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Mapping a Green Growth Strategy for UK Horticulture: From Sustainable Production to the Circular Bioeconomy

Written by:

Dr Nicola Harrison NSch

January 2026

A NUFFIELD FARMING SCHOLARSHIPS REPORT

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Title	Mapping a Green Growth Strategy for UK Horticulture: From Sustainable Production to the Circular Bioeconomy
Scholar	Nicola Harrison
Sponsor	The Worshipful Company of Fruiterers & The Food Chain Scholarship
Objectives of Study Tour	To understand how horticultural systems internationally are responding to sustainability, innovation and resource-efficiency pressures; identify what enables successful innovation to address these challenges, and what blocks it in UK horticulture; and to translate findings into practical recommendations for innovation investment in the UK.
Countries Visited	Australia, New Zealand, United States of America, the Netherlands, Spain, Belgium.
Messages	UK horticulture is entering a decisive period of transition, with mounting pressures from climate change, labour constraints, rising costs, regulation and supply chain disruption. Yet it can also play a strategic role in food security, net-zero and the circular bioeconomy. This Nuffield study, reshaped by COVID-19 through a blend of early travel and online engagement, found that the main barriers for transition to more sustainable solutions are systemic: fragmented innovation support, linear models and short-term funding that fails to carry ideas to commercial scale, especially for SMEs. Where change happens fastest, it is driven by strong collaboration and well-coordinated innovation ecosystems. The report argues for long-term (10+ year) investment to build capability and supply chains, enabling horticulture to move from reacting to pressures, to actively shaping a more resilient, sustainable UK food and materials economy.

EXECUTIVE SUMMARY

UK horticulture is entering a period of significant transition. The sector faces increasing pressures from climate change, labour availability, rising input costs, environmental regulation, and supply chain disruption. At the same time, horticulture is uniquely positioned to contribute to national priorities around food security, net-zero delivery, circular economy development, and regional economic growth. This report explores how UK horticulture can move beyond short-term adaptation and position itself as a strategic contributor within a connected, innovation-led economy.

This Nuffield Farming Scholarship study began in early 2020 with the intention of undertaking extensive international travel to explore how horticultural systems were responding to sustainability, innovation, and resource efficiency challenges. Shortly after travel commenced, the COVID-19 pandemic caused widespread disruption and the suspension of physical travel. Whilst challenging, this created an opportunity to engage with a broader range of stakeholders through extended online interviews. The combination of early travel experiences and prolonged virtual engagement provided valuable insight into how horticulture responds to uncertainty and systemic disruption.

This study demonstrates that many of the challenges facing horticulture are not isolated or purely technical. Instead, they are systemic, arising from linear production models, fragmented innovation support, and short-term funding structures that are poorly aligned with the biological and commercial realities of the sector. Across multiple international contexts, successful innovation was consistently associated with strong collaboration between growers, researchers, and industry partners, supported by well-funded innovation ecosystems.

A central conclusion of this report is that innovation in horticulture does not fail due to a lack of ideas or ambition. Rather, it falters where there is insufficient long-term support to enable collaboration, build capability, develop new supply chains, and take innovations through to commercial scale. This challenge is particularly acute for start-ups and small and medium-sized enterprises, which often struggle to bridge the gap between proof of concept and market adoption.

The report highlights the circular bioeconomy and materials innovation as major strategic opportunities for UK horticulture. Horticultural systems can play an important role not only as producers of food, but also as suppliers of renewable biomass, enablers of bio-based materials, and participants in circular supply chains. Opportunities include sustainable packaging, waste valorisation, renewable energy integration, and plant-based product development. Realising these opportunities requires integration between horticulture and wider innovation systems, rather than isolated, farm-level solutions.

In conclusion, this report argues that UK horticulture requires a shift towards long-term (10+ year) innovation funding models that support ecosystem building and collaboration. With the right structures in place, horticulture can move from responding to external pressures to actively shaping a more resilient, sustainable, and innovative future for the UK.

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The opinions expressed in this report are those of the author alone and not necessarily those of the Nuffield Farming Scholarships Trust, of the author's sponsor, or of any other sponsoring body.

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CHAPTER 1: INTRODUCTION

Photo Plate 1: The Author, Dr Nicola Harrison. Source: Author's own.

This Nuffield Farming Scholarship set out to explore an important question: Can UK horticulture achieve green growth? Growth that is environmentally sustainable, economically resilient, and globally competitive, at a time of increasing environmental, economic, and societal pressure?

Horticulture operates at the intersection of food security, environmental stewardship, and economic productivity. The sector faces increasing pressure to reduce greenhouse gas emissions, protect biodiversity, and use water and nutrients more efficiently, whilst continuing to deliver high-quality produce in competitive domestic and international markets.

The aim of my study was to investigate how UK horticulture can transition towards more sustainable production systems without compromising profitability or resilience. In particular, I sought to explore how innovation (technological, biological, and organizational) could enable the sector to grow within environmental limits.

This report brings together international insights, sector analysis, and practical approaches to examine how a green growth strategy for UK horticulture could be developed and implemented. It reflects not only what I learned during my study tour and research, but how those insights were later translated into actions.

CHAPTER 2: BACKGROUND TO MY STUDY SUBJECT

2.1 Ambitions

In the years leading up to my Nuffield Farming Scholarship, I became increasingly aware of two converging forces shaping the future of UK horticulture. The first was the urgent need to transition towards low-carbon, resource-efficient production systems in response to climate change, environmental regulation, and societal expectations. The second was the opportunity to grow the sector's economic contribution through innovation in new products, supply chains, and markets.

These pressures were not emerging in isolation. Horticultural businesses were already operating within a challenging environment characterised by labour shortages, rising input costs, tightening margins, and increasing exposure to market volatility. Whilst there was broad recognition across the sector that change was required, the pathway to achieving it, particularly in a way that protected profitability and resilience, was far from clear.

It became apparent to me that the long-term viability of the sector depended on the development of a clear and forward-looking **Green Growth** strategy. By this, I mean an approach that enables horticulture to grow economically whilst operating within environmental limits, reducing reliance on fossil-based inputs, and making more effective use of biological resources. The challenge was not simply defining such a strategy in principle, but understanding how it could be delivered in practice across a diverse and predominantly small and medium-sized enterprises (SME) led sector.

At the time of applying for my scholarship, I was working as a horticultural scientist with responsibilities spanning multiple crop sectors. This position provided insight into both the scientific advances emerging within crop research, and the realities faced by growers attempting to adopt new approaches. I could see that innovation potential existed, but that it was often fragmented, poorly connected to commercial practice, or inaccessible to many businesses.

My ambition over the following five years was therefore to take on a leadership role in shaping a green growth pathway for UK horticulture. I wanted to help future-proof primary food production systems, supported not only by traditional levy funding (which has since been discontinued), but also by wider UK Research and Innovation (UKRI) and government funding streams. Central to this ambition was the desire to strengthen the sector's voice within policy and funding discussions, ensuring that

horticultural priorities were better understood and aligned with national research, innovation, and net-zero agendas.

2.2 Reasons for Applying

The Nuffield Farming Scholarship offered a unique opportunity to explore these ambitions through a global lens. I was keen to understand how other countries were integrating sustainability, innovation, and market development within their horticultural systems, and to assess which approaches might be relevant or adaptable to the UK context. A key motivation for applying was the opportunity to build a strong network of professional relationships across the horticultural sector and beyond, both nationally and internationally. I believed that exposure to different production systems, innovation models, and policy environments would deepen my understanding of the challenges facing UK horticulture and broaden my perspective on potential solutions.

The scholarship also offered significant personal development opportunities. As a senior female scientist working in a traditionally male-dominated sector, I saw value in using this platform to help champion careers in horticulture from multiple perspectives: as a scientist, as a leader, and as someone balancing professional ambition with family life. I hoped that the scholarship would enable me not only to develop my own capability and confidence, but also to contribute more effectively to conversations about leadership, diversity, and the future of the sector.

Specifically, my objectives in applying were to:

- Develop a broad and diverse professional network across horticulture, research, and innovation.
- Gain a global perspective on sustainable production systems and emerging technologies.
- Strengthen my ability to act as an informed and credible advocate for Green rowth within UK horticulture.

2.3 From Green Growth Concept to Practical Application

Even before my study tour began, I had started engaging with growers, researchers, and policymakers to explore what a green growth strategy for UK horticulture might look like in practice. These early discussions consistently highlighted both enthusiasm and uncertainty. Whilst there was widespread awareness of the need to improve sustainability, many businesses (particularly SMEs), lacked clarity around where to focus effort, how to access support, and which changes would deliver the greatest environmental and commercial benefit.

Several common barriers emerged. These included limited access to trusted, independent advice; fragmented innovation support; and a lack of joined-up market intelligence on emerging opportunities such as bio-based materials, waste valorisation, and plant-based product development. For many growers, sustainability was viewed as important but difficult to prioritise alongside immediate operational pressures.

My Nuffield Scholarship became the catalyst for testing and refining these early ideas. Through international travel, online engagement during the COVID-19 pandemic, and follow-up discussions over several years, I was able to compare different innovation models, funding approaches, and sector structures. This process helped clarify that achieving green growth would require more than high-level strategy or isolated technical solutions. Instead, it demanded accessible, practical support that connected sustainability objectives with business decision-making.

In subsequent years, these insights would directly inform the development of **Growing Green**, a sustainability training and grant programme for horticultural and plant-based food and drink businesses in Kent and Medway. Whilst the programme itself is explored in detail in later chapters, its origins lie in the research and reflections undertaken during my Nuffield journey. Growing Green represented an early attempt to translate the concept of green growth into tangible action by combining knowledge, peer learning, and financial incentives to reduce risk and build confidence among participating businesses.

By the end of my study period, I was convinced that the success of any green growth strategy for UK horticulture would depend not only on technological innovation, but on the design of supportive systems that enable businesses to engage, experiment, and invest. This conviction underpins the analysis presented in the following chapters, which explore how sustainable production, circular bioeconomy development, and place-based innovation can together support a more resilient and prosperous future for the sector.

CHAPTER 3: MY STUDY TOUR

3.1 Original Study Tour Design and Disruption

My Nuffield Farming Scholarship was originally designed around an extensive international study tour, intended to explore how leading horticultural nations were responding to sustainability pressures, integrating innovation into production systems, and creating new market opportunities from biological resources. Planned visits included Australia, New Zealand, North America and Europe, reflecting a deliberate mix of production environments, policy contexts, and innovation ecosystems.

I began my travels in February 2020, arriving in Australia with a clear research plan and a strong sense of anticipation. However, within weeks of my departure from the UK, the global COVID-19 pandemic escalated rapidly. International borders closed, flights were cancelled, and it became clear that continuing physical travel was no longer possible. Whilst I was able to complete an initial visit in Australia, I was forced to return home far earlier than planned, with the remainder of my study tour postponed indefinitely.

At the time, this disruption felt like a significant setback. Travel is a core component of the Nuffield experience, and the opportunity to see systems firsthand and engage in person with growers and researchers had been central to my original study design. However, as the scholarship progressed, this disruption proved to be a pivotal moment that reshaped both the method, breadth, and depth of my research.

3.2 Adapting the Study: Learning Without Borders

Rather than pause my scholarship, I adapted my approach and shifted to a programme of online engagement. Over the following two years, I conducted interviews and discussions with growers, researchers, innovators, policymakers, and entrepreneurs across multiple countries. This approach allowed me to engage with a broader range of perspectives than would have been possible through travel alone.

Unexpectedly, the timing of these conversations proved highly valuable. COVID-19 was placing unprecedented strain on food systems, labour availability, supply chains, and input markets. As a result, interviewees were not speaking hypothetically about resilience and sustainability, they were actively navigating disruption in real time. This provided unique insights into how businesses and systems respond under pressure, where vulnerabilities lie, and which innovations are most likely to be adopted when circumstances demand change.

This period of online engagement also enabled deeper reflection and comparison across countries and sectors. Without the constraints of travel schedules, conversations could be revisited and extended, allowing themes to be tested, refined, and challenged over time. In many respects, the shift away from a purely travel-based study strengthened the strategic and systems-level understanding that underpins this report.

3.3 Australia: Early Insights into Responsible Innovation

The first stage of my study tour took place in Australia, where I visited Kangaroo Island in South Australia. There, I met Larry Turner, whose business provided a compelling early example of what I came to describe as **responsible innovation** in practice.

Larry Turner's enterprise is centred on eucalyptus production and essential oil extraction. His transition into this sector followed a deliberate move away from sheep farming in search of a more sustainable and resilient business model. Supported by a Winston Churchill Fellowship, he had travelled internationally to explore alternative production systems before identifying eucalyptus oil as a viable opportunity.

What distinguished this business was not diversification alone, but the integration of sustainability, research, and innovation throughout the system. Collaboration with the University of Adelaide supported optimisation of eucalyptus genetics for both yield and oil profile. Investment in innovative extraction technology improved efficiency and product quality, whilst on-site laboratory capability enabled ongoing analysis and product development.

Crucially, waste was treated as a resource rather than a cost. By-products from oil extraction were analysed for secondary uses, and waste wood from distillation was earmarked for use in a community-scale biomass heating system, reducing reliance on imported fossil fuels. This place-based, circular approach linked horticultural production with energy resilience, research capability, and community infrastructure.

This visit provided an early reference point for my study, demonstrating how environmental sustainability, commercial viability, and regional benefit can be aligned within a single horticultural system.

3.4 New Zealand: Alignment of Industry, Research, and Policy

In 2024, I was able to resume international travel and visited New Zealand, where I observed one of the most coherent and strategically aligned horticultural systems encountered during my study. In particular, visits to Hawke's Bay and a country-wide tour of the renowned Plant & Food Research (PFR) Institutes, illustrated the impact of long-term investment and clear national ambition.

Discussions with industry representatives highlighted the scale and focus of the New Zealand apple sector. The industry is valued at approximately NZ$800 million, with around 95% of production exported, primarily to East Asia. Importantly, the sector has set a clear growth ambition to reach NZ$1 billion in export value, supported by strong alignment between industry priorities, research funding, and government policy.

3.4.1 Photo Plate *2*: Kangaroo Island – Responsible Innovation in Practice

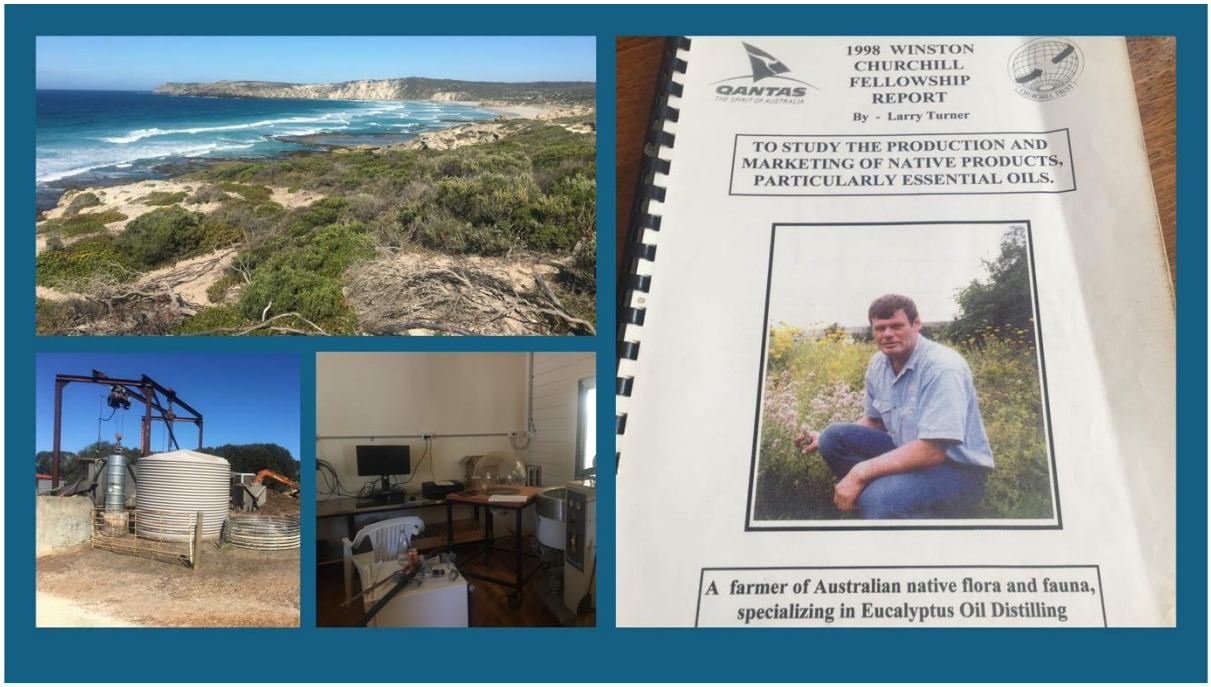

Photo Plate 2: Main Right: Front cover of Larry Turner's Winston Churchill Fellowship report. The Fellowship enabled international learning that directly informed the development of a resilient, research-led horticultural enterprise on Kangaroo Island, illustrating the long-term value of scholarship programmes in driving sector innovation. Bottom Left: On-site eucalyptus oil extraction infrastructure, enabling local value retention through integrated processing, reduced waste, and improved resource efficiency. Top Right Middle: Kangaroo Island, Australia. Bottom Middle: On-site research laboratory for eucalyptus oil extraction research, enabling local value retention through integrated new product development and reduced waste. Source: Author's own.

One long-running trial, now over a decade old, has delivered yields of up to 220 tonnes per hectare using new, elite rootstocks and optimised systems, levels that could not be sustained using traditional rootstocks. Whilst climatic differences between New Zealand and the UK must be acknowledged, the lesson here was not about replication, but about the value of long-term, coordinated investment in foundational science.

3.5 Biosecurity, Health, and Whole-System Thinking

A further defining feature of the New Zealand system was the seriousness with which biosecurity and long-term resilience are treated. Significant, well-funded research programmes address emerging and existing threats such as Brown Marmorated Stink Bug and grapevine viruses, framed explicitly around protecting export access and reducing future reliance on chemical controls.

At the PFR Palmerston North site, the breadth of integrated research was particularly striking. The institute's work is structured around interconnected impact domains, including sustainable ecosystems,

climate resilience, smart food systems, and healthy foods. This systems-based framing avoids artificial separation between production, environment, and consumer outcomes.

One notable difference from the UK context was the close integration between horticultural production and human health research. Work on functional foods, nutritional enhancement, and dietary impact sits alongside cultivar development and post-harvest science. This reinforces the idea that horticulture can deliver value far beyond yield alone, strengthening market differentiation and societal impact.

3.6 Circularity, Waste Reduction, and Post-Harvest Innovation

Across New Zealand, circular economy principles were increasingly embedded within crop science and innovation activity. At the PFR Insect Bioconversion Facility, food and crop waste streams are converted into insect protein, reducing waste whilst producing alternative feed and nutrient sources. Post-harvest research links fruit ripening, storage, and senescence directly back into breeding programmes and supply chain decision-making.

These examples reinforced a consistent theme from my wider study: circularity is most effective when considered at a system level, rather than as an add-on. Where waste reduction, product development, and processing are designed together, value can be retained and multiplied across the supply chain.

3.7 Supplementary European and North American Study Visits

In addition to the core study tour and extended programme of online interviews, a series of shorter, targeted visits across Europe further strengthened and validated the findings of this report. Visits to Spain, the Netherlands, and Belgium provided insight into leading approaches in protected cropping, resource efficiency, bio-based innovation, and integrated supply chains, particularly within highly productive, export-oriented horticultural systems. A further trip to St Louis, Missouri, focused on emerging technologies and practices underpinning regenerative agriculture, including soil health, biological inputs, and data-enabled decision-making. Whilst more limited in duration, these visits provided valuable real-world context and reinforced many of the themes identified elsewhere in the study. Insights from these European and US visits are integrated throughout this report and have informed the analysis, case examples, and recommendations presented in subsequent chapters.

3.8 Reflections for the UK Context

Taken together, the experiences from Australia, New Zealand, and online engagement highlight several lessons for the UK horticultural sector. Successful systems share common characteristics: clear long-term ambition, strong alignment between industry and research, sustained investment, and a willingness to view horticulture as part of a wider economic and innovation ecosystem.

The UK does not need to replicate other countries' models wholesale. However, my study reinforced the importance of moving beyond fragmented, short-term approaches towards coordinated systems that support innovation from concept through to commercialisation.

These reflections directly informed the analysis in subsequent chapters. In particular, they shaped my understanding of green growth not as a single intervention, but as a systems transition, one that integrates sustainable production, circular bioeconomy development, and place-based innovation. Chapter 4 builds on these insights to map out what such a strategy could look like for UK horticulture in practice.

CHAPTER 4: MAPPING A GREEN GROWTH STRATEGY FOR UK HORTICULTURE

4.1 Context: Why Green Growth Matters for UK Horticulture

UK horticulture is operating at a point of profound structural transition. The sector faces mounting pressures from rising energy and input costs, chronic labour shortages, increasing environmental regulation, climate volatility, and supply chain disruption. At the same time, horticulture is increasingly expected to deliver against a broader set of societal objectives, including carbon reduction, biodiversity enhancement, resource efficiency, and regional economic growth, whilst continuing to provide high-quality, affordable food.

When my Nuffield journey began in early 2020, many of these pressures were already evident. As a horticultural scientist working across multiple crop sectors, I could see that growers were being asked to adapt at pace, often without clear direction or adequate support. Sustainability was frequently framed as a compliance issue rather than a strategic opportunity, and innovation activity was fragmented across technologies, crops, and funding mechanisms.

For many businesses, the immediate priority was survival. Investment decisions were shaped by short-term cost pressures rather than long-term system transformation. Yet at the same time, advances in crop science,

digital technology, materials innovation, and bio-based processing were opening up new possibilities for how horticulture could operate and where it could add value.

Green growth provides a framework for navigating this complexity. Rather than positioning sustainability and growth as competing objectives, green growth recognises that environmental performance, resilience, and economic opportunity can be mutually reinforcing when systems are designed accordingly. For UK horticulture, this means moving beyond incremental efficiency gains towards a more integrated approach that connects sustainable production with innovation, circularity, and new markets.

This chapter draws together insights from my study tour, online interviews conducted during the COVID-19 pandemic, conference presentations, and subsequent practical delivery experience to map what a green growth strategy for UK horticulture could look like in practice.

4.2 Defining Green growth in a Horticultural Context

Green growth in horticulture is not a single intervention, technology, or policy lever. Instead, it represents a shift in how biological production systems are valued, organised, and connected to wider economic activity.

In a horticultural context, green growth involves:

- Producing crops with lower environmental impact and improved resource efficiency
- Designing systems that are resilient to climate, market, and supply chain shocks
- Creating additional value from biomass, by-products, and waste streams
- Integrating horticulture into wider innovation, materials, and manufacturing ecosystems

A recurring insight from my research was that these elements cannot be addressed in isolation. Improvements in production efficiency create opportunities for circularity; circular systems improve resilience; resilience supports long-term profitability and investment confidence. Green growth therefore requires a whole-system perspective that considers production, processing, markets, and policy together.

Across my study, three interdependent themes emerged as foundational to green growth in horticulture:

1. Responsible innovation in climate-neutral production

2. Optimised growing systems through the integration of biology and technology
3. Embedding circular economy thinking across horticultural value chains

These pillars structure the remainder of this chapter.

4.3 Responsible Innovation and Climate-Neutral Crop Production

From my earliest conversations with growers, researchers, and industry leaders, there was broad agreement on the need to reduce reliance on fossil fuels and cut greenhouse gas emissions. Where approaches differed was in how innovation was applied and prioritised.

Responsible innovation, as observed throughout my study, is innovation that delivers environmental benefit whilst remaining commercially viable and operationally realistic. It is innovation that strengthens resilience rather than introducing new vulnerabilities, and that considers long-term system impacts alongside short-term gains.

As my study progressed, it became increasingly clear that many of the challenges described in this chapter were not unique to individual crops, businesses, or countries. Instead, they reflected systemic issues arising from linear production models that separate biological production from downstream processing, materials use, and end markets. This realisation began to shape my understanding of horticulture not simply as a production sector, but as a potential connector within much wider value chains.

4.3.1 Energy Transition and Decarbonisation

Energy use remains one of the most significant contributors to carbon emissions and cost volatility in horticulture, particularly in protected cropping systems. Across the systems I examined, several common strategies emerged:

- Transitioning from gas and oil to renewable energy sources, including solar photovoltaics, biomass boilers, and geothermal heat
- Investing in energy efficiency through insulation, heat recovery, improved ventilation, and optimised environmental control
- Developing cooperative or shared infrastructure models to spread risk and reduce capital barriers

Examples from Australia and the Netherlands demonstrated that renewable energy adoption accelerated most effectively where it addressed multiple challenges simultaneously: reducing emissions,

stabilising costs, and improving energy security. In these cases, environmental drivers alone were rarely sufficient. Uptake increased when innovations aligned with business resilience and long-term viability.

Larry Turner's business, Emu Ridge, provided a clear example of what responsible innovation looks like in practice. Faced with high energy costs and a fragile island grid that relied upon ship-imported oil, Larry was investing in a shared community energy system powered by his own company's local wood residues. This not only provided reliable and affordable energy but reduced his carbon footprint significantly. The integration of renewable energy was not just an environmental decision, it was also about business resilience and independence.

4.3.2 Dutch Geothermal Networks

In the Netherlands, I researched large-scale geothermal heat networks. These systems distribute heat from deep geothermal wells to multiple greenhouses, drastically cutting gas use and stabilising costs. Whilst the initial infrastructure investment is high, the cooperative model spreads risk and cost among participants.

In more advanced systems, carbon was not treated solely as an emission to be reduced, but as a variable to be actively managed. Captured carbon dioxide from boilers, fermentation, or industrial processes was reused within protected cropping systems to enhance plant growth, improving productivity whilst reducing net emissions. This reframing of carbon, from waste to resource, mirrors wider circular economy thinking and highlights the importance of system design over isolated mitigation measures.

Key Insight:

Climate-neutral production is most achievable when carbon reduction is embedded within the design and operation of systems, rather than treated as a bolt-on requirement.

4.4 Optimised Growing: Integrating Biology and Technology

One of the most consistent lessons from my study was that the most productive and sustainable horticultural systems do not rely on technology or biology in isolation, but on their effective integration. The most successful systems I observed were those that combined deep biological understanding with targeted technological intervention to produce more with fewer inputs, whilst improving resilience and consistency.

Rather than representing a trade-off between 'high-tech' and 'natural' approaches, these systems demonstrated that biological knowledge and technological precision are mutually reinforcing. Innovation was most

effective where technology acted as an enabler of biological processes, supporting better decision-making rather than replacing grower expertise.

Across multiple contexts, system optimisation focused on improving efficiency, reducing waste, and enhancing crop performance under increasing environmental and economic pressure. Core strategies consistently included:

- **Controlled Environment Agriculture (CEA)**, where climate, irrigation, and nutrient delivery are tightly managed to maximise yield, improve quality, and minimise resource use.
- **Biological crop protection and nutrition**, using beneficial microbes, natural predators, and biostimulants to reduce reliance on synthetic crop protection products and fertilisers.
- **Data-driven decision-making**, integrating sensor networks, artificial intelligence, and machine learning to guide irrigation, nutrition, and harvest timing with greater precision.
- **Breeding for resilience**, selecting cultivars for heat tolerance, pest and disease resistance, flavour, and nutrient density, reducing system vulnerability whilst improving market value.

4.4.1 Biological Foundations

Advances in crop genetics, soil health management, and biological crop protection are reshaping what is possible in both protected and field horticulture. Breeding programmes increasingly prioritise traits that support system-level resilience, including pest and disease resistance, climate tolerance, flavour, and nutritional quality. These traits reduce reliance on external inputs whilst improving yield stability and consistency.

A notable theme during my research was the convergence between organic and conventional systems. Practices traditionally associated with organic production, such as cover cropping, biological pest control, and diversified rotations, are increasingly being integrated into high-tech conventional systems. Rather than representing a binary choice, these approaches are converging around shared principles of system health, efficiency, and long-term sustainability.

This convergence reflects a broader shift away from input substitution towards system redesign. By improving soil biology, enhancing plant resilience, and supporting beneficial ecological interactions, growers are creating production systems that are both more productive and more robust under changing climatic conditions.

4.4.2 Precision and Data-Driven Systems

Technological innovation plays a critical role in enabling this biological potential to be realised at scale. Precision irrigation systems,

environmental sensors, AI-driven decision tools, and controlled environment technologies allow growers to better understand and respond to crop needs in real time.

Across the examples I observed, these technologies delivered multiple benefits, including:

- Reduced water, nutrient, and energy use
- Improved timing and accuracy of interventions
- Greater consistency in yield and product quality
- Reduced labour intensity and operational risk

However, the effectiveness of data-driven systems depended heavily on their design and implementation. Technologies delivered the greatest value when they were integrated into existing decision-making processes and aligned with grower priorities, rather than imposed as stand-alone solutions. Systems that combined robust data with grower knowledge and experience consistently outperformed those that relied on automation alone.

4.4.3 Cross-Learning from Organic and Low-Input Systems

Throughout my study, I saw how insights from organic and low-input systems were informing more sustainable conventional production. Techniques such as biological pest control, soil-cover strategies, and reduced disturbance practices are increasingly supported by precision technologies that improve reliability and scalability.

This cross-learning illustrates a broader trend within horticulture: the move towards hybrid systems that draw on the strengths of both biological and technological innovation. Rather than choosing between nature and technology, the most advanced systems deliberately combine the two.

The perceived divide between technology and nature is a false one. The most productive, resilient, and sustainable horticultural systems of the future will be those that integrate biological understanding with technological precision, enabling growers to optimise performance whilst reducing environmental impact.

4.4.3.1 Photo Plate 3: Optimised Growing – Integrating Biology and Technology

Photo Plate 3: Examples of modern horticultural environments where improved genetics, crop management, and precision technologies are converging to strengthen productivity, quality, and resilience. Source: Author's own.

4.5 Embedding Circular Economy Thinking

The integration of circular economy principles emerged as one of the most underdeveloped yet high-impact opportunities for green growth in UK horticulture. The concept of the circular economy is no longer niche, it is becoming central to forward-thinking agricultural systems. Across my interviews, waste was frequently described as an unavoidable cost of doing business. However, where growers and processors had begun to explore alternative uses for biomass and by-products, a fundamentally different strategic mindset was evident.

4.5.1 Horticulture as a Strategic Feedstock Provider: Reframing Waste as a Resource

Horticultural systems generate a wide range of biological materials in addition to primary produce. These include crop residues, prunings, trimmings, processing by-products, unsold or cosmetically rejected produce, and waste streams arising from protected cropping systems. Historically, many of these materials have been treated as low-value outputs, typically destined for composting, animal feed, or disposal, and managed as an unavoidable cost of production.

Within a circular bioeconomy framework, these materials can instead be repositioned as strategic biological feedstocks. Advances in processing, extraction, and bioconversion technologies now enable horticultural biomass to be transformed into a broad range of higher-value outputs, including food and feed ingredients, functional compounds, bio-based polymers, fibres, energy, and fertiliser products. This shift fundamentally reframes horticultural 'waste' from a liability into a co-product of production systems.

My research found a growing recognition across the sector that waste valorisation represents a significant opportunity, provided that appropriate collection, processing, and market systems are in place. Circular approaches observed during the study included the upcycling of food and crop by-products into ingredients and materials, the deliberate design of production systems with resource loops in mind, and the development of regional processing hubs to aggregate and valorise residues at scale. In such systems, outputs from one process, such as spent mushroom substrate or processing residues, become inputs for another, including compost, bioenergy, or secondary material applications.

Treating biomass as a co-product rather than a disposal challenge has important implications for horticultural businesses. It creates opportunities for income diversification, improves overall resource efficiency, and strengthens economic resilience by reducing reliance on single markets or products. At a sector level, it also brings horticulture into closer alignment with national priorities around materials innovation, plastic reduction, and domestic resource security, repositioning the industry as a contributor to wider industrial and environmental objectives.

Despite the technical feasibility of many valorisation pathways, barriers to adoption remain. In most cases, these are not related to the availability of technology, but to structural challenges, including the lack of aggregation infrastructure, weak coordination across supply chains, and uncertainty around standards, regulation, and long-term market demand. These constraints limit the ability of individual businesses to realise value independently and reinforce the need for collective, regionally coordinated solutions.

4.5.1.1 Photo Plate 4: From Biomass to Value – Enabling Circular Supply Chains

Photo Plate 4: Horticultural biomass and processing residues, illustrating the scale and diversity of biological feedstocks available for valorisation within a circular bioeconomy. Source: Author's own.

4.5.2 Sector Transformation Through Bio-based Products and Materials

One of the most significant realisations from my research was the extent to which horticultural primary production can contribute to entirely different sectors beyond food. Advances in processing, materials science, and biological engineering mean that horticultural crops, residues, and by-products can now supply renewable alternatives to fossil-based raw materials. This shift opens up new revenue streams, diversifies farm income, and strengthens the economic case for circular production systems.

Demand for bio-based materials is accelerating rapidly across multiple sectors, driven by climate targets, plastic reduction policies, and consumer expectations. Packaging, textiles, construction, and advanced food manufacturing are all actively seeking renewable feedstocks that can deliver both functional performance and improved environmental outcomes. Within this context, horticulture has the potential to reposition itself as a strategic supplier of biological raw materials, rather than being viewed solely as a food-producing sector.

This transformation carries several important implications for UK horticulture. First, it enables diversification beyond traditional commodity markets, reducing exposure to price volatility and supply chain disruption.

Second, it aligns horticultural production more closely with national net-zero, materials innovation, and industrial strategy objectives. Third, it increases the strategic visibility of horticulture within the wider economy, strengthening its case for long-term investment and policy support.

During my research, I observed a range of examples demonstrating how horticultural by-products and residues are already being valorised into higher-value outputs. These included the extraction of essential oils and flavour compounds from citrus peel, the conversion of crop residues into plant-based fibres for textile applications, and the development of new food ingredients from surplus or cosmetically rejected produce. Such approaches enable horticulture to supply inputs into sectors well beyond traditional food markets, creating entirely new food ingredients, new supply chains, and commercial relationships.

4.5.3 Emerging Opportunities in Packaging, Textiles, and Construction

Green growth opportunities are not limited to food-related applications. Packaging represents one of the most immediate and high-impact cross-sector opportunities. Packaging is essential to horticultural supply chains, yet it is also under intense scrutiny due to plastic pollution, carbon emissions, and end-of-life challenges. Bio-based and biodegradable packaging materials derived from horticultural biomass offer a compelling alternative to fossil-based plastics, provided that performance, safety, and scalability requirements can be met.

Horticultural residues and fibres have the potential to supply compostable or recyclable packaging solutions that meet the functional needs of fresh produce supply chains whilst delivering improved environmental outcomes. Importantly, this creates the opportunity to close material loops, with crops and crop residues supplying the raw materials for packaging that can ultimately return safely to biological systems through composting or recycling.

A UK example illustrates this closed-loop potential. A collaboration between APS Produce and Biotech Services Ltd demonstrated how waste tomato leaves can be converted into packaging used for the tomatoes themselves (Photo Plate 5). This project shows how circular design principles can be applied across production and packaging, retaining value within the supply chain and reducing reliance on external materials.

The textile sector presents both significant opportunity and challenge for horticulture. Innovations such as mycelium-based leather alternatives and man-made cellulosic fibres demonstrate how plant-derived materials can displace resource-intensive textiles such as cotton and synthetic fibres. Whilst current processing methods can be environmentally intensive, there is clear scope for horticultural expertise to contribute to improved,

lower-impact systems. Skills inherent within horticulture, including controlled production, biological process management, and quality control, are highly transferable to this sector.

Similarly, the construction industry, which accounts for approximately one third of global carbon emissions, is actively seeking low-carbon materials. Bio-based insulation panels, construction blocks grown from mycelium, and experimental buildings incorporating plant-derived materials illustrate how horticulture can contribute to decarbonising the built environment. These applications extend the value of horticultural biomass far beyond the farm gate and reinforce its role within a broader green industrial transition.

Across all of these sectors, a common challenge remains. Whilst technical solutions are advancing rapidly, realising their potential requires coordinated supply chains, processing infrastructure, and clear standards. Without aggregation, investment, and market certainty, many promising materials struggle to move beyond pilot scale. This reinforces the need for joined-up, place-based approaches that connect growers, processors, manufacturers, and end users, ensuring that horticulture can fully participate in and benefit from the transition to a circular, bio-based economy.

4.5.3.1 Photo Plate 5: From Biomass to Value – Enabling Circular Supply Chains

Photo Plate 5: Examples of bio-based material applications observed during the study, demonstrating how horticultural systems can supply renewable alternatives to fossil-derived products. Source: Author's own.

Photo Plate 6: Plant-based materials and by-products with potential application in food ingredients, bio-based materials, and secondary markets. Source: Author's own.

4.6 Skills, Knowledge, and Collaboration

One of the strongest lessons from my study was that successful innovation rarely occurred in isolation. Where growers, researchers, and industry partners were well connected, change happened more quickly and with greater confidence. These relationships enabled ideas to be tested, refined, and adopted in commercial settings, rather than remaining confined to research environments. This reinforced the importance of collaboration and knowledge exchange as fundamental enablers of progress, particularly when addressing complex challenges that extend beyond the farm gate.

My research also highlighted that collaboration is only effective when underpinned by appropriate and sustained levels of innovation funding. In the most successful systems I observed, funding mechanisms were deliberately designed to reduce risk, encourage partnership working, and support continuity between research, demonstration, and commercial adoption. Where funding was fragmented, short-term, or poorly aligned with industry needs, promising innovations frequently stalled at pilot stage.

A strong UK example of a new approach is **Growing Kent & Medway**, supported through the UKRI **Strength in Places Fund**. In 2020, I became the Director of this new regional innovation programme which has now demonstrated how place-based, well-coordinated funding can enable collaboration across growers, researchers, and commercial partners, whilst also supporting innovation in horticulture and plant-based product

development. Importantly, it recognises that innovation does not stop at discovery, but requires sustained support to develop new supply chains, attract investment, and access markets.

A recurring challenge identified during my study was the difficulty faced by start-ups and small innovative businesses in bridging the gap between proof of concept and commercial scale. The Growing Kent & Medway model illustrates how a well-supported innovation ecosystem can address this challenge by providing access to facilities, skills, networks, and commercial expertise, alongside research capability. This type of long-term, integrated support is critical if innovation is to translate into viable businesses and scalable solutions rather than isolated projects.

From a policy perspective, this highlights the importance of innovation funding models that are long-term, place-based, and explicitly designed to support collaboration and scale-up. For the horticulture sector, funding that enables sustained partnerships and supports innovation through to commercialisation is essential if the sector is to respond effectively to environmental pressures, market demands, and supply chain vulnerability. These themes are explored further in Chapter 5, where the role of a connected innovation ecosystem is examined in the context of the circular bioeconomy and materials innovation.

4.7 Early Translation into Practice: The Growing Green Pilot

The principles I had been researching: responsible innovation, system optimisation, and circular economy thinking; all found immediate application in 2021 when I led the Growing Green pilot in Kent and Medway. The Growing Green pilot was a sustainability training programme for horticultural and plant-based food and drink businesses in Kent and Medway funded by the UK Government through the UK Community Renewal Fund.

The pilot programme helped 33 horticultural and plant-based food and drink businesses in Kent and Medway on their journey to reduce their carbon emissions and become more sustainable.

It provided training, co-developed decarbonisation action plans and issued grants to 24 of the businesses to the value of £180,000. Over three months, participating SMEs received:

- Accredited sustainability training and professional qualification
- Environmental sustainability assessment
- Bespoke action plans
- Grants to implement low-carbon innovations

- Networking and events

Impact:

The Growing Green pilot was heralded as a success in an independent assessment report: (https://www.growingkentandmedway.co.uk/post/independent-assessment-of-the-growing-green-programme) for both the local economy and environment. The independent evaluation found all participating businesses were on track to reduce their carbon footprint, with additional benefits including waste reduction, recycling, and water savings.

As well as driving down carbon emissions, the independent report anticipates the pilot project will deliver over 20 new jobs and £3 million in GVA (gross value added) in Kent and Medway by 2028.

Key Insight:

Translating research into action is not only possible, it is urgently needed. Pilot programmes like Growing Green demonstrate that the barriers to change can be overcome with the right mix of knowledge, incentives, and peer learning.

4.8 Synthesis: What Green growth Requires

This chapter demonstrates that green growth in UK horticulture is both achievable and already emerging in practice. However, progress remains uneven and fragmented. Across multiple conversations, I was struck by the fact that innovation was rarely constrained by a lack of ideas or technical capability. Instead, hesitation was more often linked to uncertainty around standards, long-term policy direction, and market demand. This insight helped explain why promising technologies frequently struggled to move beyond pilot scale, despite clear environmental and operational benefits.

Green growth requires:

- System-level thinking rather than isolated solutions
- Integration across production, processing, and markets
- Long-term support for research, innovation and collaboration
- Infrastructure that enables scale and coordination

These requirements extend beyond individual businesses and demand coordinated action across industry, policy, research, and investment.

4.9 Looking Ahead

Green growth is not an endpoint but a transition pathway. It positions horticulture as a contributor not only to food production, but also to

climate solutions, materials innovation, and regional economic development. The following chapter builds on this foundation by examining the circular bioeconomy in detail, using data, investment trends, and policy analysis to position UK horticulture within national industrial and net-zero strategies.

The lessons from this chapter reinforce that green growth is not a single technology or intervention, but a systems-based transition enabled by knowledge, collaboration, and place-based investment.

CHAPTER 5: THE CIRCULAR BIOECONOMY – STRATEGIC OPPORTUNITIES FOR UK HORTICULTURE

5.1 From Green Growth to the Circular Bioeconomy

Chapter 4 set out how green growth in UK horticulture can be achieved through responsible innovation, optimised growing systems, and the integration of circular economy thinking. This chapter builds on that foundation by examining one of the most significant strategic opportunities arising from this transition: the circular bioeconomy.

The circular bioeconomy provides a framework for transforming how biological resources are used within the economy. Rather than following linear models of production, consumption, and disposal, it focuses on retaining value by reusing, recycling, and revalorising biomass and biological materials. For horticulture, this represents a shift from being viewed solely as a food-producing sector to one that also supplies renewable raw materials, functional compounds, and ecosystem services.

Importantly, the circular bioeconomy is not an abstract or future concept. It is already shaping investment decisions, industrial strategy, and innovation priorities in the UK and internationally. The question for horticulture is not whether it is relevant, but how the sector can engage in a way that strengthens resilience, delivers environmental benefits, and creates new economic opportunity.

5.2 Scale and Direction of the Bioeconomy

The bioeconomy now represents a substantial and growing share of global economic activity. International estimates place its value at approximately US$4.7 trillion, with annual growth rates of 6–8% driven by demand for sustainable products, climate policy, and advances in biotechnology and materials science.

In the European Union, the bioeconomy contributes around €2.4 trillion in turnover and employs over 18 million people. The EU Bioeconomy Strategy identifies agriculture, food systems, and bio-based materials as critical growth areas, with a strong emphasis on circularity and efficient use of biomass.

In the UK, the bioeconomy contributes an estimated £220 billion in gross value added and supports more than five million jobs (BEIS, 2022). The UK Government's Bioeconomy Strategy 2030 aims to double this value by 2030, with innovation in sustainable agriculture, bio-based products, and waste valorisation identified as key levers. However, much of the current focus remains on large-scale industrial biotechnology, energy systems, and manufacturing, with comparatively limited attention paid to the role of horticulture as a source of diverse, high-quality biomass.

This represents both a gap and an opportunity.

5.2.1 Investment Trends – Where the Money is Flowing

Investment in the circular bioeconomy is accelerating, particularly in bio-based packaging, alternative proteins, and valorisation technologies. Global venture capital (VC) and private equity (PE) investment in bioeconomy-related sectors reached $51 billion in 2023, up from $30 billion in 2020. The UK government committed £120 million through the Industrial Decarbonisation Challenge and £60 million via the Sustainable Innovation Fund for bio-based R&D and demonstration projects. Corporate players are moving fast: Unilever, Nestlé, and PepsiCo have invested heavily in plant-based packaging solutions, signalling future demand for bio-based feedstocks.

However, despite this momentum, UK investment in horticultural waste valorisation infrastructure remains limited. Processing hubs are rare, and supply chain fragmentation limits scalability. The result is that much of our high-value biomass leaves farms as low-value compost, animal feed, or simply waste, losing potential GVA and export earnings.

5.2.2 National Strategic Need – Linking Horticulture to UK Net-Zero and Industrial Strategy

The UK's Net-Zero Strategy requires deep decarbonisation across all sectors, including primary production. The Industrial Strategy seeks to build globally competitive sectors in clean growth and advanced manufacturing. The circular bioeconomy, and specifically the valorisation of horticultural residues, sits at the intersection of these goals.

Why this is a national priority:

- **Carbon reduction:** Using waste biomass in place of fossil-based materials reduces life-cycle emissions.
- **Energy security:** Biomass can be a domestic source of bioenergy and bio-based chemicals.
- **Economic growth:** Developing bio-based industries in the UK keeps value, jobs, and IP within our borders.
- **Resilience:** Diversified revenue streams for farmers and processors reduce vulnerability to market volatility.

This is not just about environmental sustainability, it is about industrial competitiveness. Countries such as the Netherlands, Finland, and Canada are already positioning themselves as bioeconomy leaders. The UK needs to act now to avoid being a technology taker rather than a technology maker.

5.3 Horticulture, Feedstocks, and System Coordination

The findings presented in Chapter 4 demonstrate that UK horticulture has the potential to function not only as a producer of food, but as a strategic supplier of renewable biological feedstocks into a wider circular bioeconomy. Crop residues, processing by-products, and surplus produce represent valuable resources that can be transformed into bio-based materials, sustainable packaging, functional ingredients, and energy products.

Whilst the technical feasibility of these pathways is increasingly well established, their adoption remains limited by a lack of coordinated supply chains, processing infrastructure, and market alignment. The recurring challenge is therefore not innovation capability, but system design.

Realising the full value of horticultural biomass requires collective approaches that enable aggregation, shared infrastructure, clear standards, and reliable routes to market. This reinforces the central conclusion of this study: that green growth in horticulture depends less on isolated technological advances, and more on the development of connected innovation ecosystems capable of translating circular opportunities into commercial reality at scale.

5.4 Energy, Technology, and Circular Integration

The circular bioeconomy also intersects with horticulture through energy systems and agri-tech integration. Anaerobic digestion, biomass heating, and agrivoltaic systems provide opportunities to convert biological residues into energy whilst improving energy security and reducing emissions. At the same time, advances in sensor technology, data systems, and materials science are enabling more precise management of inputs and resources. These technologies support circular outcomes by reducing

waste, improving efficiency, and enabling better decision-making across production systems. Crucially, these innovations are most effective when integrated into wider system redesign rather than adopted as isolated technologies.

5.5 Policy, Standards, and Market Enablement

Policy and regulation play a critical role in shaping how quickly and confidently horticulture can engage with the circular bioeconomy. Clear standards for bio-based materials, compostability, and life-cycle assessment are essential to build trust and unlock markets.

Alignment between agricultural policy, industrial strategy, and materials regulation is particularly important. Where policy signals are fragmented or short-term, investment is slowed and innovation risk increases. Conversely, clear and consistent frameworks encourage collaboration across sectors and accelerate adoption.

5.6 Strategic Implications for UK Horticulture

The circular bioeconomy offers UK horticulture a pathway to strengthen its strategic relevance within the wider economy. By supplying renewable biomass, engaging with materials innovation, and participating in circular supply chains, the sector can diversify income, reduce dependency on external inputs, and improve resilience to future shocks.

This transition also enhances the visibility of horticulture within national policy discussions, reinforcing its role not only in food production, but in delivering net-zero, resource efficiency, and regional economic growth.

In 2023, I led a funding application for a new Growing Green Bioeconomy Centre, an ambitious proposal to create a hub for translating plant-based biomass into high-value products and markets. The Centre would have provided scientific and technical expertise, research and demonstration facilities, innovation support, commercialisation advice and development of new supply chains, facilitating cross-sector partnerships between crop production, food, materials, and manufacturing industries. The application was not funded. This is not just a missed opportunity for the UK, but highlights a wider gap in the UK's national capability to support the scale-up of bio-based innovation, and without centres like this, we risk falling behind in the global race to develop bio-based industries.

5.6.1 The Window of Opportunity

The UK stands at a crossroads. We can continue with fragmented, small-scale waste utilization, or we can build a coordinated, innovation-driven bioeconomy that turns horticulture's by-products into strategic assets.

The next ten years will be decisive. Global competitors are scaling quickly, and demand for bio-based products is rising sharply. If the UK can link its world-class research base with practical, farmer-focused innovation and regional infrastructure, we can lead, not follow, in this space.

In short, the circular bioeconomy is not a niche. It is the future of sustainable, profitable horticulture and a key driver of the UK's clean growth economy.

5.7 Conclusion

The circular bioeconomy should be understood not as a separate agenda, but as an extension of green growth principles applied at system scale. For UK horticulture, it provides a practical mechanism for turning sustainability challenges into economic opportunity.

The discussion in this chapter highlights the opportunity is real, but that realisation depends on coordination, infrastructure, and long-term commitment. These themes are explored further in the Discussion and Recommendations chapters that follow, where the implications for policy, funding, and leadership are drawn together.

CHAPTER 6: DISCUSSION

This study set out to explore whether an ambitious yet realistic green growth strategy could be developed for UK horticulture. Drawing together international travel, online engagement during the COVID-19 pandemic, and subsequent practical delivery through innovation initiatives, this chapter reflects on the key themes that emerged and what they mean for the future of the sector.

This chapter synthesises the findings of Chapters 4 and 5, focusing on the systemic patterns, structural barriers, and enabling conditions that determine whether green growth and circular bioeconomy ambitions can be realised at scale.

6.1 From Insight to Implementation: Closing the Delivery Gap

One of the most consistent findings from this study is that the challenge facing UK horticulture is not a lack of understanding or ambition. Across growers, researchers, processors, and policymakers, there is widespread recognition of the need to reduce environmental impact, improve resource efficiency, and adapt to changing market and regulatory expectations. However, awareness alone has not translated into action at scale. The gap between intent and implementation remains a defining feature of the sector.

This implementation gap arises from a combination of factors:

- Limited access to trusted, sector-specific advice
- Uncertainty over which investments will deliver meaningful returns
- Fragmented innovation and funding support
- High upfront costs and perceived commercial risk

The Growing Green programme demonstrated that when these barriers are addressed through integrated support that combines training, practical guidance, peer learning, and targeted grants, businesses respond quickly and decisively. This suggests that green growth is constrained less by willingness and more by the structure of support systems.

6.2 Responsible Innovation as a Unifying Principle

Across all regions and systems examined during this study, successful innovation shared a common characteristic: it was responsible. Responsible innovation was not defined by novelty alone, but by its ability to:

- Reduce environmental impact
- Improve economic performance
- Strengthen resilience
- Fit within existing operational realities

Examples ranging from renewable energy integration on Kangaroo Island to precision input management in UK horticulture illustrate that innovations gain traction when they solve multiple challenges simultaneously. In these cases, sustainability improvements were not a cost burden, but a route to cost stability, efficiency gains, and business resilience.

This challenges the persistent narrative that environmental ambition and commercial viability are in tension. On the contrary, many of the most compelling examples showed that environmental and economic objectives are mutually reinforcing when innovation is applied thoughtfully and systemically.

6.3 The Circular Bioeconomy as a Strategic Lever

Perhaps the most significant strategic insight from this study is the central role that the circular bioeconomy can play in unlocking green growth for UK horticulture.

Waste valorisation emerged as a missed opportunity, not because of technological limitations, but because of structural and organisational barriers. Horticulture produces diverse, high-quality biomass streams that

are well suited to bio-based markets, yet much of this potential remains unrealised. My research highlighted a recurring pattern: circular innovation rarely succeeds when attempted in isolation. Aggregation of feedstocks, access to processing infrastructure, market development, and regulatory clarity are all required, and these elements sit beyond the control of individual businesses.

This reinforces the conclusion that circular bioeconomy development is a system-level challenge, requiring coordinated investment and collective action rather than isolated farm-level solutions.

6.4 Lessons from Disruption: COVID-19 as a Stress Test

The COVID-19 pandemic disrupted this study in unexpected ways, but it also provided valuable insight into the resilience of horticultural systems under pressure. Several patterns emerged from interviews conducted during this period:

- Businesses with diversified income streams were more resilient
- Shorter and more local supply chains reduced vulnerability
- Digital tools enabled rapid adaptation and market access
- Innovation was often accelerated out of necessity rather than strategy

These observations align closely with the principles of green growth and circularity. Localised processing, resource efficiency, and diversified markets all contribute to resilience. COVID therefore reinforced, rather than undermined, the case for systemic change. The pandemic also highlighted the risks inherent in highly linear, globally dependent systems, strengthening the argument for retaining more value and capability within domestic and regional supply chains.

6.5 Place-Based Innovation: Effective but Fragile

The success of place-based initiatives such as Growing Kent & Medway demonstrates the power of regional innovation ecosystems. By aligning research capability, business support, skills development, and infrastructure around sector strengths, these programmes can accelerate adoption and deliver measurable outcomes.

However, this study also revealed the fragility of such models when funding is short-term or fragmented. Pilot programmes can demonstrate what is possible, but without mechanisms for continuity and scale-up, their impact remains limited.

The unsuccessful funding bid for the Green Bioeconomy Centre is therefore an important point of reflection. It highlighted strong industry

demand and strategic alignment, yet failed to secure public funding support. This suggests a disconnect between policy ambition and delivery mechanisms, particularly for initiatives that sit across traditional sector boundaries.

6.6 A Sector Ready, but a System Not Yet Aligned

Despite these challenges, one conclusion from this study is clear: the horticultural sector is ready for change.

Growers, processors, and innovators are already experimenting with new approaches, learning from peers, and seeking opportunities to reduce negative impacts whilst strengthening commercial performance. What they lack is not motivation, but alignment.

Alignment between: policy objectives and funding structures; research priorities and industry needs; innovation timelines and biological realities; and environmental ambition and commercial incentives.

Without this alignment, innovation remains fragmented and under-scaled. With it, horticulture has the potential to move from responding to external pressures to actively shaping its future role within the UK economy and beyond.

6.7 Framing the Way Forward

The discussion presented in this chapter leads directly to the recommendations that follow. These recommendations are grounded not in abstract theory, but in lived experience, informed by international best practice, tested through practical delivery, and shaped by the realities faced by businesses on the ground. They focus on creating the conditions under which green growth and circular bioeconomy ambitions can be delivered at scale: long-term funding, place-based ecosystems, integrated innovation pathways, and strong leadership.

The following chapter sets out how these insights can be translated into action through policy, funding, and leadership.

CHAPTER 7: RECOMMENDATIONS – BUILDING A RESILIENT INNOVATION ECOSYSTEM FOR UK HORTICULTURE

This study set out to explore how UK horticulture can respond proactively to increasing environmental, economic, and supply chain pressures through innovation. Evidence presented throughout Chapters 4 and 5

demonstrates that whilst the sector faces significant challenges, it also occupies a uniquely strategic position at the intersection of biological production, materials innovation, and circular economy development.

A central conclusion from this research is that innovation in UK horticulture is **not constrained by a lack of ideas, technical capability, or willingness to change**. Across growers, SMEs, researchers, and industry partners, there is strong appetite for more sustainable, resource-efficient, and resilient production systems. Instead, the primary constraint lies in the **structure, duration, and coordination of innovation support systems**. Short-term, fragmented funding approaches are poorly aligned with the biological, commercial, and infrastructural realities of horticulture, limiting the translation of promising innovations into scalable, market-ready solutions.

Evidence from UK initiatives such as **Growing Kent & Medway** and **Growing Green**, alongside international insights gained during the Nuffield programme, highlights the importance of **long-term, place-based innovation ecosystems**. Where growers, researchers, and industry partners are supported through sustained funding, shared infrastructure, and coordinated leadership, innovation progresses more rapidly and with greater confidence. These ecosystems enable start-ups to develop, new supply chains to form, and established businesses to adopt new technologies and materials at scale.

The circular bioeconomy opportunities explored in Chapter 5 further reinforce this conclusion. Delivering value from biomass and waste by-products, developing new plant-based products, and integrating horticulture into materials innovation systems all require **long-term investment, cross-sector collaboration, and policy alignment**. Without a stable and supportive innovation ecosystem, these opportunities will remain fragmented and underexploited.

This final chapter therefore sets out a series of recommendations aimed at policymakers, funders, and industry leaders. Together, they provide a framework for positioning UK horticulture as a resilient, innovative, and strategically important sector within the UK's future economy.

7.1 Recommendations: Enabling Long-Term Innovation Ecosystems in UK Horticulture

Recommendation 1: Adopt Long-Term (10+ Year) Funding Horizons for Innovation Ecosystems

To align with the UK's stated ambition for long-term economic resilience, innovation funding for horticulture should operate on a minimum ten-year horizon. Short funding cycles are poorly matched to the timescales

required for ecosystem building, commercialisation, and supply chain development. Longer-term commitments would provide the stability needed for strategic planning, infrastructure investment, and partnership development, consistent with national industrial strategy and place-based growth policy led by UK Research and Innovation and supported by Defra.

Recommendation 2: Expand Place-Based Innovation Models Linked to Regional Strengths

Place-based programmes, such as **Growing Kent & Medway**, demonstrate how regional ecosystems can accelerate innovation by aligning research, skills, infrastructure, and industry engagement. Policy should expand and support such models and approaches, building on principles established through the Strength in Places Fund. Long-term place-based funding supports levelling up, rural productivity, and regional resilience, whilst allowing regions to specialise and compete internationally.

Recommendation 3: Support the Full Innovation Pathway, from Discovery to Scale-Up

Funding models should be designed to support the **entire innovation journey**, rather than isolated stages. This includes early-stage research, demonstration, start-up development, pilot manufacturing, and commercial scale-up. Long-term funding horizons are particularly critical for horticulture, where biological, seasonal, and market factors extend development cycles. Without continuity of support, innovations risk failing not through lack of merit, but through lack of time and resource to mature.

Recommendation 4: Support Market and Supply Chain Creation, Not Just Technology Development

Defra's focus on resilient food systems and sustainable land use requires funding mechanisms that recognise **market creation** as a core component of innovation. Long-term programmes should support the development of new supply chains and markets for horticultural and plant-based products, including bio-based materials. This reflects the reality that commercial adoption depends as much on market confidence, coordination, and standards as on technical performance

Recommendation 5: Align Horticultural Innovation with Net-Zero, Circular Economy, and Food Security Goals

Innovation funding should explicitly position horticulture as a delivery partner for national priorities, including net-zero, circular economy development, and food security. Aligning horticultural innovation programmes with wider industrial and environmental strategies maximises return on public investment, avoids fragmentation, and

reinforces the sector's strategic value. Long-term funding horizons enable horticulture to contribute proactively to these agendas rather than responding through short-term, piecemeal initiatives.

Recommendation 6: Prioritise Circular Bioeconomy Infrastructure and Market Development

Waste valorisation and circular bioeconomy opportunities represent one of the most underexploited growth areas for UK horticulture. However, these opportunities cannot be realised without appropriate infrastructure and coordination.

Recommendations include:

- Supporting regional processing hubs to aggregate and valorise horticultural residues
- Investing in market intelligence and supply chain matchmaking
- Encouraging collaboration between horticulture, agriculture, food manufacturing, materials, and construction sectors

This study demonstrates that individual businesses cannot deliver circular solutions alone; collective infrastructure and coordinated delivery models are essential**.**

Recommendation 7: Revisit and Deliver a UK Green Bioeconomy Centre

The unsuccessful funding bid for the **Green Bioeconomy Centre** represents a missed opportunity, but the strategic need remains. A national, or network of regional, centre(s) focused on bio-based innovation would address critical gaps in the UK's innovation ecosystem.

Future action should:

- Revisit the Green Bioeconomy Centre concept, with a phased or modular approach
- Align delivery explicitly with the UK Net-Zero Strategy, Industrial Strategy, and National Materials Innovation Strategy
- Secure co-investment from industry, regional authorities, and private capital to de-risk public funding

Such a centre would provide the infrastructure required to move from pilot projects to commercial-scale deployment, ensuring value is retained within the UK.

Recommendation 8: Build Skills, Leadership, and Long-Term Policy Confidence

Delivering green growth requires not only technology, but people and confidence.

Policy should:

- Invest in skills programmes covering sustainability, data-driven decision-making, and innovation management
- Support leadership development across the horticultural sector
- Promote diversity and inclusion in sector leadership
- Provide stable, long-term policy signals by aligning horticultural, industrial, and environmental policy

Stable policy environments give businesses the confidence to invest, collaborate, and innovate.

7.2 Final Conclusions

This study has shown that UK horticulture sits at a critical juncture. The sector faces mounting pressures from environmental change, market volatility, labour constraints, and supply chain fragility, yet it also holds unique strengths as a producer of food, renewable biomass, and innovation-ready systems.

Through my Nuffield journey, including early international travel and extended online engagement during the COVID-19 disruption, it became clear that the future resilience of horticulture will not be secured through isolated technological fixes or short-term interventions. Instead, it depends on the creation of connected, well-funded innovation ecosystems that link growers, researchers, industry, and policymakers over the long term.

Programmes such as Growing Kent & Medway demonstrate that when collaboration is supported by sustained investment, innovation can move from concept to commercial reality, enabling new supply chains, markets, and businesses to emerge.

If UK horticulture is to play a meaningful role in delivering net-zero, circular economy ambitions, and food security, it must be supported by long-term (10+ year) funding models that recognise the biological, commercial, and systemic nature of innovation. With the right structures in place, horticulture can move from responding to change, to actively shaping a more resilient, sustainable, and prosperous future for the UK.

CHAPTER 8: AFTER MY STUDY TOUR

The Nuffield Farming Scholarship did not conclude when my formal study period ended. Instead, it marked the beginning of a new phase, one in which the insights, networks, and confidence gained through the scholarship were, and still are, being translated into practical actions and long-term career direction.

8.1 From Insight to Implementation

One of the most significant outcomes of my scholarship has been the opportunity to move beyond theory and into delivery. The ideas explored during my study: green growth, responsible innovation, circular economy thinking, and waste valorisation, directly informed my professional work in the years that followed.

In 2021, I led the development and delivery of the Growing Green programme in Kent and Medway. This initiative represented a tangible application of my Nuffield findings, providing horticultural and plant-based food and drink businesses with the tools, knowledge, and confidence to reduce their carbon footprint whilst strengthening their commercial resilience.

The success of the programme, including its independent evaluation and subsequent second funded phase, reinforced a key lesson from my scholarship: **change happens when strategy is matched with practical support**. Businesses want to act, but they need clear pathways, trusted advice, and the confidence that investment will deliver both environmental and economic returns.

8.2 Leadership, Networks, and Confidence

The Nuffield experience also had a profound impact on my personal development. The combination of international exposure, peer learning within my Scholar group, and the challenge of navigating a disrupted study tour during the COVID-19 pandemic strengthened my confidence as a leader.

The global network I developed, through both in-person visits and online engagement, has continued to shape my work. Many of these connections have evolved into ongoing collaborations, advisory relationships, and sources of inspiration. Just as importantly, the scholarship helped me refine my own voice within the sector, giving me the confidence to contribute to national and international conversations on sustainability, innovation, and the future of food production.

8.2.1 Photo Plate 7: Leadership, Networks, and Confidence

Photo Plate 7: International exposure, peer learning, and adapting through COVID disruption strengthened my leadership confidence and expanded my network. These are connections that now underpin ongoing collaborations and my contribution to sustainability and innovation in the Agrifood sector. Source: Author's own.

8.3 Learning from Setbacks

Not every initiative influenced by my Nuffield work was successful. The unsuccessful funding bid to UKRI for the Green Bioeconomy Centre was a disappointment, but it also provided valuable learning. It highlighted the complexity of securing large-scale innovation funding, particularly for initiatives that cut across traditional policy and funding silos.

Rather than discouraging me, this experience reinforced the importance of persistence, adaptability, and partnership. The concept remains relevant, and the need it sought to address has only grown stronger. The bid also strengthened relationships across academia, industry, and regional stakeholders, creating a foundation for future opportunities.

8.4 Broadening Perspective – A European Context

In 2024, I took on a new role as Managing Director of StartLife, based in the Netherlands. This role represents a natural evolution of my Nuffield journey, allowing me to work at the interface of science-based innovation, entrepreneurship, and global agri-food systems.

StartLife operates within one of the world's leading agrifood innovation ecosystems, working closely with Wageningen University & Research and has an extensive international network that includes global corporates,

Agrifoodtech investors, Dutch regional development agencies and innovation support partners. My work now focuses on supporting agrifoodtech and horticultural startups from across the world, fostering pre-competitive collaboration, strengthening the agrifood ecosystem, and accelerating the translation of research into scalable commercial solutions.

This role has given me a broader, European perspective on many of the themes explored in this report. It has reinforced the importance of coordinated, well-supported innovation ecosystems, long-term investment in infrastructure, and strong links between research, industry, and policy. It has also highlighted areas where the UK has significant strengths, and where it risks falling behind without sustained commitment.

8.5 Reflection

Looking back, the Nuffield Farming Scholarship was a pivotal moment in my career. It provided the space to think strategically, the freedom to explore new ideas, and the network to turn those ideas into action. It challenged me to step outside my comfort zone, adapt to unexpected circumstances, and lead with conviction.

Perhaps most importantly, it reaffirmed my belief in the potential of the horticultural sector, not only as a producer of food, but as a driver of innovation, sustainability, and economic growth. The journey from concept to implementation has not been linear, but it has been deeply rewarding.

The scholarship has shaped not only what I do, but how I do it. It has instilled a long-term perspective, a collaborative mindset, and a commitment to ensuring that innovation delivers real-world impact.

CHAPTER 9: ACKNOWLEDGEMENTS

This Nuffield Farming Scholarship would not have been possible without the support, generosity, and encouragement of many individuals and organisations, to whom I am deeply grateful.

First and foremost, I would like to thank the **Nuffield Farming Scholarships Trust** for awarding me this scholarship and for providing such a unique opportunity to step back from day-to-day responsibilities and explore the future of horticulture through a global lens. The Trust's commitment to developing people who can lead positive change in agriculture is evident throughout the Nuffield programme, and I am proud to be part of the Nuffield Scholar community.

I am sincerely grateful to my scholarship sponsors, the **Worshipful Company of Fruiterers** and the **Food Chain Scholarship**, for their financial support and belief in the value of this study. Their backing enabled me to

pursue an ambitious topic at a time of significant change for the horticultural sector.

I would like to thank my employers, both past and present, for their support throughout my Nuffield journey. In particular, I would like to acknowledge colleagues at **AHDB** and **NIAB**, who supported my application and encouraged me to undertake this scholarship. Their ongoing commitment to innovation, science, and industry engagement has played an important role in shaping my career and this study.

My thanks also extend to the many growers, researchers, policymakers, entrepreneurs, and industry leaders who generously gave their time to speak with me, often during the extraordinary circumstances of the COVID-19 pandemic. Although my study tour was disrupted, the willingness of so many people to engage through online interviews ensured that my research continued and, in many cases, was enriched by a wider range of perspectives than originally planned.

I am especially grateful to Larry Turner for welcoming me to Kangaroo Island at the very start of my travels and for providing such a powerful early example of responsible innovation and circular thinking in practice. His story became a touchstone throughout my scholarship.

I would also like to thank my **2020 Nuffield Scholar group**, whose friendship, insight, and mutual support were invaluable, particularly during a year when our shared experience differed so greatly from what we had all expected. The sense of community and openness within the Nuffield network is one of its greatest strengths.

Finally, my deepest thanks go to my family, Richard, Millie and Thomas, for their unwavering support, patience, and encouragement throughout this journey. Balancing travel, research, professional responsibilities, and family life has not always been easy, and their understanding made it possible.

This scholarship has strengthened my belief in the power of people, ideas, and collaboration to drive positive change. I hope that this report contributes in some small way to the ongoing conversation about the future of UK horticulture and inspires others to engage with the opportunities ahead.

SECTION B - LIST OF VISITS

B.1 Australia (February 2020)

- Kangaroo Island, South Australia — Larry Turner, Emu Ridge: eucalyptus production and essential-oil extraction enterprise;

B.2 New Zealand (2024)

- Hawke's Bay — New Zealand Apples and Pears (NZAPI) & apple sector industry representatives; orchard research sites.
- Plant & Food Research (PFR), Hawke's Bay — long-term rootstock and orchard systems trials.
- Plant & Food Research (PFR), Palmerston North — integrated impact-domain research (sustainable ecosystems, climate resilience, smart food systems, healthy foods).
- Plant & Food Research (PFR) Insect Bioconversion Facility, Palmerston North — food and crop waste valorisation into insect protein.
- Plant & Food Research (PFR), Te Puke - Kiwifruit Breeding Centre
- Plant & Food Research (PFR), Auckland - new cultivars and improving the sustainability of food production

B.3 Europe (2022-2025)

- Spain — protected cropping, resource efficiency and export-oriented horticultural systems. IRTA Mas Badia in Girona, bio-incubator ICECYL with the Institute of Natural Resources and Agrobiology of Salamanca (IRNASA), ACOR, the University of Almeria and Cajamar cooperative in Almeria.
- The Netherlands — bio-based innovation and integrated supply chains; Wageningen University and Research, FoodvalleyNL, and surrounding cluster.
- Belgium — protected cropping and circular supply chains. ProefCentrumFruit, Inagro vzw, Greenyard.

B.4 North America (2024-2025)

- St Louis, Missouri, USA — regenerative agriculture, soil health, biological inputs, data-enabled decision-making. BioSTL, Bayer, 39 North, Donald Danforth Centre.

B.5 Online interviews and engagement (2020–2022)

Many online interviews undertaken with growers, researchers, innovators, policymakers and entrepreneurs across multiple countries during the COVID-19 travel restrictions.

B.6 UK delivery and activity

- Growing Kent & Medway, Niab. A place-based innovation programme (Strength in Places Fund).
- Growing Green Community Renewel Fund, led by Growing Kent & Medway, Niab — programme led by the scholar (2021 onwards).

SECTION C - READING LIST / KEY SOURCES

C.1 Cited in the report

- Growing Kent & Medway (2024) *Summative Assessment of the Growing Green Project*. Available at: https:// https://www.growingkentandmedway.com/media/0vvc1svk/summative-assessment-of-the-growing-green-project.pdf
- UK Government / MHCLG (2021) *UK Community Renewal Fund: Prospectus* available at: https://www.gov.uk/government/publications/uk-community-renewal-fund-prospectus

C.2 Programmes, strategies and policy frameworks referenced

- UK Research and Innovation (UKRI) — *Strength in Places Fund*. Available at: https://www.ukri.org/what-we-do/browse-our-areas-of-investment-and-support/strength-in-places-fund/
- HM Government — *UK Industrial Strategy*. Available at: https://www.gov.uk/government/publications/industrial-strategy
- HM Government — *Net Zero Strategy*. Available at https://www.gov.uk/government/publications/net-zero-strategy/executive-summary:
- HM Government — *National Materials Innovation Strategy*. Available at https://www.royce.ac.uk/collaborate/innovationstrategy
- Defra — *Government Food Strategy*. Available at https://www.gov.uk/government/publications/a-uk-government-food-strategy-for-england/a-uk-government-food-strategy-for-england-considering-the-wider-uk-food-system.
- Defra — *Environmental Land Management (ELM)*. Available at https://assets.publishing.service.gov.uk/media/60104205e90e071434ad0ae5/ELM-evidencepack-28jan21.pdf.

C.3 Sector and research organisations consulted

- Plant & Food Research (PFR), New Zealand — https://www.plantandfood.com/en-nz/
- Growing Kent & Medway — https://www.growingkentandmedway.co.uk/

- NIAB — https://www.niab.com/
- AHDB Horticulture — https://ahdb.org.uk/
- Wageningen University & Research — https://www.wur.nl/
- Winston Churchill Memorial Trust - https://www.churchillfellowship.org/

SECTION D — APPENDICES

Appendix 1 - Glossary of Acronyms and Terms

Acronym	Definition
AHDB	Agriculture and Horticulture Development Board
BBSRC	Biotechnology and Biological Sciences Research Council
Defra	Department for Environment, Food and Rural Affairs
ELM	Environmental Land Management
NIAB	National Institute of Agricultural Botany
PE	Private Equity
PFR	Plant & Food Research (New Zealand)
R&D	Research and Development
SME	Small and Medium-sized Enterprise
TRL	Technology Readiness Level
UKRI	UK Research and Innovation
VC	Venture Capital

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