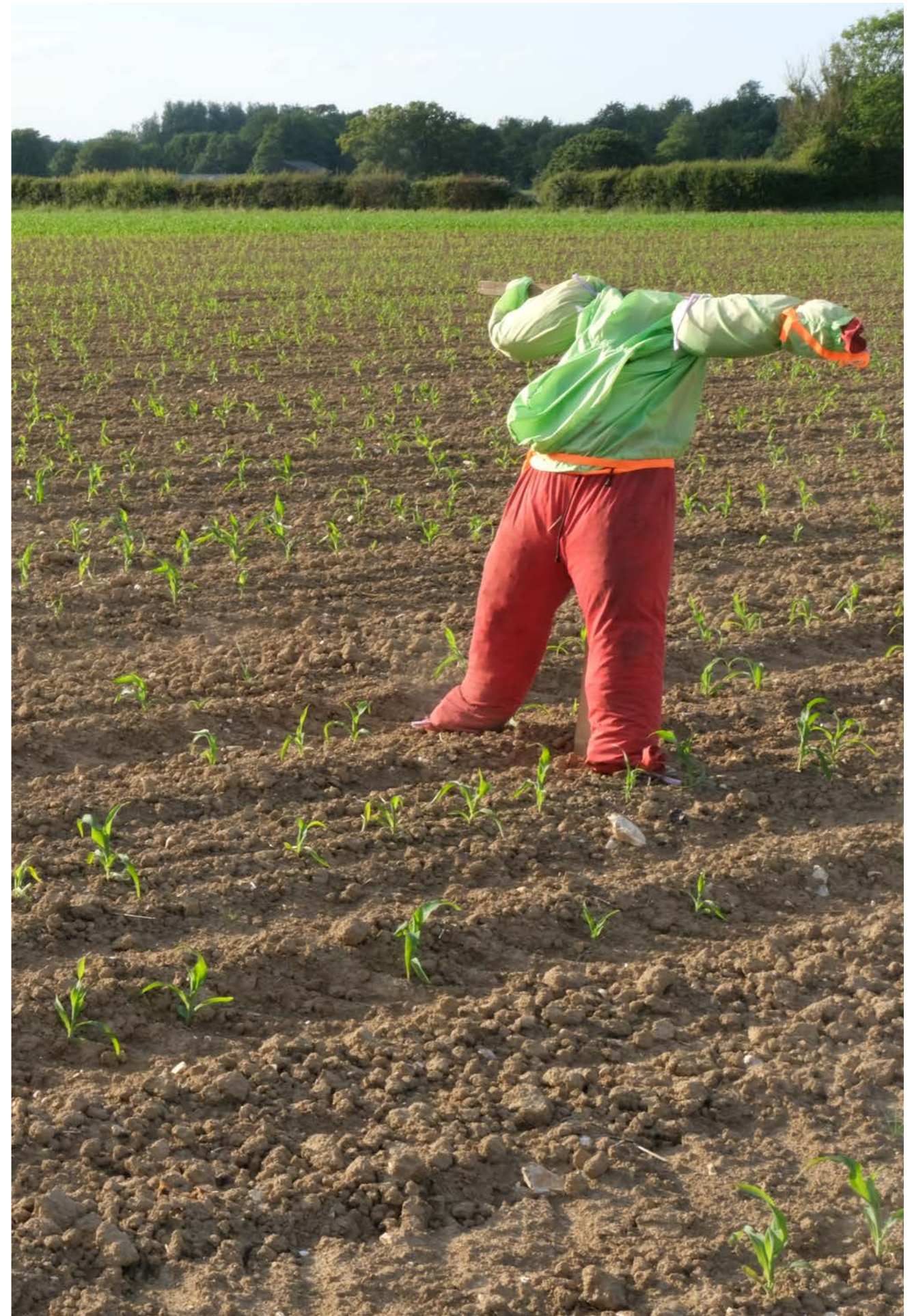
The reliance on machines for economic survival and progress in agriculture has had some negative consequences for people and ecology and on our trial it also compromised the potential to extract a good fibre product. Our research revealed that a strategic approach to mechanisation combined with skilled manual labour could allow for an efficient use of whole crops, whilst providing varied, intrinsically rewarding work, as well as retaining human connections to the land and making processes that are currently lacking.

Technical and operational difficulties that emerged during the project led to unexpected solutions that have exciting potential to help mitigate and circumvent the ecological impacts of industrial agriculture when applied to fibre production. Ensiled plant fibres could incorporate a range of food crop residues and break crops, around the year, providing an efficient way to produce feedstock for building materials, in the more extensive, agroecological systems of the future. Any new methods will need to maintain a fine balance between efficient extraction and giving back to the living soil that supports it, as well as careful consideration of associated emissions.

The potential for widespread adoption of plant-based building materials in the UK will be dependent on external factors beyond technical innovation. What is needed now, to support and expedite innovation in agriculture and construction, is not only further proof-of-concept, but supportive frameworks such as: investment in infrastructure; incentives that derisk good practice; policy clarity on migrant labour; financial models that account for true environmental costs; and realistic building standards for natural materials.

Examining the impacts on people of these new land-based industries was at the heart of this research project. Interviews revealed the pressures that an increasingly isolated population of farmers and land workers are under and the importance of collaboration and mutual support to the success of new enterprises. Local processing hubs could provide structure for closer relationships between agricultural and construction sectors, diverse farms and across generations, offering lower risk avenues for experimentation, testing and demonstration of new materials and applications. They could also meet the identified need for educational opportunities, ‘good work’ and a foothold for new entrants. Knowledge could diffuse internationally through migrant workers and the wider discourse around sustainability and place-making offers powerful cultural momentum.

In short, ‘Harvest to House’ is not just a technical possibility but a social and cultural opportunity. The challenge is to ensure that it is taken seriously, and that farms are supported to play their part in building a sustainable future.



## 8. References

Ahmad, M. S., Ahmad, M. N., Muhammad, T., Khan, M. J., Jabbar, F., Alghamdi, S. A., ... & Shah, S. (2025). Utilizing agricultural waste in brick manufacturing for sustainable consumption and circular economy. *Scientific Reports*, 15(1), 22741.

AMA Research. (2021). Building Insulation Products Market Report – UK 2021-2025 [Market Report]. Barbour AB

Balador, Z. (2024). Agricultural by-products as construction materials. Sustainability and toxicity of building materials, 263-287.

Barbulescu, R., & Robertson, B. (2023). Accommodation Offset, National Minimum Wage and Seasonal Migrant Workers: Report for Low Pay Commission. School of Sociology and Social Policy, The University of Leeds.

Department for Business, Energy and Industrial Strategy, (2018). Good work: a response to the Taylor Review of modern working practices.

Fire Industry Association (2023) <https://www.fia.uk.com/news/insulation-firm-had-research-showing-product-used-on-grenfell-released-toxic-smoke.html>

Göswein, V., Arehart, J., Phan-huy, C., Pomponi, F., & Habert, G. (2022). Barriers and opportunities of fast-growing biobased material use in buildings. *Buildings & Cities*, 3(1), 745-755.

Lumivero. (2023). NVivo (Version 14) [Computer software]. Retrieved from: <https://www.lumivero.com>

Mayer, C., Ibarra, L. H., Palumbo, M., Breysse, A., Mabilie, F., Lacasta, A., & Barron, C. (2017, March). Corn pith as insulating biomaterial: from biomass fractionation to composite production. In 4. International Conference on Biobased Materials and Composites (ICBMC 2017) (p. np).

Material Cultures. (2021). Circular Biobased Construction in the North East and Yorkshire. Material Cultures.

Nye, C. & Loble, M. (2021). Farm labour in the U.K. Accessing the workforce the industry needs. A report prepared in collaboration with the Worshipful Company of Farmers. CRPR.

Nye, C. (2021). The farm worker and the 'drift to the land'. Roots, routes, opportunities and constraints to career pathways in farming. *Journal of Rural Studies*, 83, 201-214.

Nye, C., Wilkinson, T. & Loble, M. (2022). Labour and skills in the horticulture and agriculture sectors in England, 2022: Full report. A report for The Institute for Agriculture and Horticulture (TIAH).

Sangmesh, B., Patil, N., Jaiswal, K. K., Gowrishankar, T. P., Selvakumar, K. K., Jyothi, M. S., ... & Kumar, S. (2023). Development of sustainable alternative materials for the construction of green buildings using agricultural residues: A review. *Construction and Building Materials*, 368, 130457.

Soil Association. (2015). Runaway maize: Subsidised soil destruction [Report]. <https://www.soilassociation.org/media/4671/runaway-maize-june-2015.pdf>.

Stanwix, W. & Sparrow, A. (2014). *The Hempcrete Book*. Bloomsbury

## Acknowledgements

The authors would like to thank the Engineering and Physical Sciences Research Council (EPSRC) and the Royal College of Art (RCA) project, The Ecological Citizen(s) Network+, for funding this study. In particular, we would like to thank Emily Boxhall, Robert Phillips, Jude Pullen and Jeremy Keenan from the RCA for their support and constructive input. We would also like to thank everybody who kindly took the time to participate in the research through interviews, workshop, or trials. Special thanks go to everyone working at the trial farm, who's trust, patience and generosity made this project an absolute pleasure to work on.

## Image credits

All photographs and diagrams by Local Works Studio unless otherwise mentioned below:

Nicholas Condy (top left) - Page 4

Felix-Edouard Guerin (bottom left); John Houseman and Matthew Ford (top right) - Page 5

New Holland (bottom left) - Page 14

Emily Fleur (right) - Page 30

Chris Radburn/PA (bottom left) - Page 34

## Report authors

Project lead:

Loretta Bosence

Ben Bosence

Local Works Studio

Unit 6, Sewell's Farm

Birds Hole Lane

Barcombe, Lewes

East Sussex, BN8 5FH

[www.localworksstudio.com](http://www.localworksstudio.com)

Academic lead institution:

Centre for Rural Policy Research (CRPR),

University of Exeter,

Lazenby House,

Prince of Wales Road,

Exeter, EX4 4PJ

[www.socialsciences.exeter.ac.uk/research/centres/crpr/](http://www.socialsciences.exeter.ac.uk/research/centres/crpr/)

Project Principal Investigator:

Dr Caroline Nye

Project Co-Investigator:

Professor Matt Loble

## Citation

Bosence, L., Bosence, B., Nye, C. and Loble, M. (2025). *Ag.Lab.On-farm production of building insulation from crop residues*. Final report. Ecological Citizens, RCA

ISBN: