N8 White Paper – What next for the UK's 'Controlled Environment Agriculture' Sector

Dr Harry Langford

Sector overview

The UK's agricultural sustainability is being triply challenged by resource and labour pressures, ever-increasing consumer demand and the consequences of anthropogenic climate change, from an increase in extreme weather events to an increased incidence of disease, pests and weeds. In an increasingly urbanised country, wherein the market for local food is expanding, and where recent developments in computation, connectivity and high-resolution sensing have spawned a fourth industrial revolution, many see Controlled Environment Agriculture (CEA) as a critical part of the solution. CEA is an umbrella term for indoor food production systems that typically employ a form of soil-free growing (e.g. hydroponics, aquaponics or aeroponics) and use smart technology to maintain optimal growth conditions throughout the crop's lifecycle. The unique selling points of CEA are that it can alleviate pesticide usage, it is highly economical with space, its water usage is significantly lower than conventional agriculture, and it allows for both shorter growth cycles and year-round cropping. These systems also take pressure off the land, allowing for better conservation and management.

The UK CEA sector is buoyant and expanding, with a host of innovative start-ups and SMEs, showcasing patented technology and operating within specific consumer, R&D and educational niches. Significant venture capital interest means that these start-ups have recently been joined by a number of companies operating large, commercial, peri-urban facilities and supplying major supermarkets. Beyond growing, the CEA sector also includes a diverse group of companies specialising in LED lighting, heating, ventilation and cooling (HVAC), sensing and control, software and automation, and supply chain integration and assurance.

Socio-economic context

The fresh produce market in the UK has been growing steadily over the last five years and is now worth £10.8bn as of 2019 (IBISWorld; Kantar). Spending on healthy, convenience food (prepared salads and vegetables) has been a particular area of growth, more than doubling to £1.1bn in the ten years up to 2017 (Kantar). With up to 90% of fruit and 50% of vegetables imported, a weaker sterling and the ramifications of Brexit could force prices up and put real pressure on supply chains. Migrant worker availability and urban drift put direct pressure upon our UK production. Factors gaining greater influence over the fresh produce market include: healthy eating, social media, big data and supply chain transparency. The consumer preference for fresh, local food from a transparent supply chain is gaining more and more traction.

Focusing on CEA, the vertical farming market globally is expected to grow at a CAGR of 24.8% to reach $5.8bn by 2022 (Hexa). The ability to transcend emerging limitations in conventional agriculture and grow healthy crops 2-4 times faster than outdoors is critical for food security and ensuring good nutrition and health amongst the UK population. Given that the sector is emergent, a number of different business models exist, from 'high value: low volume' to 'close to customer' to 'speciality crops'. Challenges for the sector include: high capital investment costs, poor integration with the agrifood supply chain, limited technology and data integration and consumer acceptance/market differentiation. Initial capital expenditure is significant, often exceeding £500 per square metre, and over 50% of the typical operational costs at a CEA facility are utilities

and labour. Embodied energy costs are also high at approximately double that of an efficient glasshouse system.

Next steps for the sector

The key innovation areas for the CEA sector are: a) system efficiency and cost, b) yield, resilience and trait optimisation, c) artificial intelligence and data analytics, and d) integration within urban society and supply chains. Businesses in the sector are most likely to invest in management systems, LED lighting and climate control in the short-term (Statista). Whilst continual engineering refinements across a suite of standard elements can be expected, i.e. across growth infrastructure, fertigation, illumination, sensing and control, critical and novel innovation is likely to occur around a number of specific technologies and challenges:

- **Targeted breeding and growing:** Crops currently grown in CEA were originally bred for either outdoor or glasshouse environments, and trait-based development of light recipes has focused largely on yield. Future developments will breed crops specifically for CEA and target further advantageous traits, including micronutrient composition, auto-harvest architecture, and specific photo-induced quality traits.
- **Speed breeding:** The John Innes Centre recently bred one generation (seed to seed) of wheat in 8 weeks within a CEA setting, and UK seed companies are now beginning to explore this approach, which has excellent prospects for breeding seeds for particular agro-climatic settings across the world, to withstand climate change or to tackle specific crop health issues.
- **Nutraceuticals:** Medicinal nutrients, inclusive of vitamins, amino acids and herbal remedies, are becoming increasingly important in our health-conscious society. Functionalised foods can be grown in CEA, for consumption or for nutraceutical extraction and processing. The focus for CEA is to utilise fully tuneable LED systems and sensor/metabolite data to produce higher concentrations of e.g. anti-oxidants, flavonoids, vitamins or enzymes.
- **Sensing and machine learning:** As higher resolution sensors and spectral imaging become affordable, it is now possible to monitor crops at the individual level. This, in concert with tuneable LED lighting and environmental control, paves the way not only for more advanced growth recipes, but also for real-time, targeted and autonomous adaptation within growth conditions based on big data and machine learning.
- **Robotics and autonomous systems:** Robotics has the ability to transform low productivity activities within the agricultural sector, including CEA. Back-end automation already exists within the agrifood supply chain, mainly focused on inputs, delivery and logistics. Further automation will focus both upon novel robotics for planting and harvesting, and upon integrating discrete technologies for e.g. navigation, manipulation, and perception.
- **The circular economy:** Urban/industrial waste streams include food waste, grey water, industrial heat, combustion exhaust gases and even plant transpiration water. Integrating renewable energy, waste streams and circularity into CEA would allow the industry to optimise resource use and become more competitive and sustainable. The Vertical Farming Association's white paper illustrates a viable, circular CEA system using fish, mushrooms and insects in addition to plants.
- **Collaboration:** One of the principal, but least mentioned, barriers for the sector is collaboration, including data sharing and interoperability. Beyond technologies for growth, collaboration is needed across the supply chain, distribution and energy in order to gain a competitive advantage. An example of such collaboration is Agriport A7, in the Netherlands, where innovative collaboration on processing, storage, sustainable water and energy provision enables resilient growth.

Next steps for N8 AgriFood

Across N8 AgriFood, we are currently undertaking a number of cutting-edge research projects in CEA, to explore such diverse topics as novel growth media, novel lighting and crop phenotyping, photobiology, low-cost sensing and control, approaches to breeding, life cycle analysis and digital learning platforms for the education sector. We are keen to explore further opportunities across the breadth of key challenge areas identified above.