

Recommendations on support for the development of SME-scale Controlled Environment Agriculture in the Highlands & Islands of Scotland

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Summary & Context

This research was commissioned by Highlands and Islands Enterprise in collaboration with SEFARI Gateway, Scotland's Centre of Expertise for knowledge exchange and innovation. The aim of the fellowship as a whole is to investigate business models for Controlled Environmental Agriculture (CEA) in rural and island communities (in the Highlands and Islands), with consideration to benefits to local food and wellbeing and low-carbon investment.

Previous reports by SAOS in 2022 for Scotland Food & Drink¹ provide detail into benefits of CEA systems, practical considerations for their development, available technologies and systems, as well as comments on skills and market development, and links to suppliers, support and examples of companies operating in the CEA space. A series of feasibility studies were conducted across Orkney in 2021 to explore business models for CEA operations, although to-date, none have been commercialised.

The Global CEA report 2024, listed the following barriers for CEA development in Europe, in order of priority (REF):

- Cost and affordability of advancing equipment and technologies
- Limitations of integrating new technologies (e.g. IoT, robotics, automation etc.) into existing infrastructure
- Challenges in software and hardware integration
- Organisational resistance and adoption
- Regulatory and compliance hurdles
- Uncertainty around return on investment
- Skills and expertise gaps

Based on research conducted through expert interviews, case studies, and desk-based analysis, SAC identified several barriers specific to the application of CEA in the Highlands and Islands:

- Small-scale CEA schemes often face challenges due to limited or cost-inefficient energy systems. Renewable energy infrastructure tends to favour larger operations, and unless a scheme can access its own off-grid energy source, viability may be compromised.
- Labour, capital expenditure (particularly for infrastructure), and energy are the most significant cost drivers in CEA. Without careful planning and cost modelling, these factors can render a scheme financially unfeasible.
- Understanding the local market is critical. Without clear demand for specific products, producers risk growing at scale without a viable customer base—

¹ SAOS Ltd. (2022) *Controlled Environment Agriculture Feasibility Study for Highland Good Food Partnership*. Edinburgh: SAOS Ltd. Available from: Highland Good Food Partnership.

potentially requiring long-distance transport that undermines sustainability goals and low food mile ambitions.

- A perceived gap can remain between organic/regenerative agriculture and technologically enhanced farming. Some farmers may be reluctant to engage with CEA due to concerns about identity, values, or the high capital costs associated with entry.
- Remote producers face high haulage costs and difficulties integrating into centralised supply chains. This limits competitiveness and market access, particularly for perishable crops.

This fellowship explored several of these challenges in greater depth, particularly in relation to opportunities for CEA development in the Highlands and Islands:

- **Balancing Community Benefit with Commercial Viability:** A key tension lies in aligning the goals of local food resilience and community empowerment with the financial realities of running a CEA business. Community-led models often prioritise equity and accessibility but may struggle to remain financially sustainable without compromising values or relying on external funding.
- **Limitations of High-Tech Systems:** Fully enclosed, high-tech systems (e.g. vertical farms) have so far proven viable mainly for niche crops or premium markets. Their high capital and energy demands make them less suitable for broad-based food resilience in rural areas, highlighting the need for blended or lower-tech alternatives.
- **Integration with Local Systems and Just Transition Goals:** CEA and vertical farming should not be seen as silver-bullet solutions for local food system sustainability or supply chain resilience. Without economic support and incentives, these models may struggle to meet the diverse nutritional needs of remote communities—particularly given the constraints of centralised supply chains.

Despite the challenges, the research identified several promising opportunities for CEA development in the region:

- Scalable, lower-tech solutions—such as polycrubs or container farms—offer a more accessible entry point for SMEs. These systems align better with local infrastructure and values, while reducing capital risk.
- CEA can contribute to rural repopulation and just transition goals by creating high-quality, future-facing employment and training opportunities—especially when connected to Scotland's broader CEA knowledge ecosystem.

- Horticulture at a small scale remains financially challenging. However, more research can be done on the opportunity to blend with CSA or CARE farming/employability models—or a hybrid of both.
- Viability improves when CEA schemes can either generate their own energy or tap into waste/energy streams from existing businesses. It's important to recognise that controlled growing and technological innovation exist on a spectrum, and tailored advice can be developed for any type of business or growing system.

The recommendations presented in this short report summarise observations from the research and suggest options for HIE and OIC to integrate into planning and business support provided for CEA initiatives across the Highlands and Islands. These are based on recommendations both to reduce barriers for CEA development in the region, as well as to optimise or facilitate potential opportunities identified.

Update on innovations and advances in CEA

According to market data, indoor farming is growing at 13% per year², and while North America comprises nearly half of global controlled environment growing operations, Europe accounts for 20%. As such, technology is rapidly evolving, with new products and systems coming onto the market nearly monthly. Key trends in controlled environment innovations since the completion of SAOS's 2022 Controlled Environment Agriculture Feasibility Study are as follows:

1. Real-Time Monitoring and Sensing Technologies

Real-time monitoring of environmental and plant health variables is an important part of modern CEA systems³. Sensors track key parameters such as humidity, nutrient levels, carbon dioxide, light intensity, and pH, enabling precision control of the growing environment. Advanced soil and plant sensors, including texture and organic matter sensors, allow for continuous assessment of soil quality and plant condition, enhancing decision-making around irrigation, fertilisation, and crop management⁴.

Sensor networks, with increasing scope to integrate with actuators, enable automated responses to environmental changes⁵; regulating lighting, ventilation, and irrigation to maintain optimal conditions without constant human intervention. Nutrient-sensitive systems further refine this control by offering more specific insights than traditional pH and electrical conductivity monitoring, supporting tailored nutrient delivery.

2. Automation and AI-Driven Control

Commercial scale CEA is increasingly characterised by the adoption of automation and AI to reduce labour demands and increase efficiency⁶. Automated systems manage climate control, irrigation, and nutrient delivery, often guided by predictive modelling and simulation. AI takes this further by interpreting real-time sensor data to dynamically optimize growing conditions. For instance, AI-controlled water systems have demonstrated water savings of up to 40% according to the European Technology Platform for Sustainable Chemistry.

² Market Data Forecast. (2025). *Europe indoor farming market size, share & growth, 2033*. Retrieved June 16, 2025, from <https://www.marketdataforecast.com/market-reports/europe-indoor-farming-market>.

³ Ilmi, F. et al. (2023) *Microplastic Risk Assessment in River Sediments along the Cascading Dam System (Case Study: Midstream of the Citarum River, Indonesia)*. *Water, Air, & Soil Pollution*, 234(358). Springer. Available from: [SpringerLink](#)

⁴ Chuah, Y. D. et al. (2019) *Implementation of Smart Monitoring System in Vertical Farming*. IOP Conference Series: Earth and Environmental Science, 268(1), 012083. Available from: [ResearchGate](#)

⁵ Santosh, D. T., & Shukla, C. (2024) *Innovations in Greenhouse and Controlled Environment Agriculture*. Center for Smart Agriculture, Centurion University of Technology and Management. Available from: [ResearchGate](#)

⁶ Ibid.

The integration of AI also enables systems to learn and adapt, improving over time with exposure to new data; an example of this is through novel applications of systems such as ChatCEA⁷, an advanced language model tailored for CEA environments. It links datasets (e.g. crop images), identifies patterns, and provides validated, expert-reviewed recommendations for environmental control and resource management.

3. Robotics and Precision Farming

Robotics play a growing role in automating labour-intensive tasks such as seeding, harvesting, pruning, and packaging. Equipped with computer vision and AI, robotic systems are capable of selective harvesting and targeted application of nutrients and pesticides, minimizing waste and crop damage⁸. Drones also support vertical monitoring of crop health, especially in unmanned farming systems.

Advanced robotic systems reduce labour costs, which often account for 25–30% of operational expenses in CEA, while improving consistency and accuracy in crop management⁹. These systems are increasingly used in conjunction with precision agriculture tools to maintain environmental compliance and boost productivity.

4. Ergonomics and Physical Infrastructure

Ergonomic improvements in the design of growing systems, such as bench systems, facilitate scalable operations and easier harvesting. These physical infrastructure innovations not only improve workflow efficiency but also enhance the scalability of CEA operations. While not a new innovation, the design of these elements is constantly evolving to increase production efficiencies.

5. Optimised Nutrient Products and Growing Media

Sustainability is further enhanced by innovations in nutrient products and growing substrates. The development of biodegradable and compostable plugs and mats reduces environmental impact, while nutrient formulations are being refined to deliver more efficient uptake and reduced waste. These changes support circular economy principles within controlled systems.

One promising avenue under exploration is the use of hemp shiv, a byproduct of fibre hemp as a horticultural growing medium, particularly when combined with biochar to enhance soil structure and carbon retention. This approach supports both low-impact production systems and the repurposing of agricultural waste into high-value inputs. The

⁷ Kumar, A., & Singh, R. (2024) *Climate-Smart Agriculture and Controlled Environment Farming: A Pathway to Sustainable Food Systems*. SSRN. Available from: [SSRN](#)

⁸ Beacham, A. M., Vickers, L. H., & Monaghan, J. M. (2020) *Vertical farming: A summary of approaches to growing skywards*. *Current Research in Environmental Sustainability*, 2, 100009. Available from: [ScienceDirect](#)

⁹ Fountas, S., Mylonas, N., Malounas, I., Rodias, E., Hellmann Santos, C., & Pekkeriet, E. (2020) *Agricultural Robotics for Field Operations*. *Sensors*, 20(9), 2672. Available from: [ResearchGate](#).

global hemp market is forecast to quadruple by 2030, driven by demand for renewable, plant-based alternatives to fossil fuel-derived products.¹⁰ This presents a timely opportunity for Scotland, where interest in hemp cultivation is growing. However, industrial-scale processing of hemp byproducts like shiv is still in early stages. Establishing local processing infrastructure could unlock the full potential of hemp for both fibre and horticultural use, creating synergies between CEA, sustainable materials, and the bioeconomy.

6. Modular and Scalable System Design

The uptake of modular CEA systems allows for flexible and phased investment. Modular units for growing¹¹, refrigeration¹², robotics¹³, and energy production¹⁴ enable growers to test and scale operations gradually, making CEA more accessible to smaller producers or urban farming startups. These systems also support micro-level production and experimentation.

7. Genetic and Genomic Innovations

Although not universally adopted across all CEA operations, advances in genomic tools such as CRISPR-Cas9¹⁵ are beginning to influence crop development. Genomic selection and editing allow for the creation of crop varieties optimized for indoor conditions, with improved disease resistance, nutrient use efficiency, and environmental resilience¹⁶.

8. Renewable Energy and Storage Technologies

Given the energy-intensive nature of indoor farming, innovations in renewable energy integration and storage are vital. These include on-site solar and wind generation, energy storage systems, and the use of waste heat. Commercial growers across the world are constantly evaluating options for heat recovery and maximisation, exemplified by case studies in Australia and New Zealand¹⁷. Increased energy storage affordability and

¹⁰ SAC Consulting (2025) *The Potential of the Hemp Crop in Scotland*. Farm Advisory Service. Available from: [FAS](#)

¹¹ Mazac, R., et al. (2021) *An Approach for Integrating and Analyzing Sustainability in Food-Based Dietary Guidelines*. *Frontiers in Sustainable Food Systems*, 5, Article 787281. Available from: [Frontiers](#)

¹² Khoury, K. (2020) *Modular Fridge Design Helps Prevent Food Waste*. Springwise. Available from: [Springwise](#)

¹³ Benke, K., & Tomkins, B. (2025) *A Review of Automation and Robotics for Controlled Environment Agriculture*. *Computers and Electronics in Agriculture*, 213, 108123. Available from: [ScienceDirect](#)

¹⁴ <https://www.sciencedirect.com/science/article/abs/pii/S1364032120308649>

¹⁵ Santosh, D. T., & Shukla, C. (2024) *Innovations in Greenhouse and Controlled Environment Agriculture*. Center for Smart Agriculture, Centurion University of Technology and Management. Available from: [ResearchGate](#)

¹⁶ Scarano, A., et al. (2020) *Plant Polyphenols–Biofortified Foods as a Novel Tool for the Prevention of Human Gut Diseases*. Available from: [ResearchGate](#)

¹⁷ Australian Alliance for Energy Productivity (2025) *Webinar: Assessing the Feasibility of Heat Pumps for Agricultural Greenhouses*. A2EP. Available from: [A2EP](#)

capacity also makes establishing off-grid and renewable-powered systems more feasible, particularly important in a Scottish context where grid connection can be costly and complex. Combined with AI and IoT systems, renewable energy solutions can be managed dynamically, ensuring optimal efficiency and reduced carbon footprints.

Likelihood uptake of innovations in the UK and Scotland

The 2024 CEA Global Census report ranked the following grower-reported priorities for technological advancement in Europe as follows:

1. Energy efficiency
2. Remote monitoring & control technologies
3. Integration with IoT
4. Data analytics and reporting
5. Scalability for future growth
6. Compatibility with existing systems

Europe-level data was not published on intention of adoption of various technologies, but the report provided global results across the following categories:

Technology	Not considering	Researching	In motion
Climate control	40.1%	46.4%	13.5%
Lighting control	40.1%	46.4%	13.5%
Pest & disease management	32.8%	59.0%	8.1%
Seeding/planting	39.6%	54.0%	6.3%
Fertigation	40.3%	44.9%	14.8%
Crop monitoring	35.4%	64.6%	0%
Harvesting	49.6%	50.4%	0%
Packaging & post-harvest	100%	0%	0%

This shows that progress towards optimising fertigation technologies was furthest, followed closely by climate and lighting control. There is also strong interest in advancing crop monitoring, pest and disease management, while harvesting and post-harvesting innovations were clearly of least importance.

Defra’s 2023 review of technology utilisation in Controlled Environment Agriculture, produced by Harper Adams University, surveyed the CEA sector in the UK on the likelihood of technology updates, providing the following ranking of outcomes:

Item	% selecting somewhat to % selecting very likely to most likely	
	most likely	most likely
Growing media	78%	67%
Automation in growing process	72%	44%
Cooling technology	72%	50%
Alternative energy sources	67%	56%
Automated harvesting & packing	67%	50%
Growth sensing	67%	61%
Lighting	67%	56%
Water treatment	67%	50%
Heating technology	61%	44%
Upgrading fabric and structure	50%	28%

Technical and Skills

1. Crop Specialisation and Operational Compatibility

Vertegrow's ([case study 2](#)) strategic pivot from food to medicinal cannabis production highlights the complexity of operating dual-purpose CEA systems. The distinct regulatory, infrastructure, and operational requirements for pharmaceutical-grade production create significant barriers to managing both food and pharma crops within the same facility. While such dual-purpose operations are not recommended, there may be fewer constraints in combining food and non-food horticultural production (e.g., nursery stock), provided that plant health and food hygiene standards are rigorously upheld.

2. Understanding the Economics of Remoteness and Haulage

There is currently limited understanding of the economic implications of the 'remoteness premium:' the additional cost of transporting goods, particularly fresh produce, to and from remote and island communities from central distribution depots. While the higher cost of living in these areas is well documented, the specific impact of haulage costs on food retail pricing remains underexplored. In 2023, the Scottish Affairs Committee noted that rural and island residents face disproportionately high costs yet receive no additional cost-of-living support in relation to urban populations.¹⁸ Developing clearer metrics and cost models, such as per-kilogram haulage costs or retailer mark-ups, would help quantify the economic opportunity for local food production. This in turn could inform assessments of commercial viability, market competitiveness, and the role of CEA in building food system resilience in remote and island contexts. Mapping seasonal variation in demand (e.g. by hotel bed occupancy), and the extent to which this varies geographically may provide a further lens to assess commercial viability.

3. Challenges and Opportunities of Anaerobic Digestion (AD)

Heating and powering CEA operations via small-scale anaerobic digestion (AD) presents practical challenges, particularly regarding system reliability, feedstock availability, and economic viability at SME scale. While the circular economy potential is significant, especially in the context of closed-loop island or rural systems, real-world adoption has been limited by a range of technical and financial barriers. For instance, the UK's first micro-AD plant, installed at Rainton in Dumfries and Galloway, demonstrated some success using slurry and grass silage to produce heat, electricity, and digestate. However, the system cost around £220,000 and relied on consistent feedstock and

¹⁸ Scottish Affairs Committee (2024) *Cost of Living: Impact on Rural Communities in Scotland*. First Report of Session 2023–24. House of Commons. Available from: [UK Parliament](#)

heat demand to remain viable.¹⁹ Many Scottish farms, particularly smaller or upland operations, struggle to justify this investment due to seasonal slurry availability, limited access to external feedstocks, and insufficient markets for by-products such as surplus heat or digestate.

In addition, planning permission, regulatory compliance, and the logistical complexity of handling variable waste streams make it difficult to implement modular AD systems at scale without significant support. Larger facilities such as those at Charlesfield Farms have demonstrated success through long-term feedstock contracting with local farmers, substantial capital investment (approximately £10 million), and direct grid access for biomethane injection.²⁰ These enabling conditions are rarely available to small or remote enterprises, such as those in the Highlands and Islands. As such, while AD remains a promising avenue for circular, low-carbon energy within CEA systems, its broader feasibility at small scale in Scotland remains constrained.

4. Potential for Strategic Colocation

Colocation opportunities represent a promising area for future investigation and have been mentioned as determining factors by Wild & Flo (**case study 3**). Potential partners for CEA colocation include energy substations, waste treatment facilities, distilleries (e.g., using CO₂ or waste heat), aquaculture operations (especially for aquaponics), and other industrial infrastructure. These models could offer synergies in energy use, nutrient cycling, and logistics.

5. Learning from Past Failures in CEA

Examining the causes behind the failure of CEA ventures, both in Scotland and internationally, can provide critical insights for designing more resilient and sustainable businesses. A prominent recent example is the collapse of Jones Food Company, once the UK's largest vertical farming operation, which entered administration in April 2025 despite substantial backing from investors such as Ocado and the development of a 148,000-square-foot facility in Gloucestershire. The company struggled with high operational and energy costs, as well as limited profitability from low-margin crops like leafy greens.²¹ Similarly, Infarm, a Berlin-based vertical farming company, exited the UK

¹⁹ Soil Association (2015) *Field Lab Report: Farm-Scale Anaerobic Digestate in an Organic Dairy System*. Supported by the Duchy Originals Future Farming Programme. Available from: [Soil Association](#)

²⁰ Iona Capital (2020) *Charlesfield Biomethane Project*. Iona Capital. Available from: [Scotland Land & Estates](#).

²¹ The Grocer (2024) *Vertical Farming Giant Jones Food Company Appoints Administrators*. Available from: [The Grocer](#)

market in 2023 and closed its Bedford facility less than a year after opening, citing soaring energy prices and challenging market conditions across Europe.²²

These cases highlight the importance of aligning production with clear market demand, managing high capital and operational costs, and ensuring resilience in infrastructure and supply chains. They also reinforce the specific difficulties faced in remote or rural areas, such as limited access to skilled labour and logistical inefficiencies. By critically evaluating such failures, future CEA ventures, particularly in the Scottish context, can develop more effective risk mitigation strategies, foster stronger market integration, and adopt business models that are locally grounded and financially viable.

6. Technical Support and Knowledge Transfer Constraints

Without packaged support offerings, such as those mentioned by Mountain Fresh Produce ([case study 1](#)), small-scale CEA operators may struggle to recruit or maintain the necessary technical expertise. While many CEA technologies are marketed as plug-and-play and come with vendor support, successful implementation still requires horticultural expertise, systems integration skills, and knowledge of off-grid or semi-independent energy systems. Downtime risk is compounded in remote areas where access to specialist contractors and spare parts is limited, and delays can be more costly and prolonged.

To mitigate the risks outlined above, there is a need to explore models for streamlined, Scotland-wide training and technical support, particularly for bespoke CEA systems tailored to island or rural conditions. Such provision could play a key role in de-risking adoption for SMEs, especially beyond initial pilot phases.

7. Leveraging CEA for Green Skills and Regional Development

If viable energy and market models can be demonstrated, CEA presents a strong opportunity to contribute to several strategic priorities in rural and island Scotland:

- **Green jobs and skills development:** CEA could offer high-quality employment and technical training opportunities in remote areas, potentially complementing or competing with existing sectors like aquaculture. However, a recent study by the European Centre for the Development of Vocational Training found that nearly 40% of agri-businesses struggle to recruit people with expertise in precision agriculture and controlled-environment technologies—highlighting a clear need to prioritise skills development over skills sourcing, particularly where there is no standardised training pathway currently available.
- **Demographic renewal and repopulation:** Opportunities to train and retain younger or returning residents in future-facing, sustainable food production

²² Vertical Farm Daily (2023) *Infarm – Indoor Urban Farming GmbH Enters Administration in UK*. Available from: [Vertical Farm Daily](#)

technologies align with broader repopulation and just transition goals, particularly where CEA can offer flexible, semi-skilled work and integration with existing land-based livelihoods.

- **Integration with Scotland's wider CEA knowledge cluster:** There is significant potential to leverage and expand connections between small-scale producers and Scotland's growing CEA expertise across industry, academia, and innovation centres. These connections are vital to overcome a key finding from the EIP-Agri working group—that smaller farms often lack access to technical support networks, a challenge that more coordinated national knowledge systems can help address.
- **Strengthening extension and advisory systems:** Scotland is uniquely well placed to support this growth through the development of its new Agricultural Knowledge and Innovation System (AKIS), the existing Farm Advisory Service (FAS), and dedicated support for crofters, smallholders, and new entrants. This networked approach stands in contrast to the limited extension infrastructure in other parts of the UK and offers a significant policy and operational advantage.
- **Infrastructure considerations:** While automation and cloud-based monitoring tools may enhance labour productivity and enable semi-skilled or part-time engagement, digital infrastructure limitations—such as poor rural broadband—must be taken into account. There may be opportunities to co-locate operations with internet hubs or community infrastructure to mitigate this barrier.

In short, investment in tailored training, infrastructure, and advisory support will be essential to fully realise the economic and community benefits of CEA in remote and island contexts. These steps can help ensure that local producers are not only able to adopt emerging technologies, but are equipped to adapt and innovate in ways that are appropriate to their own ecological, cultural, and economic conditions.

8. Cultural Barriers

Stakeholders across the Highlands and Islands, including commercial horticultural producers and researchers such as those at UHI Orkney, have highlighted potential cultural and practical barriers to the uptake of fully enclosed or highly artificial CEA systems in rural contexts. In many cases, there appears to be greater acceptance and potentially greater technical and economic feasibility for systems that enhance or extend traditional growing seasons, rather than replace them entirely.

This aligns with views expressed by large-scale commercial growers such as G's Fresh, who see the economics of fully controlled vertical farming as currently unviable for many crops but recognise the value of targeted technological interventions. For instance, indoor propagation using enhanced lighting or aeroponics can support uniform, disease-resistant plants for subsequent outdoor production. Similarly, season extension through

low-energy infrastructure such as polytunnels or low-tech greenhouses may offer a more appropriate and acceptable entry point for CEA in remote and rural communities.

HIE should consider supporting training, demonstration sites, and innovation funding focused on these blended models **of CEA—systems that** combine natural growing conditions with technological enhancement. This approach may lower the barrier to entry for growers, align with local values and practices, and deliver tangible benefits in productivity and crop quality without the steep capital and cultural investment required by fully vertical or artificially lit systems.

Regulatory & planning

CEA developments in the Highlands and Islands face a range of regulatory and planning challenges that can present significant barriers to entry, particularly for small and community-led operations. Addressing these issues will be essential for enabling innovation and investment in both high-tech and lower-tech CEA systems across the region.

1. Grid Connection and Energy Systems

The cost and complexity of connecting CEA facilities to the electricity grid remains a critical barrier, especially in remote or island contexts. Upgrading infrastructure, such as installing transformers or laying new cables, can involve prohibitively high upfront costs. Moreover, access to the grid is often limited by the need to “book in” supply well in advance, with competition from larger commercial players further restricting availability.

In some areas, the use of curtailed energy — surplus renewable energy that would otherwise go unused — offers a promising opportunity, particularly where community-owned renewable schemes are already in place. However, this energy source is often volatile and inconsistent, making it difficult to rely on without storage solutions. Encouragingly, the cost-effectiveness of energy storage is improving, and there is growing evidence of viable off-grid systems that combine renewable generation with battery storage to support CEA operations.

Nevertheless, regulatory frameworks can still pose challenges. For example, loan conditions for community energy schemes such as those seen with Shapinsay Renewables may restrict how energy can be used, limiting its application for CEA. A more supportive regulatory environment is needed, including collaboration with energy regulators, planning authorities, and community benefit funds to streamline approval pathways and funding mechanisms for modular, decentralised, or community-owned systems. Aligning this work with just transition and rural decarbonisation strategies could help unlock funding and reduce approval delays.

2. Planning Process Clarity

There is currently a lack of clarity and knowledge around the planning requirements for novel CEA developments, particularly vertical farms, container farms, and bespoke low-energy greenhouse systems. This has led to uncertainty and delays for new entrants and community groups unfamiliar with the planning system. Stakeholders have called for published planning guidance specifically tailored to CEA, covering likely regulatory requirements, location-based considerations (e.g. proximity to settlements, land use classifications), and environmental impact assessments.

There may be lessons to draw from existing CEA projects in Scotland (IGS, Vertegrow, and Standhill Farm) to create a practical planning pathway for others.

3. Crofting Land Constraints

Planning and regulatory barriers are particularly complex when CEA is proposed on crofting land, where crofting law restricts most forms of commercial development. While large-scale, high-tech CEA facilities are unlikely to be permissible under current rules, there is potentially a grey area for lower-tech or community-focused CEA, especially where evidence can be provided of clear benefits to the croft, crofting family, or the wider local community.

Although “major commercial or industrial developments” are prohibited, crofting law does allow for development for “ancillary purposes” if it serves the crofting unit or local economy. Activities such as local food production, seasonal propagation, or value-added processing (e.g. drying, packaging) may fall into this category, but legal interpretation varies by case. There have already been instances along the west coast where CEA-related planning applications were rejected based on crofting land status.

As such, further legal clarification and case-based guidance are needed to inform crofters and planners about what is permissible under the law—and under what conditions flexibilities might apply. This could include consultation with the Crofting Commission and legal experts to identify pathways for CEA development that align with the principles of crofting while enabling innovation.

Business support & finance

1. Addressing Economic Viability and Market Demand

While healthy, nutritious food often commands a higher price in rural and island areas due to limited local production, the input costs required for advanced CEA technologies may exceed local demand, undermining the economic rationale for high-tech investments without external funding support. In many cases, focusing on margin optimisation and breakeven points drives producers toward either commodity-style production or specialist crops that can command premium prices. However, this can limit the diversity of produce available to meet the full nutritional needs of local communities.

Recent trends, highlighted by the closure of several vertical farms, illustrate the risks of over-investing in large-scale production without securing viable markets or consumer willingness to pay premiums. Many farms expanded rapidly, assuming demand would follow, but high operational and energy costs, coupled with challenges in consumer acceptance, led to unsustainable financial pressure. This underlines the critical importance of securing proven market demand and realistic premium pricing before scaling up, echoing the need for robust economic assessments that evaluate the sensitivity of CEA systems' viability relative to conventional farming.

2. Market Premiums and Product Assortment

Additional guidance is needed on factors that influence the ability of CEA producers to secure price premiums. This includes understanding consumer willingness to pay for local or specialty crops, perceived quality differences, and branding opportunities.²³ This Sifted article highlights that many consumers do not yet fully recognize or value vertically farmed produce enough to consistently pay higher prices.²⁴

Urban vertical farms benefit from proximity to consumers, reducing distribution expenses and enhancing freshness. In contrast, remote producers must carefully analyse haulage cost savings versus premium pricing to determine commercial viability, underscoring the need for detailed assessments of local market clusters and potential colocation opportunities near population centres or tourism hubs.

Flexibility in business models is key. The experience from the vertical farming sector suggests that hybrid approaches, combining traditional outdoor or greenhouse cultivation with controlled environment enhancements may be more pragmatic, especially in rural areas. This blended approach can reduce energy costs, lower technical

²³ Russo, C., & Revoredo-Giha, C. (2024) *Food Expensiveness in Remote Areas of Scotland: A Natural Experiment Measuring the Out-Shopping Effect*. *Food Security*, 16, 1019–1029. Available from: [Springer](#)

²⁴ **Sifted (2022)** *Can Vertical Farming Survive the Downturn?* Available from: [Sifted](#).

complexity, and better align with cultural preferences, while still delivering improvements in yield, uniformity, and disease control.

5. Investment Barriers and Financing Models

The capital-intensive nature of CEA—covering energy systems, controlled growing environments, and potentially land acquisition—poses a significant entry barrier. Though beyond the scope of this study, mapping out potential developers and their financing capabilities, aligned with public policy objectives, could unlock investment. Importantly, business structures—private companies versus community organizations—and opportunities to leverage community benefit funds linked to renewable energy projects must be considered when designing support mechanisms.

Initial practitioner guides have begun identifying routes to technical and financial support. However, HIE, in partnership with Orkney Islands Council (OIC), could expand this by packaging and signposting support offerings more effectively. Addressing any conflicting or overlapping funding streams will reduce barriers for emerging CEA businesses and increase uptake.

8. Strategic Colocation and Market De-risking

Locating CEA operations near population clusters or tourism hubs can help de-risk markets by providing stable demand, create local employment, and generate value-added opportunities such as farm shops or cafés. Furthermore, colocation with waste management or processing facilities could enhance circular economy benefits. Given the critical role of market access in attracting investment, a detailed expert-led assessment of market opportunity clusters in the Highlands and Islands would be valuable.

Supporting business models that minimise speculative risk, such as cooperatives, market brokers, or contract growing arrangements will be key, especially in pilot stages where market proof of concept is still being established.

9. Exploring Alternative and Non-Food Crops

In early stages, alternative crops grown primarily for contracts rather than speculative local markets may provide useful lessons and proof of concept. Examples include hops (as suggested in Orkney), microalgae (from Eday studies), medicinal cannabis, seed potatoes, tree nurseries, and mushrooms. However, market size and haulage costs must be carefully considered, alongside opportunities for local processing, which often remain economically challenging.

To support this evolving sector, further work is needed to:

- Produce comprehensive economic assessments comparing different CEA systems to conventional agriculture, identifying missing data and the factors most impacting profitability.

- Clarify land access issues, including crofting legislation’s implications for commercial and community–scale developments, to unlock opportunities.
- Explore the range of business and finance models available, including the potential for community benefit funds linked to renewables, and how these align with public policy goals.
- Package and streamline technical and financial support pathways for CEA businesses to reduce barriers and enhance uptake.
- Connect with ongoing local food market initiatives to leverage existing expertise rather than duplicating efforts.
- Promote market de–risking mechanisms such as cooperatives, contract farming, and brokerage systems to stabilize demand for pilot projects.
- Investigate alternative and non–food crop opportunities (e.g., hops, microalgae, medicinal cannabis) as potential avenues for early market proofing and revenue diversification.

In summary, the vertical farming boom and subsequent slowdown provide valuable lessons for Highlands and Islands CEA development. A cautious, phased approach focused on securing markets, managing energy and logistics costs, and integrating with local food systems will be vital to unlocking the sector’s potential for green growth, rural employment, and food resilience

Social & community

1. Nutritional and community relevance

Many CEA operations, especially those led by agri–tech companies, focus on high–margin niche crops like microgreens, herbs, and specialty lettuces. Although profitable, these crops typically serve urban or export markets and are often supplementary rather than staple foods. Consequently, such models do not fully address the core nutritional needs of local rural communities, where access to affordable, fresh produce is often limited. For CEA to contribute meaningfully to local food resilience, it must support a diverse crop range tailored to community diets.

2. Local ownership and economic benefits:

Ownership structures significantly influence the social impact of CEA. External agri–tech firms operating CEA systems may generate revenue and jobs, but profits and decision–making often leave the local area, potentially leading to “green extractivism”—the use of local land, energy, and water resources to grow food that does not serve the community. Additionally, if a vertical farm produces only basil or arugula for urban restaurants or export markets, it may generate revenue but fail to enhance local food resilience.

Conversely, community-led or cooperative CEA models can reinvest profits locally, prioritise crops that meet community needs, and enhance food sovereignty.

3. Options for community-led CEA initiatives:

- **Asset transfers:** Explore opportunities to retrofit underutilized public facilities for CEA, enabling cost-effective local production.
- **Role of development trusts:** Development trusts often support community gardens with a voluntary focus rather than commercial operations, potentially limiting their capacity to manage the financial risks of CEA infrastructure. A review of previous feasibility studies, such as those in Orkney (2021), is recommended to assess their suitability as CEA hosts.
- **Community benefit funds:** Identify and map relevant community benefit funds (e.g., from local renewables) that can provide financing aligned with local market opportunities and wider public benefits. For example, the Point of Sandwick community benefit fund generates approximately £1 million annually from a small turbine, demonstrating potential local funding sources.
- **Business support and legal structuring:** Direct new CEA enterprises to support networks like the Just Enterprise consortium to develop robust business plans and select appropriate legal structures (cooperative, social enterprise, limited company) that reflect community participation and governance.
- **Addressing cultural barriers:** Existing horticultural producers in the Highlands and Islands have expressed concerns about adopting high-tech CEA systems, often due to rising costs, labour shortages, and a preference for organic or seasonal methods tied to soil and natural growing environments. This cultural resistance suggests that blended or lower-tech CEA approaches may be more acceptable and practical in the near term. There are biological and ecological limitations to soil-less systems, like hydroponics, aquaponics, and aeroponics, that further complicate their integration into regenerative or organic farming models. These systems, by design, cannot contribute to soil restoration or long-term soil carbon capture, which are central goals of regenerative agriculture. The absence of soil also means that symbiotic relationships between plant roots and microorganisms, such as mycorrhizal fungi, cannot occur—limiting natural nutrient cycling and potentially affecting the nutritional quality of the produce.

4. Contributions to Community Wealth Building

When thoughtfully designed and locally embedded, CEA pilots have the potential to deliver on key pillars of CWB by:

- Promoting local food networks and food security
- Supporting the growth of local enterprises and suppliers

- Providing fair, secure, and decent employment
- Diversifying ownership and retaining wealth within communities

However, these outcomes are not guaranteed, and in some cases, CEA pilots could have limited or even adverse impacts on local economies. For example, high-tech CEA operations that rely on automation and imported systems may displace local alternatives, reduce employment opportunities through capital-labour substitution, or direct profits outside the region.

Higher-tech CEA systems—such as vertical farms—tend to focus on high-margin crops for external markets (e.g. restaurants and specialist retailers) due to their high capital and operating costs. These systems typically rely heavily on non-local technology suppliers, limiting the scope for local procurement and community control. As such, they may be less aligned with CWB objectives, particularly in the short term.

In contrast, lower-tech CEA solutions—such as polycrubs and season-extension tunnels—are often locally owned, serve local markets, and require lower upfront investment, making them more accessible to community groups or smaller producers. These models are likely to deliver greater or more immediate CWB benefits per £ of public support.

Next steps & further information

To support the future development of Controlled Environment Agriculture (CEA) in the Highlands and Islands, the following next steps are recommended. These are designed to address current knowledge gaps, identify strategic opportunities, and ensure that CEA development aligns with local needs, market conditions, and sustainability goals.

1. Strengthen Links with Research and Knowledge Exchange

HIE should deepen engagement with academic and research institutions to build a stronger evidence base and contribute to ongoing research streams. Potential avenues include the NISRIE programme, Professor Cesar Revoredo-Giha's work, and the next Scottish Government Strategic Research Programme.

Priority research topics include:

- **Economic feasibility:** There is a notable lack of robust data on the economic viability of CEA models, particularly in rural and remote contexts where high capital and operational costs remain a major barrier.
- **Market demand:** Engage with wholesalers, distributors, and retail chains (e.g. Scotmid) to assess demand for CEA-grown produce in remote and island markets.

- **Geographic vulnerabilities:** Identify communities most affected by high food prices, low produce freshness, and intermittent supply to target interventions effectively.
- **Food cluster development:** Explore models for establishing and supporting local food clusters that could anchor CEA initiatives.
- **Value-added labelling:** Investigate the potential of provenance, carbon footprint, and low-pesticide labelling to enhance marketability—while recognising that higher prices may deter some buyers.

2. Support Practical, Location-Specific Pilot Projects

Pilot projects should test a range of CEA models and partnerships, tailored to local conditions and infrastructure. Suggested opportunities include:

- Partnering with existing horticultural growers to leverage local expertise.
- Collaborating with UHI Orkney on research-led or demonstration pilots.
- Enhancing existing systems, such as early-stage propagation of nursery stock in partnership with commercial growers like Angus Soft Fruits.
- Exploring contract-based production models for specific crops (e.g. tree stock, mini-tubers, or produce for public procurement).
- Identifying population hubs with distribution potential (e.g. Skye/Kyle, Campbeltown, Ullapool) for geographically clustered pilots.
- Investigating colocation opportunities with waste heat or excess energy sources, such as substations or modular anaerobic digestion systems—beyond areas with community benefit funds.

Note: While some development trusts (e.g. Kinlochbervie, Assynt & Scourie) are exploring seaweed farming, this is likely separate from terrestrial CEA due to seaweed's natural marine growth environment.

3. Align CEA Development with Community Wealth Building Principles

To ensure CEA contributes to inclusive and sustainable local economies, HIE should embed CWB principles into its support mechanisms:

- **Integrate CWB Criteria into Options Appraisal:** Prioritise projects that are locally owned, serve regional markets, offer fair employment, and partner with anchor institutions or community networks.
- **Engage with Community Development Trusts:** Explore feasibility of piloting CEA through development trusts, many of which already support local food systems. A

review of the 2021 Orkney CEA feasibility studies may offer insights into their suitability.

- **Explore Community Benefit Funds:** Map and assess community benefit funds as potential sources of CEA finance, especially where they align with local market opportunities and deliver public or social benefits. For example, the Point and Sandwick Trust's turbine generates ~£1 million/year for community investment.
- **Asset Transfer and Public Facilities:** Consider retrofitting underutilised public buildings or sites through asset transfer for CEA pilots, particularly where they support public benefit and regeneration.
- **Enterprise Support and Governance Models:** Signpost emerging CEA initiatives to support services such as Just Enterprise, which offers help with business planning, legal structures (e.g. co-ops, social enterprises), and participatory governance.
- **Cultural Sensitivity:** Recognise resistance among some growers to non-soil-based systems. Support should be sensitive to existing values and promote models that complement rather than replace traditional growing.

4. Develop Strategies to Increase Feasibility and Reduce Risk

To encourage uptake and long-term success of CEA pilots, the following enabling strategies are recommended:

- **Capital support:** Offer grants, subsidies, or blended finance to offset high upfront investment costs.
- **Energy optimisation:** Prioritise use of underutilised or curtailed renewable energy, especially in off-grid or high-renewables areas.
- **Low-tech solutions:** Explore lower-cost, modular CEA systems (e.g. container farms or DIY-style units) in collaboration with partners such as the James Hutton Institute, as alternatives to high-spec commercial systems like Freight Farms.
- **Collaborative trials:** Co-design and test models with existing growers and food enterprises in real-world settings.
- **Scalable approaches:** Focus on modular systems that can start small and scale as confidence, markets, and infrastructure grow.
- **Opportunity mapping:** Map existing energy assets and community infrastructure to identify synergies with potential CEA pilots.

4. Identify Market-Driven Niches and High-Need Areas

Targeted CEA development should focus on areas where it can address clear market gaps or community needs, such as:

- Communities where imported fresh food carries a significant cost premium or where food poverty is prevalent.
- Locations vulnerable to supply disruptions (e.g. ferry-dependent islands) where CEA could improve resilience and freshness of local produce.