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Online Survey Responses

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Aim of research

The overall aim of this project is to review the implications for food safety from decarbonisation measures implemented within the food system. Food producers, processors and manufacturers may implement adaptations as part of moving the UK to a net zero carbon economy. These measures could have positive or negative effects for food safety.

This report presents the findings from an online survey which sought to canvas expert opinion regarding the UK’s transition to a net zero carbon economy over the next decade.

Survey respondents

31 experts responded to the survey. The majority were from academia (9) and the manufacturing sector (7). 10% were from the farming sector (3). The other 12 participants included representatives from: Policy, “RTO”, Industrial R&D (Food and Life Sciences), Consultancy, Innovation broker, Science services business, Trade associations, Retail, Public body supporting farming, Charity, Research Council, and veterinary sciences. For the purposes of seeing trends between the respondent groups, respondents have been categorised as “Academia”, “Manufacturing”, “Farming”, including veterinary science, and “Other” which includes the rest of the list stated above.

The respondents’ areas of expertise lie in sustainability/climate change (7), “the food system” (6), livestock/seafood (5), food safety (4), food manufacturing (4), research and development (4), nutrition (2), packaging (2) and food science/engineering (2). Eight other subject areas had one mention each: agronomy, crop production, accounting for food and drink, certification/farm assurance, foresight, food ingredients, renewable energy and science policy. Respondents’ familiarity with the food sector was predominantly in the areas of food manufacturing (12), livestock/seafood (5), and “end-to-end” (4).

Data analysis

The survey responses reflect the diversity of sectors represented by participants. Most answers were open-ended and so were manually reviewed to ensure nuances were captured. Categories were identified based on themes connected to that category. For example, hydrogen fuel and biofuel were themes categorised as “energy”. The categories and associated mechanisms generated from respondents’ answers are detailed in the tables found in the Appendices (Appendix 1-8). The main themes (topics which were mentioned the most times by respondents) are discussed in the Results section of this report.

Results

Changes towards net zero

All respondent groups agreed that changes to achieve net zero are already being implemented within their sector (Appendix 1). Most respondents noted that these changes are also being implemented in farming methods, particularly

regenerative and precision farming. The Academia group saw this mainly in the areas of soil health and animal husbandry. Farmer respondents described how changes primarily related to alterations in crop management, such as reducing the amount or type of fertilisers or pesticides used and improving productivity on the farm. The Farmer group also listed some risks as a consequence of crop production inputs changing. These were in environmental hygiene from using less biocides, product contamination due to a reduction in herbicides and the removal of food safety steps including product washing (Appendix 4).

The Academia and Manufacturing groups also perceived activity with respect to waste management and packaging. Examples provided were either in the reduction of both waste and packaging or changing packaging materials. The main packaging change expected was a move from plastic to bio-based materials. One Manufacturer suggested this change may increase emissions as the use of plastic packaging has benefits in terms of product protection journeying through the supply chain (Appendix 1). Other respondents suggested that implementation was focussed on encouraging consumer diet changes and providing alternative protein sources for both food and animal feed.

Changes associated with green energy remained a key theme, with respondents describing trials underway that have the potential for mainstream roll out in the next decade. Respondents saw key interest in the areas of replacing fossil fuels with renewable sources such as solar and wind, hydrogen, electrification of the supply chain and improved energy efficiency especially in refrigeration. Furthermore, the Other group stated that developments in urban/vertical farming using Light Emitting Diodes (LEDs) are already in development. It is important to note that concern was raised by the Manufacturer group that some of these changes could result in higher costs. This was in specific reference to the rising cost of energy including short-term Opex price rises and in electricity in general (Appendix 5).

Source of information

The main sources respondents suggest the FSA review for net zero information were academic and scientific literature, industry publications, and published material from government departments/initiatives such as the United Nations (UN) and United Kingdom Research and Innovation (UKRI) (Appendix 6). There was a general suggestion that industry publications, with specific reference to Agriculture and Horticulture Development Board (AHDB), could also be useful sources of information.

Stakeholders at the forefront of net zero

The responses to questions connected with who is developing, exploring and implementing actions towards net zero were less varied.

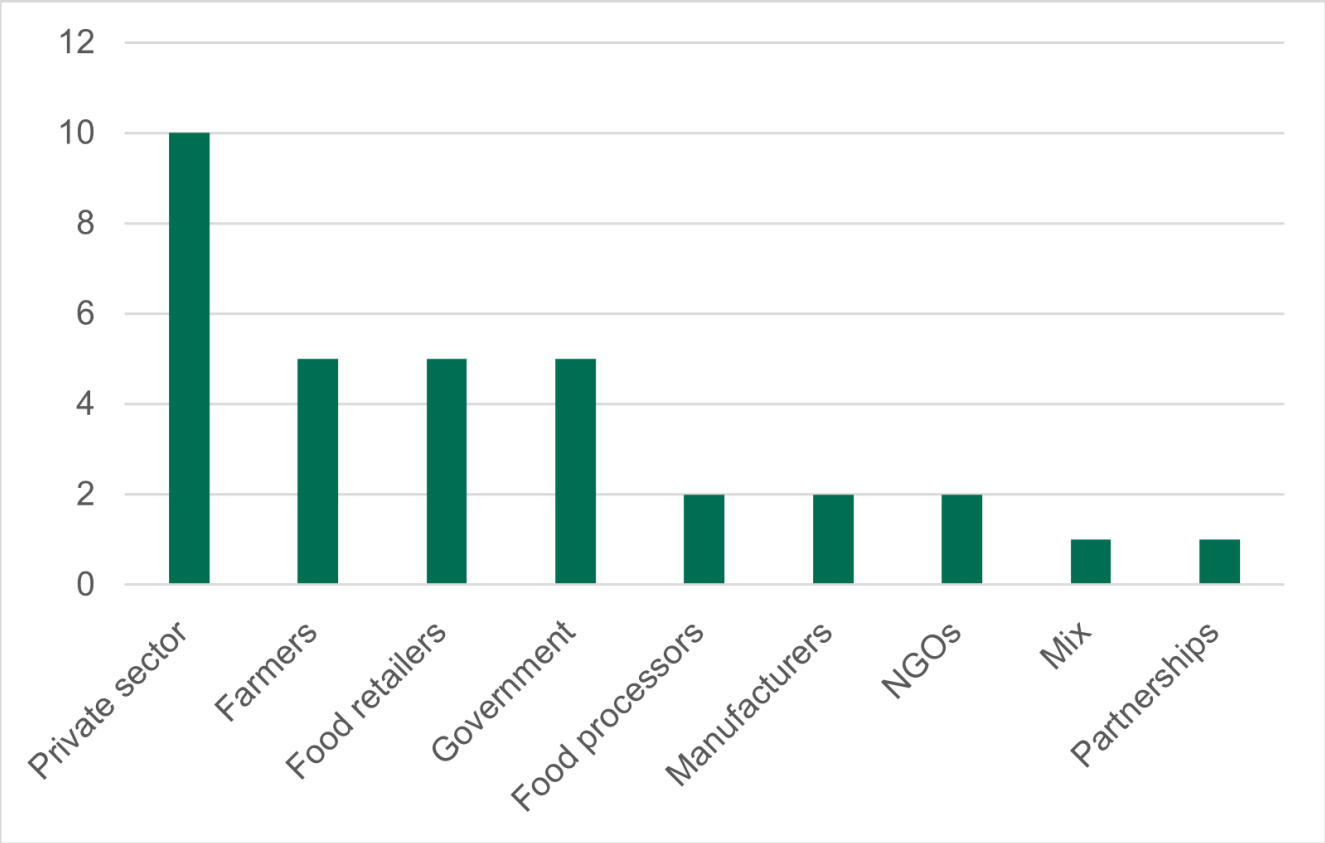

Figure 1: Who is making changes already in roll out / implementation?

The private sector from start-ups to Fortune 500 companies was seen as leading the way in implementing actions towards net zero (Figure 1). Although food retailers are also private companies, this sector was given a separate category as it was explicitly mentioned five times.

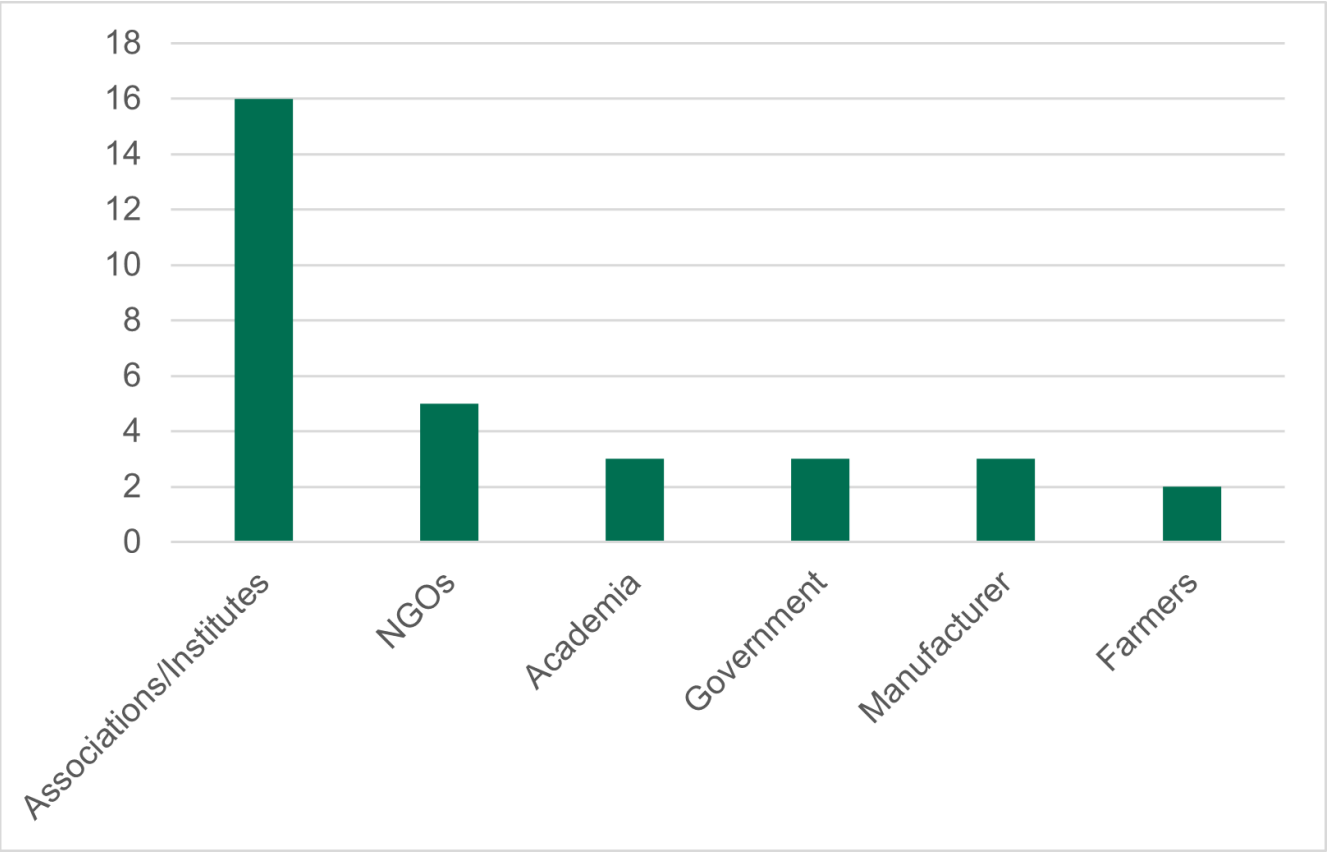

Figure 2: Who is developing potential future ideas aimed at food chain net zero?

Associations and institutes were listed by most respondents as having the potential to develop future ideas (Figure 2). This included organisations such as The Waste and Resources Action Programme (WRAP, (3x)), the Agriculture and Horticulture Development Board (AHDB, (2x)) and The Institute of Grocery Distribution (IGD, (2x)).

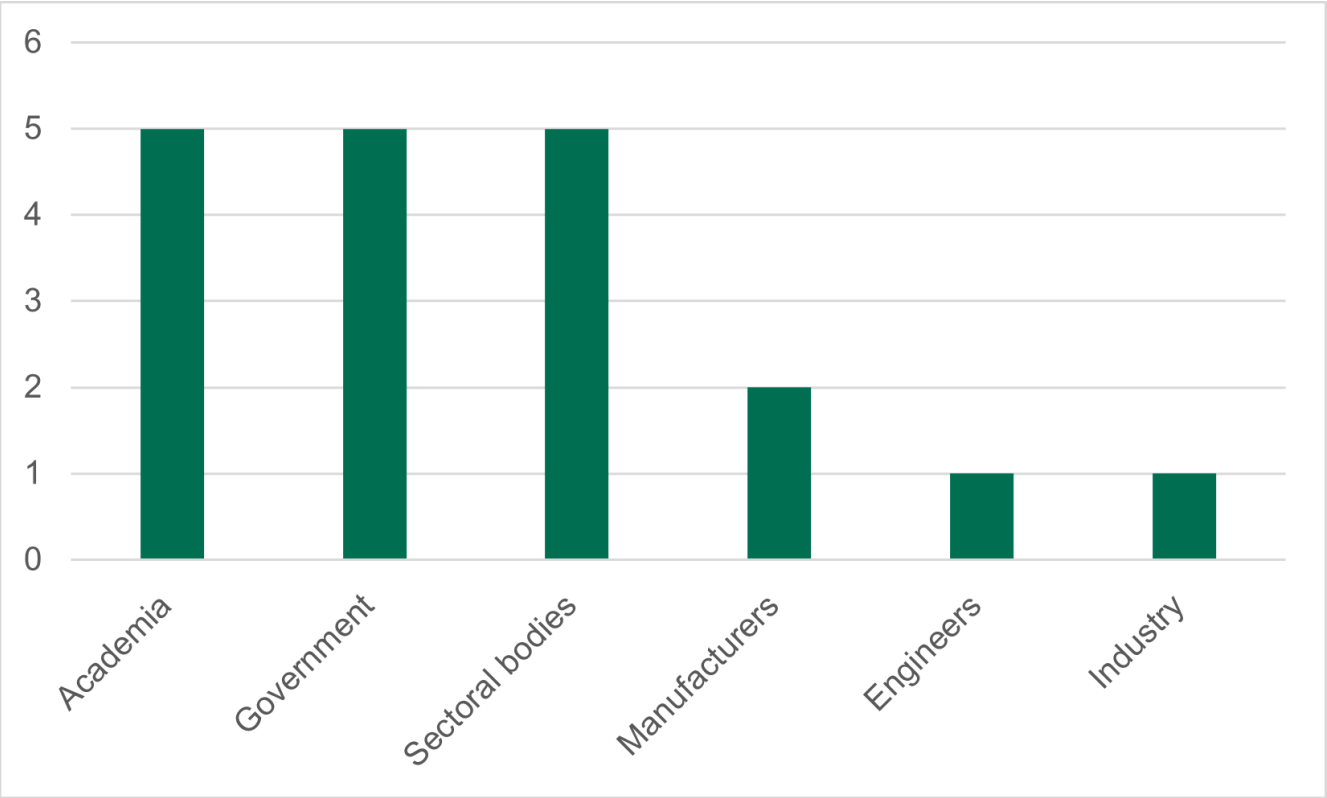

Figure 3: Who is exploring other net zero developments?

There were mixed responses to the question of who is exploring other net zero developments. Answers were spread evenly between academia, sectoral bodies (such as Business in the Community and the Carbon Trust) and Government (Figure 3). The full list of suggestions for further information is included in Appendix 9.

Conclusion

A consistent theme across respondents was the potential for green energy to be a driver of change towards net zero. The main changes already being implemented were in the areas of renewable energy and the use of electric from renewable sources across the supply chain. Respondents also expected further developments in these areas. Alterations to farming practices was another common theme.

However, there was high variability between respondent groups as well as within the category as to the precise mechanisms for change. Farmers expect to see more change in farming methods, particularly in regenerative and precision farming (for both crop inputs and animal feed). Whereas, Manufacturers and the

Other group, saw further developments in packaging and reducing waste. Associations, institutes, and industry were seen by all respondents as being at the forefront of developing initiatives and as key sources of information.

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Appendix 1

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Table 1. Summary of responses: What new changes towards net zero are being implemented already? (Inside your sector)

Category	Academia	Manufacturing	Farmers & Veterinary Surgeon	C

Farming methods	• Soil Management
	  ◦ Improving nutrients
	  ◦ Increase carbon sequestration
	  ◦ Offsetting carbon pollution through NPP
	• Manure management
	  ◦ Anaerobic digestion
	• Animal husbandry
	  ◦ Improving utilisation of feed
	  ◦ Improve fertility
	  ◦ Improve genetics
	• Changes to procurement practices
		• Regenerative farming techniques
		  ◦ No/minimal till
		  ◦ Cover crops and nitrogen fixing crops
		  ◦ Mixed rotations which include livestock
		  ◦ Nutrient management
		  ◦ Hedgerow and woodland management
		• Productivity improvements
		  ◦ Animal and plant health
		  ◦ Basic knowledge exchange
		  ◦ Improved genetics
		  ◦ Energy efficiency
		  ◦ Precision farming
		  ◦ Nutrition
		  ◦ Reproduction

Energy	• Green energy
	  ◦ Closer connectivity between heating and cooling systems
	  ◦ Renewable energy
	  ◦ Changing energy grid
	  ◦ Enhanced efficiency in existing systems through energy conservation, monitoring and utilisation
	• Crop breeding
	  ◦ Low energy rice and grain processing, potential for 90% energy reduction.
		• Green energy
		  ◦ Removal of coal and fossil fuels
		  ◦ Renewable sources
		  ◦ Solar panels
		  ◦ Electric vehicles
		• Energy use reduction
			• Green energy
			  ◦ Through anaerobic digestion
			  ◦ On-site renewable sources

Farming inputs	• Integrated pest management (IPM)
	• Targeted pesticide and agrochemical use.
		• Alterations to fertiliser practises
		  ◦ Move from inorganic to organic fertilisers
		  ◦ Abated fertiliser due to supply in the UK
		  ◦ Reduced reliance on ammonium nitrate fertiliser
		• Integrated Pest Management (IPM)
		• Reduced reliance of Plant Protection Product (PPP)

Land use	• Environmental Land Management (ELM) • Trials associated with soil carbon	• Land use change • Planting woody biomass

Consumer diet change	• Protein self sufficiency • Use of alternatives to imported protein sources.	
Waste	• Food waste reduction	• Waste reduction and management ◦ Zero waste to landfill • Water recycling and reduction.

Packaging	• Food packaging material and weight changes.	• Packaging materials
		  ◦ Net impact is negative as packaging protects and preserves products through the supply chain and the product loss that it prevents has a greater Greenhouse Gas (GHG) footprint than packaging itself.
		  ◦ Media and Corporate Social Responsibility (CSR) driven reduction of packaging (particularly substitution of plastics packaging by alternative materials) will increase GHG impact and must "follow the science" not rhetoric.
		  ◦ Including recycled content into primary food

Measurement	• Measuring of parameters	• Complete carbon footprints on-farm
Manufacturing	• Improved manufacturing efficiency • Reduce rejection and reduce rework and achieve zero waste • Deforestation policies among manufacturers	
Technology		• Innovation • Increased use of high-tech production systems (glasshouses, Controlled Environment Agriculture (CEA), hydroponics)

Transport

Processing methods

Shelf-life

Retail

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Appendix 2

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Table 2. Summary of responses: What developments are in trial that have potential to roll out in the next ten years?

Category	Academia	Manufacturing	Farmers & veterinary surgeon	Other

Farming methods	• Animal breeding • More efficient and resilient animals • Lower carbon footprint • Precision agriculture in crops and livestock • Integration of arable and livestock systems • Soil health	• Sustainable intensification • Lower carbon agronomy • Crop production • Leguminous plants co cropped with wheat to replace nitrogen fertiliser • Nitrogen without CO2 • Aquaculture • Multi-stream culture systems (e.g., fish plus water plants such as watercress) • Ocean farming and harvesting of seaweed	• Crop production • Mixed rotations • Less use of manufactured fertilisers • Perennial energy crops (miscanthus, willow) • Crop inputs • Reduced inputs and increased sequestration • Reduced reliance on ammonium nitrate fertiliser-circular economy development • Precision crop and livestock agriculture • Improved reproductive performance • Specific genetic progress • Gene editing precision • Regenerative agriculture techniques	• Livestock developr e.g., inte indoor da farming • Accelera biopestic • Slurry co mitigate ammonia emission • Agrofore ecology, precision agricultu urban agricultu vertical f advance breeding techniqu

Energy	• Zero fossil fuel use • Electrification • Hydrogen generation plants • Bio-hydrogen • Ohmic and pulsed electric field heating	• Refrigeration • Improving efficiency • Onsite energy generation • Renewable energy • Electricity generation • Wind and solar are variable • Tides are predictable • Next generation technologies that consume less energy using advanced process control.	• Green energy • Electric generation • Gas to grid • Tractor biogas fuelling • Land-based renewables and energy storage, for on-farm and export • Reduced emissions methods • Scrubbers and catalyst systems • Anaerobic digestion to generate "negative emissions"	• Green en • Hydroge supply ch transpor factory • Vehicle a machine electrific	

Animal feed	• Alternative feed • Biotechnology in feed ingredients, including generation of enzymes and supplements • Reduce enteric fermentation's emission of methane - including archaeal suppressant commercial use • Feed rations that deliver lowest carbon footprint per product (not just feed input) • Home grown feed replacement of soya	• Alternative sources of protein	• Optimal nutrition including use of supplements to manage the rumen microbiome to reduce methane	• Diet • In cattle reduce m productio • Insect pr (includin aquacult • Improve feed utili • Alternati soya in f formulat

Land use	• Changes in subsidies to farmers will change land use especially in the uplands. • Peatland restoration, farm woodland / agroforestry, more hedgerows, • ELMS (Environmental Land Management Scheme)		• Nature-based solutions • Increased increments in hedges, new woodlands, soil carbon management • Agroforestry	• Optimisi for carbo sequestr
Consumer diet change	• Dietary change • Reduced meat and dairy consumption	• Alternative sources of protein		• More dai meat sub • Novel pr • Cultured • Minimall processe • Eating le but high quality • Eat local

Waste	• Use of former foods and utilisation of coproducts • Reducing food waste • Supply chain integration to reduce stocks and waste.	• Circular economy principles for waste reduction • NPD based on food by-products.	• Endemic disease control to reduce the waste associated with disease and increased productivity	• Measure reduce f and wast • Waste valorisat • Abstract slurry • Reduced waste in a result increase • Recyclin PET 5
Packaging	• Food packaging changes.	• Closed loop recycling of plastic packaging		• More inf supplied packs re carbon f of produ • Biobased packagi materials • Closed l packagi
Measurement	• Better use of manures and measures to reduce N2O and NH3 loss on farm		• Farmers using tools to measure what is going on farm	

Manufacturing	• Zero carbon factories • Cellular agriculture to produce factory grown meat		• Product a process i (net zero design) redistribu manufac
Technology	• Urban farms based on Light Emitting Diode (LED) technology for salad and similar crops.	• New technologies • Genetic • Feed additives • Feed proteins • Robotics • Drones • Electric agricultural machinery	

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Table 3. Summary of responses: Are there other changes (at any stage of development) aimed at achieving net zero that you expect to make an impact? What are they?

Category	Academia	Manufacturing	Farmers & veterinary surgeon	Other
Farming methods	• Gene editing • For crop and livestock resilience • Livestock and rumen microbes as part of the pangenome approach • Land use • Balance between for agriculture and for carbon storage	• Supply shed natural climate solutions	• Novel carbon-storing soil amendments (biochar, enhanced rock weathering)	• Alternativ the Haber bosch pro • Controlle environm farming (

Energy	• Green energy • Bioenergy with carbon capture and storage - not in the food system, but uses land so will affect the food system • Replace water heated, jacketed pipework with lower energy electrical systems • Solar powered thermally efficient systems working at the 50-95 degree Celsius range. • Energy reduction	• Green energy • Governmental support for the development of new sustainable energy technologies to replace hydrocarbon use • Clean hydrogen instead of methane as a gas supply. • Fusion	• Green en • Electrifica • Decarbon of crop sy grown in tunnels • Hydrogen economy investme governme • Carbon cr for soil sequestra

Government				• Governm investme • Adoption National I Strategy
Transport	• Shorter supply chains • Reduced car use post Covid; reduced flying.		• Move to predominantly sea freighted / road transported imported produce away from Air freight.	• Vehicle electrifica
Consumer diet change		• Public attitude and education, cultured meat expansion and acceptance and fermented meat substitutes expansion and acceptance.	• Reducing import of animal protein from high Greenhouse Gas (GHG) emission intensity systems • 'Quality not quantity' changes in consumer eating habits.	• Consume being par solution • Novel foo • Alternativ protein productio

Waste	• Development of circular economy principles to utilise waste streams			• Conversio reduction food wast • Into 'ferti at scale • Valorisati side strea • Reducing waste • Recycling polypropy
Packaging			• Bio-based materials in long-lived consumer and construction products	
Measurement		• Better diagnostics and analytical approaches	• Measuring baselines on farm	• Measuren and moni of Greenh Gas (GHG emissions environm performa

Technology	• Robotics, Information and Communication Technology (ICT) developments on farm and in factory environment (Industry 4.0).

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Table 4. Summary of responses: What do you expect the effects of changes towards net zero being rolled out already to be?

Category	Academia	Manufacturing	Farmers & veterinary surgeon	Other

			• Crop production inputs	
Farming methods	• Less food production in the UK especially of ruminants and probably wheat and barley • Circular agriculture principles, precision farming		• Move away from synthetic nitrogen-based fertiliser to more organic based • Field carbon sequestration. • Increased environmental hygiene risk (particularly Listeria mono) in non-competitive growing environments and post-harvest environments where less biocide use • Increased product contamination risks (e.g., toxic weeds) due to lack of herbicide options • Removal of food safety steps (e.g., product washing)	• Improved productivity per hectare (vertical farming)
			• Less process steps and eyes on crop	

Food safety risk		• Possibility of nutritional and some food safety risks	• Increased risk of zoonosis / animal derived pathogens – particularly with further intensification of livestock rearing • Conditioners, amendments – potential for new risks and bad practice	
Energy		• Long term energy security and resilience		
Lower carbon emissions	• Lower carbon emissions	• Lower carbon emissions	• Reduction in carbon	• Lower carbon emissions

Process optimisation	• Progressive improvement in food processing cost		• Process optimisation • Better use of the limited resources • Better materials for the same shelf life • Improvement in the efficiency of established models and supply chains.
Investment	• Higher investment	• Increased investment	
Knowledge sharing	• Greater awareness		• Sharing best practice. Better understanding of what food system we need

Land use	• Changes in land use • Greater interest in the countryside and less respect for land ownership without delivering public benefit			• Changes in land management and food production
Attitudinal change	• Attitude shift in consumer demands (e.g., less meat consumption)		• 'Quality not quantity' changes in consumer eating habits	• Less meat consumption
Taxation		• Changes in taxation		
Increased costs		• Higher costs • Short term Opex increases • In electricity	• Increased price of quality food	
More complexity		• More complexity		

Local procurement	• More local procurement	• Reducing import of animal protein from high Greenhouse Gas (GHG) emission intensity systems
Waste		• Waste collection
Packaging		• Packaging redesign
Nutrition		• Better nutrition
Data		• More data and measurable
Technology		• Roboticisatio and automation

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Table 5. Summary of responses: What do you expect the effects of developments being trialled could be?

Category	Academia	Manufacturing	Farmers & veterinary surgeon	Other

			• Financial incentives • Faster shift of investment away from unsustainable fossil fuel economy towards a sustainable bio-based and natural-resource-based economy to meet human needs for food, fibre and fuel while safeguarding natural capital
Financial incentive	• Subsidy system		

Farming methods		• Introduction of other nutrient cycling techniques • Precision agriculture • Greater integration of livestock and arable farming • Reducing import of animal protein from high Greenhouse Gas (GHG) emission intensity systems • Two tier farming with a scaled approach still in place but also a smaller more focused premium sector	• Improved productivity per hectare (vertical farming)
Energy			• Hydrogen energy

			• Lower carbon emissions
Lower carbon emissions	• Lower carbon emissions	• Lower carbon emissions	• Net zero at production, but not guaranteed in food storage or consumption (energy usage, waste)
Better nutrition			• Better nutrition
Better use of resources			• Better use of the limited resources • Better materials for the same shelf life
Risk averseness	• Retailers and the industry are risk averse to new processes		
Land use	• Changes in land use		• Changes in land management

Consumer diet			• 'Quality not quantity' changes in consumer eating habits	• Less meat consumption
Increased knowledge	• Greater engagement of local communities		• Improved understanding	• Lessons learnt and constant improvements
Increased costs & risk		• Short term risk • More complexity leading to unforeseen hazards	• Increased price of quality food	
Reduced costs		• Side effects of waste reduction could be a reduction in costs		
Technology	• Biotechnology			

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Table 6: Summary of responses: What are the key sources of information about the changes you have mentioned that we should be aware of?

Category	Academia	Manufacturing
Academia	• Academia • Including Sheffield Hallam University National Centre of Excellence for Food Engineering)	

Government departments/initiatives	• Innovate UK	• Building back better for increased resilie UK food system workshop report: https://www.foodsecurity.ac.uk/publicati back-better-for-increased-resilience-of-t system-to-future-shocks.pdf
Scientific papers/publicly available information	• Scientific papers	

Associations/Institutes	• Centre for Innovation Excellence in Livestock (CIEL) report on the Carbon footprint of UK Livestock	• Expert bodies e.g., Waste and Resources Programme (WRAP), Institute of Grocery (IGD), Institute of Environmental Manage Assessment (IEMA) • Industry bodies e.g., Chilled Food Associ Food and Drink Federation (FDF), Nation Union (NFU). • Sector trade associations • The Packaging Federation
Industry	• Industry	• Industry
Too many to mention		
Farmers	• Farmers	• People working on farms

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Table 7: Summary of responses: What new changes towards net zero are being implemented already? (Outside of your sector)

Category	Academia	Manufacturing	Farmers & veterinary surgeon	Other

Energy	• Green energy • Wind and solar energy • Improved air pollution and changes to transport • Electricity • Changes in refrigerator technology • Vehicles • Light Emitting Diodes (LED) lights	• Carbon off-set prices, European Union Emissions Trading Scheme (EU ETS) carbon costs, Future gas prices	• Green energy • Away from fossil based: solar, wind, earth, tides etc. • Solar Photovoltaic technology, coupled to (mainly) battery energy storage
Technology			• Robotics and technologies associated with detection
Waste	• Water use reduction, storage, and recycling		• Utilisation of waste streams

Farming methods	• Nature-based solutions		• Carbon sequestration (agroforestry, tree planting) • Some living manures that is leguminous co-crops.
Consumer diet	• Move towards less meat		
Packaging		• Activities around packaging should be harnessed and circulated as best practice	

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Table 8. Summary of responses: What developments are underway that have potential to roll out in the next ten years? (Outside of your sector)

Category	Academia	Manufacturing	Farmers & veterinary surgeon	Other

Energy		• Electrical baking, remove dependency on steam use • Possibly lower power consumption milling but given that wheat and corn milling were the first processes to use external power, (Roman water mills) and grain must be processed to get the nutrition this may be difficult.	• Green energy • Long-distance electricity transmission (HVDC subsea cables) are likely to become very significant in a global clean electricity grid	• Hydrogen as an energy source • Electric and hydrogen vehicles
Technology	• Robotics and sensing systems			
Waste	• Recycling of nutrients and further use of agricultural waste	• Food manufacture from former food waste streams		• Waste valorisation (to circular economy approaches)

Farming methods	• Dietary additives to reduce enteric fermentation in ruminants - but only during the period when fed concentrates • Nitrification inhibitors for application with nitrogen fertilizer.	• New crops and cultivars • Cultured meat, fish and milk
Biodiversity measures	• Biodiversity measures at scales not previously imagined	

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Who would you suggest we talk to about these changes or point us to other sources of information?

Innovate UK

Net Zero Innovation Portfolio (NZIP) coordination - to see if a food industry focus can be brought about - focusing a 'virtual centre' approach involving industry, academia, Defra, and Non-Governmental Organisations (NGO).

Syngenta AI group

Frans Timmermans of the European Commission

Google who is working on these things in the UK

Harry Norman – Managing Director of OAL group, Peterborough.

Good Food Institute (GFI)

Food and Drink Federation (FDF)

United Kingdom Research and Innovation (UKRI) for an overview of their funding investments, that contribute directly to the net zero agenda across the Research Councils

Talk to business, engage with Institute of Grocery Distribution (IGD) and British Retail Consortium (BRC) and National Farmers’ Union (NFU)

Online media - e.g., BusinessGreen, Solar Power Portal, Photovoltaic PV-magazine, etc.

Organic farmers

Milling engineers

National Energy Research Demonstrator (NERD)

Bob Docherty

John Ingram

Maurice Moloney

Pascal Chapot, Nestle