



Food Futures



from business as usual
to business unusual



Foreword

The future of food is uncertain. Not since the Second World War has there been a more pressing need to look again at how we produce, distribute, value and consume our food. My mother's generation were used to being thrifty, understanding the reasons behind post-war challenges in food supply and the need to ration and respect what food they had.

If we fast forward to today, we live in a world where challenges to future food security are becoming more obvious after decades of relative plenty; and where a third of all food grown is thrown away – that's one-in-four calories lost and a major impact not just on our future food security but on our future nutritional security.

The reality is that we are at a crossroads, a tipping point - as the decisions that governments, businesses and we, as consumers, make today will determine how and if we can meet the demands of future generations. As this report shows, the world's population is set to rise to 8.1 billion in the next decade; and a growing and increasingly urbanised middle class has aspirations for a more varied protein rich diet. This is happening at a time when the natural resources we depend upon for our food (land, soil, freshwater, biodiversity) are under growing stress; and there is an increasing risk of a major food production shock as the early squalls of John Beddington's 'Perfect Storm' of food, water and energy shortages begin to make themselves felt. Closer to home, in the UK alone, population increases mean that it will take another 5 million tonnes of food to feed the UK population in 10 years' time. These are clearly challenging times.

But where there are challenges there are also opportunities. The raft of data-enabled technologies identified in this report are becoming more accessible and affordable, driving a revolution in how the food system operates, connecting supply chain partners and consumers in new and innovative ways, improving yields and communication, reducing resource use and waste; and opening the door to new food chain collaborations and partnerships.

"The future food system will need to play an active role in helping consumers make healthier and more sustainable food choices."

Not all solutions or opportunities are technology-based. The potential to create more concrete links between food system sustainability and public health and nutrition are of increasing interest to policymakers, businesses and civil society. If obesity rates and diet-related ill-health rise as predicted, with the resultant costs to society and the health system, a wider coalition of interests need to come together to ensure a joined-up policy and business response. There are some obvious synergies and win-win situations in the debate around healthy, sustainable diets (e.g. more plant-based foods; new and more sustainable sources of protein; better

range of portions reflecting different dietary needs, resulting in less food waste and overconsumption) that deserve further exploration. The future food system will need to play an active role in helping consumers make healthier and more sustainable food choices.

If the past decade has been one of discovering the nature and scale of the issues we face and beginning to respond to them, then the success of the next 10 years will be judged on the choices we make in finding solutions that transform the food chain and our relationship with food.

We have to ensure that we have a food chain that is 'FIT' for the future (flexible, intelligent, transparent) - one that is ready to respond to future challenges and trends; and is able to reconcile the needs of consumers, whilst protecting and enhancing our natural environment.



Dr Liz Goodwin, OBE
CEO, WRAP



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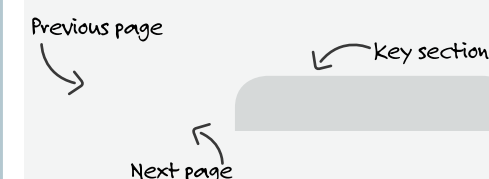
How to use this report



This report is best viewed in [Adobe Reader](#) - this will enable the navigation functionality.



You can navigate between topics by clicking hyperlinks embedded in the topic icons.



Additional navigation buttons can also be found at the bottom left hand side of each page. These enable you to move forward and back within the document or jump to the contents page using the contents button.



All of the sources of information used to develop this report are available in a separate document. This can be downloaded from www.wrap.org.uk/foodfuturesreferences

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Executive summary

Achieving food and nutrition security in an increasingly complex and uncertain world means that “business as usual” approaches may no longer be a credible option. The UK food system was built for an era that has passed; businesses and policymakers are having to adapt and react to new and rapidly evolving economic, environmental and social realities. The challenges are well rehearsed and cover a dizzying range of issues, from shifting global trade patterns, to water stress and increasing consumer expectations. Understandably therefore, the leaders of tomorrow will need to look further ahead to find ways to tackle the emerging challenges of today - something we term ‘**doing business unusual**’.

Through this research we have identified a range of areas where businesses and policymakers can foster innovation, develop more resilient value chains and improve the offer to consumers. This report presents an in-depth analysis of where these opportunities for doing business unusual will come from. It has been created to inspire, provoke debate and ultimately influence the choices made today. In all, 15 ‘priority topics’ have been identified that range from the expansion of global aquaculture to the opportunities presented by automation and data exchange in food manufacturing (so-called ‘Industry 4.0’).

Each topic establishes its critical relevance to the future of the food system and presents key risks, opportunities and existing examples of innovation. Three cross-cutting trends also emerge as priorities for attention: the increasing challenges to food system resilience; the explosion in data-enabled technology and the alignment of health and sustainability agendas.

These trends, explored in more detail below, are used as a framework for prioritising the steps we need to take toward a healthier, more sustainable society.

Resilient supply chains that are FIT for the future

In the ten years since the WRAP *Grocery Futures* report was published, the food system and wider society have witnessed significant changes: social media was born and has continued to expand its influence; global food security has come to mainstream attention – as has the food system’s exposure to

climate change. These changes have meant that many ‘sustainability’ issues have become strategic issues for businesses across the food value chain. Key risks and impacts and the business case for action are now understood far more clearly than they were in 2006. However, the complexity of addressing the many issues that stand in the way of achieving a sustainable and

resilient food future have also become more clear.

Events such as the 2007/8 World Food Price Crisis and ‘Horsegate’ have highlighted the fragility of the food system. Investors and financial institutions, perhaps sensitised by the recent global financial crisis, are also increasingly conscious of systemic risks to the economy and the food system. While concerns about external pressures, such as water scarcity and the degradation of our soils, have become the focus of debate on supply chain risk, there is now a growing appreciation of the risks that stem from the form that modern food systems and economies take: they are large, complex, interconnected and specialised.

“The leaders of tomorrow will need to look further ahead to find ways to tackle the emerging challenges of today.”



To respond to these challenges, future supply chains will need to be remodelled to be **flexible, intelligent, and transparent (FIT)**.

- **Flexibility** will come from a range of attributes that encourage resilience, such as diversity and redundancy.
- **Intelligence** will come from businesses and policymakers investing more in understanding, communicating and managing risks – and identifying and realising new opportunities. This will require interdisciplinary partnerships, the smarter use of data and a reassessment of the skills and training needs of the UK food workforce.
- Greater **transparency** will be needed to help highlight hidden risks that come from complexity and create incentives that drive better decision-making and collaborations in supply chains.

A number of opportunities exist for business and policymakers to engage in this area, such as the development of new products from diversified protein sources; opportunities to realise efficiencies and reduce food waste; or creating new high value by-products from undervalued waste streams. The location-specific nature of many critical food system challenges will also call for a new breed of local and ‘landscape-scale’ partnerships that deliver more sustainable

Executive summary

resource use. Policymakers can support these initiatives through the development of an open spatial data infrastructure for the UK – a national-level framework of geographically relevant data, policies and tools that are easy to access and use.

New opportunities from data-enabled technology in the food chain

Data and data-enabled technology are at the core of a number of the opportunities identified in this research. The effective use of data-enabled technology presents one of the greatest opportunities for the food system since the Green Revolution. Whereas the Green Revolution saw increased agricultural productivity through techniques, such as plant breeding and the use of synthetic fertilisers, the **'Green Data Revolution'** will create a smarter, more flexible and resilient food system, as more data is created and shared between supply chain partners and consumers.

The characteristics of the food system, such as complexity, huge geographical range, and diversity of operators make it particularly suitable for exploiting data-enabled technologies. This report explores a number of exciting opportunities open to business and policymakers including precision agriculture, smarter certification, factory automation, 'intelligent' packaging, risk analytics, supply chain forecasting, product personalisation and new means of engaging with consumers.

Our research shows that the delivery of the potential benefits from these technologies is by no means inevitable: there is a need to actively promote the adoption of these approaches and invest in skills and capacity. Also, care will be

needed to avoid the downsides of increased digital connectivity – such as new data security and privacy risks.

To unlock the potential of this area food businesses and policymakers should develop ambitious data strategies that identify and leverage the data-enabled technologies that are most appropriate to their organisations.

Product innovation and consumer engagement on health and sustainability

In the last ten years, the link between food sustainability and public health has become of increasing interest to business leaders, policymakers and civil society. The concept of **'healthy sustainable diets'** has come to dominate research and policy discussions - in particular the synergies and trade-offs between dietary preferences and the environmental impacts of global supply chains. National governments are starting to add weight to this debate by providing dietary recommendations that aim to deliver improved environmental and nutritional outcomes.

"The effective use of data-enabled technology presents one of the greatest opportunities for the food system since the Green Revolution."

This report underlines the wider set of interdependencies between public health, the food system and the integrity of the natural environment. For example, how environmental change has the potential to impact public health by increasing food safety risks or reducing the nutritional quality of crops. In addition to this, ensuring the UK has a diversified, sustainable and healthy supply of protein will be one of the defining challenges of the coming decades. The solutions, such as new models of land-based aquaculture and the use of alternate sources of protein in animal feed (likely to be the main focus in the next decade) and as novel ingredients in food products, have many potential



advantages as long as any new risks to human and environmental health are properly managed. A systems approach to dealing with health and sustainability outcomes is therefore critical when it comes to considering our future food and protein options, but also calls for more engagement and support from the public. Consumer interest in health and nutrition is increasing but it is important that this trend is capitalised on to also deliver broader sustainability outcomes, as well as new products and services.

The future of food

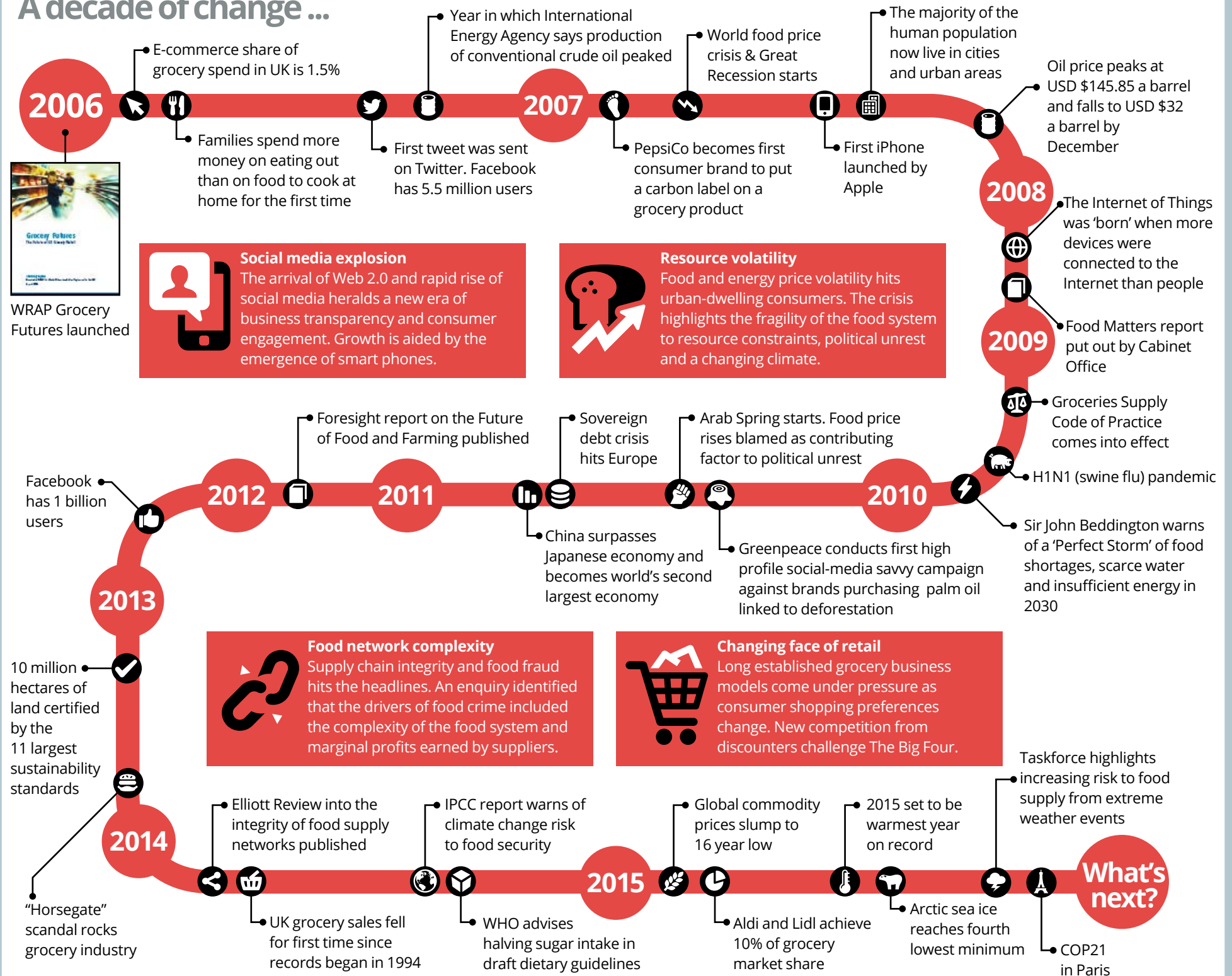
Making the most from these opportunities over the next ten years will be judged by the degree to which we find scalable solutions that transform the sector and our relationship with food.

In order to adapt and respond to future shocks, opportunities and trends, UK policymakers and businesses will need to take a leadership role: exploring and supporting the uptake of new technologies, production systems and raw materials; realising the benefits of investing in data and skills; and establishing new and innovative collaborations and regulatory frameworks. **By embracing 'business unusual' we can ensure that our food system is truly fit for the future.**

Introduction

Since the WRAP *Grocery Futures* report was published in 2006 the food system and wider society has witnessed significant change (see timeline, right). Ten years on and these changes have meant that 'sustainability issues' have become strategic issues for food and drink businesses. The key risks across the value chain and the business case for action are now understood far more clearly than they were in 2006. But the complexity of addressing the many 'wicked problems' that stand in the way of achieving a sustainable food future have also become clear. If the past decade has been one of discovering the nature and scale of the issues we face, then the success of the next ten years will be judged on the choices we make in finding solutions that transform sectors. This report presents an in-depth, yet accessible, farm-to-fork analysis of where these solutions are to be sought. In all, 15 priority topics and 3 key trends have been identified by a cross-section of food industry experts convened by WRAP. These topics range from the implications of changing consumer behaviours to the challenges of meeting the future protein needs for an increasingly affluent global population.

A decade of change ...

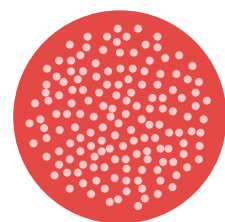


Identifying food system priorities

This report was developed using a three stage approach that consisted of horizon-scanning, expert workshops and in-depth research.

Stage 1: Horizon scanning

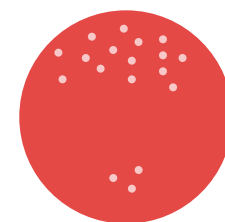
A diverse range of sources were reviewed to identify areas of future concern and innovation across the food system. In total 152 different topics and trends were identified. This long list was sorted and consolidated, so that it could be reviewed.



**152
Topics &
trends**

Stage 2: Expert identification of key trends and topics

A Thought Leadership Group of food and drink sector experts was convened by WRAP. During two workshops, attendees filtered and prioritised areas of most importance to the future food system. The main output of these sessions was the selection of 15 priority topics and 3 key trends for further research and analysis. A larger number of underlying trends were acknowledged but not examined in any more detail within the project (see next page).



**15 priority
topics &
3 key
trends**

Stage 3: In-depth research and analysis

Finally, in-depth research was conducted into the 15 priority topics. This included literature reviews and further expert interviews. The results of the topic research form the basis for the 15 topic sections in this report (see below). In addition, an analysis of overarching themes and recommendations were developed. These are presented in the final section of this report.



**This
report**

Topic sections: Presenting key risks and opportunities

The results of the research into the 15 priority topics form the foundation of this report. Each topic section takes a similar 4-page format: The first page summarises why the topic should be of particular interest to business and policymakers. The second page provides an overview of the topic as things stand today. The third page examines each

topic through the lens of current trajectories, key risks, opportunities. The final page outlines examples of best practice and innovation. The use of the opportunities/risks lens enables business and policymakers to think about how to engage with the topic which is inherently complex and uncertain (see graphics right).



Opportunities

Options to improve food system sustainability through changes to business and policy practice.



Current trajectory

What is expected to happen in the coming decade given current practices and trends.

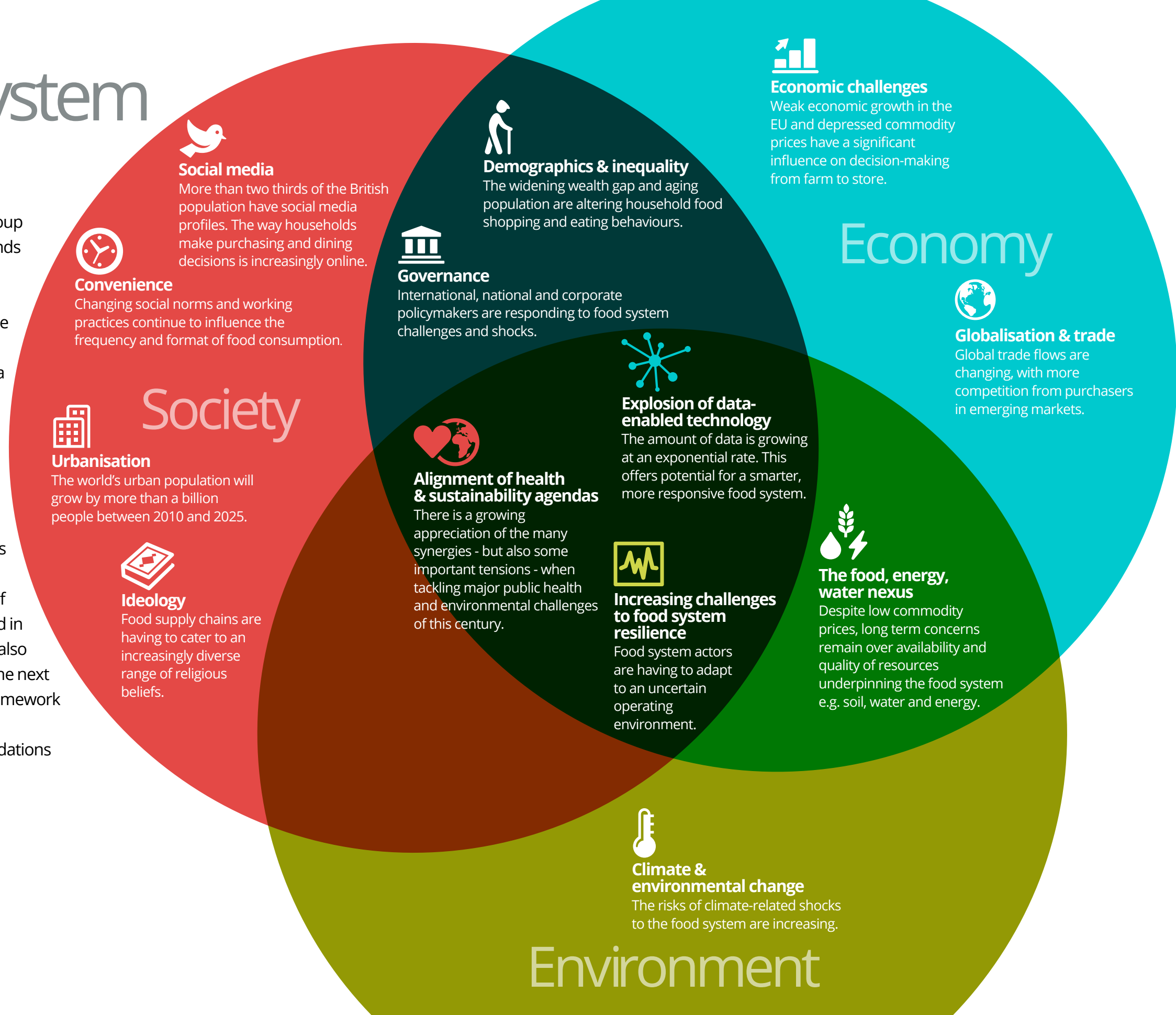


Risks

Issues to watch-out for that could jeopardise food system sustainability in the next ten years.

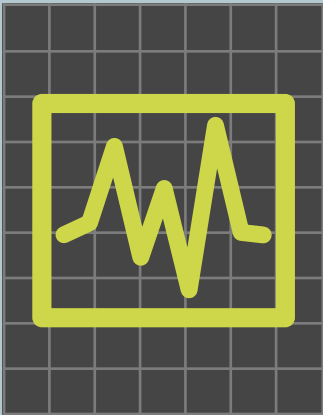
Food system trends

The Thought Leadership Group considered a number of trends that will influence the food system over the coming decade. However, early in the research it was agreed that the project should focus on a small number of 'key trends' that industry, policymakers and WRAP have the power to influence and engage with in the short term. These trends, which touch on a number of issues across the environmental, social and economic dimensions of sustainability, are highlighted in the diagram, right. They are also explored in more detail on the next page and are used as the framework for presenting the research conclusions and recommendations at the end of this report.



Food Futures: key trends for the next decade

Of all the trends identified during the research, three stood out as posing unique challenges and opportunities for the UK food system in the next decade: dealing with increasing challenges to food system resilience; capitalising on the explosion of data enabled technology; and adopting a joined-up approach to health and sustainability challenges (see right). Whilst the other trends identified - such as globalisation and urbanisation - are perpetual issues of interest, the three key trends identified in this project are only being addressed effectively by a few organisations and policymakers. Developing the capacity to prepare for the impacts of these trends will help create a more competitive, productive and sustainable UK food system in 2025. These trends, which are revisited at the end of the report in the concluding analysis and recommendations section, impact on all of the 15 topics included in this report and introduced on the next page.



Increasing challenges to food system resilience

By 2025 the “Perfect Storm” of energy, water and food shortages are expected to be impacting society. The food systems developed in the last century will not be fit for dealing with the increasing complexity and volatility of environmental, social and economic systems. Failure to respond proactively to these new

challenges will leave businesses exposed to disruptions or left with business models that are unresponsive to changing societal and consumer demands. There is a need to understand and create a food system that has greater resilience to shocks and pressures that will be placed on it.



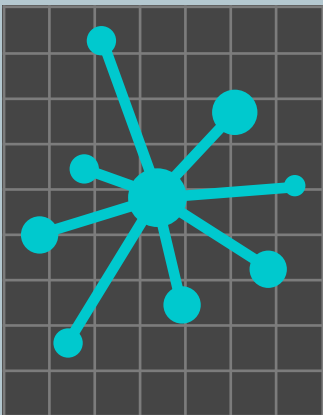
Increasing

Impacts of extreme weather events, agricultural pest ranges and food system interconnectedness



Decreasing

Soil health, crop diversity underpinning global nutrition and quality and availability of water resources



Explosion in data-enabled technology

The growth in ‘smart’ technology is driving a revolution in how the entire food system operates, from a better understanding of land resources to automated factories and kitchens. Data-enabled technology is becoming cheaper and more accessible all the time, but the food system has yet to fully capitalise on the benefits

these technologies can unlock. Over the next ten years these benefits will be explored as companies, households and policymakers seek to make better use of data. Those organisations that have the capabilities to realise this potential will be better placed to respond to the challenges of tomorrow.



Increasing

Number of devices connected to the internet and number of social media users



Decreasing

Cost of data storage technology and size of data-enabled devices



Alignment of health & sustainability agendas

The links between food system sustainability and public health are of increasing interest to business leaders, policymakers and civil society. The concept of ‘healthy sustainable diets’ has become an important area of this debate - in particular the synergies and trade-offs between dietary preferences

and the environmental impacts of food supply chains. Beyond diet, there is growing agreement that the serious environmental and public health challenges we face need to be addressed in an integrated manner so that new opportunities can be promoted - and unintended consequences can be avoided.



Increasing

Costs of obesity and environmental footprint of global food and drink consumption



Decreasing

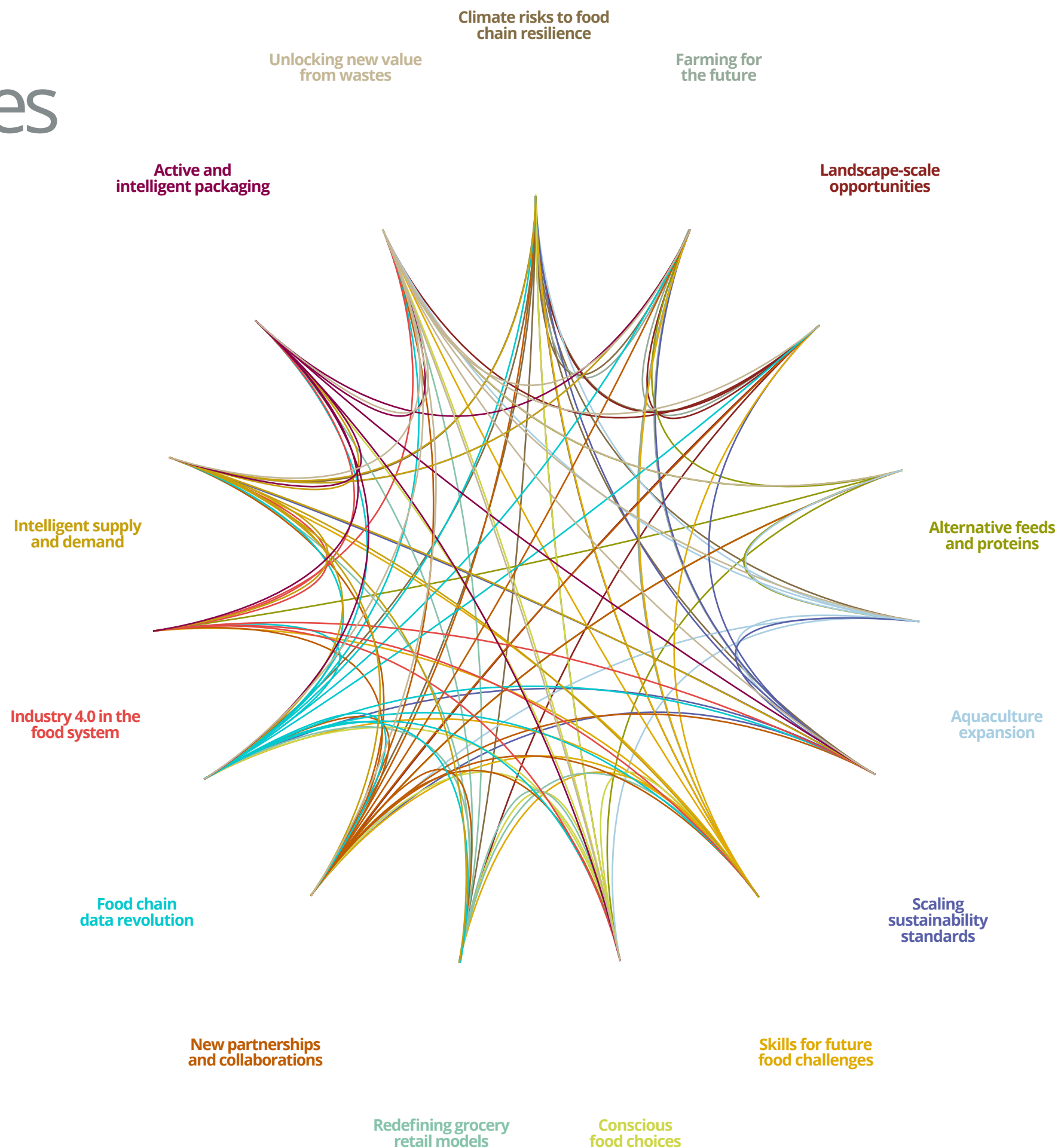
Levels of physical exercise and time spent by consumers in the kitchen and global fish stocks

Food Futures topics

The foundation of this report is an exploration of 15 topics of importance in delivering a more sustainable, resilient UK food system in the coming decade. Whilst the topics are explored in discrete sections, it is important to recognise the many connections that exist between them (see right). For example, *New partnerships and collaborations* will be critical to delivering *Intelligent supply and demand* and *Unlocking new value from wastes*.

Navigation

The next page provides an overview of all 15 topics, before we dive into the detail of each topic. Readers can navigate to a topic section by clicking on topic icons and links on the topic 'clock' or by returning to the main topics page using the 'topics menu' icon found on the bottom left of every page.



Overview of the Food Future topics

Climate risks to food chain resilience

Climate change will significantly affect the food system - for example through its impacts on agricultural yields, food prices, reliability of supply, food quality, and food safety. How the UK food system adapts to and mitigates its impact on the climate will be critical for ensuring long term food security and supply chain resilience.

Scaling sustainability standards

Over the past decade, voluntary private sector standards have become the dominant means of embedding and communicating sustainability performance within food and drink supply chains. However the costs of implementation and questions over their actual impact, means new approaches are being developed.

Food chain data revolution

A revolution in data availability has the potential to fundamentally change the way the food system operates by enabling informed decision making throughout the value chain. However to equitably realise the potential of this opportunity for the entire sector, new relationships, standards and technologies will be needed.

Farming for the future

Agriculture is becoming a key area of innovation in the food system. Developments include the use of advanced monitoring systems to increase input efficiencies and anticipate production risks, such as adverse weather. Emerging technologies will also challenge established models of production and encourage new entrants into the industry.

Skills for future food challenges

Training in the agri-food industry will need to evolve to help staff in a diverse set of roles deal with rapidly changing operating environments and new external challenges, such as climate change. These new skills have the potential to give businesses a competitive advantage and help safeguard them from important business risks.

Industry 4.0 in the food system

Globalisation, product customisation, shorter innovation cycles and cost reduction will drive increased adoption of IT-enabled systems such as automation and The Internet of Things. This '4th Industrial Revolution' is well-suited to the sector, where high levels of product variability means flexibility can generate productivity gains.

Landscape-scale opportunities

Many issues affecting land-based sectors don't respect organisational boundaries. The need to deliver sustainable land use therefore requires interventions and collaboration at a scale where processes such as pest migration and pollination occur. An emerging technique to deal with these issues is landscape-scale partnerships.

Conscious food choices

Consumer engagement with food has been steadily increasing with more sustainable, ethical and healthy choices arguably becoming more aspirational and associated with improved quality and taste. In the coming decade product transparency and storytelling will play a positive role in increasing trust and will help address important consumer concerns.

Intelligent supply and demand

A key driver of waste within the food supply chain are difficulties in managing changes in demand for products - especially highly perishable goods. Through the development and adoption of new processes and techniques, improved demand forecasting can secure improvements in business and environmental performance.

Alternative feeds and proteins

Global meat consumption is expected to double between 2000 and 2050. Livestock products are a major source of protein, but a large expansion of existing production systems is unsustainable due to high resource needs and impacts on local and global environments. Alternatives are needed to address this key food system challenge.

Redefining grocery retail models

The landscape of food retailing is changing rapidly. The sharp focus on price, the emergence of new retail models and actors in the UK food market, opportunities for closer relationships across the supply chain, and shoppers who are increasingly prioritising convenience will all play roles in shaping the future retail market.

Active and intelligent packaging

Advances in packaging materials and technologies have significant potential to deliver reductions in food waste, food safety improvements, brand protection and improved supply chain traceability. Through the use of technologies such as RFID and nanotechnologies, future packaging will help track, preserve and monitor the food it protects.

Aquaculture expansion

Aquaculture has the potential to be a key source of sustainable protein, however some aspects of current production methods pose environmental and social risks to food businesses and local communities. Addressing these risks requires a range of actions, such as the adoption of new technologies and standards.

New partnerships and collaborations

To create a more sustainable and resilient food system, businesses are increasingly acknowledging that collaboration is essential for delivering change at scale. Collaborations will include pre-competitive work within industry - but also the promotion of more partnerships with research institutions and NGOs.

Unlocking new value from wastes

With increasing resource competition and regulatory pressure the food chain will seek to derive as much value as possible from previously underutilised organic waste streams. Concerted efforts by government and industry to implement the 'circular economy' is leading to an increasing emphasis on reassessing the value of by-products.

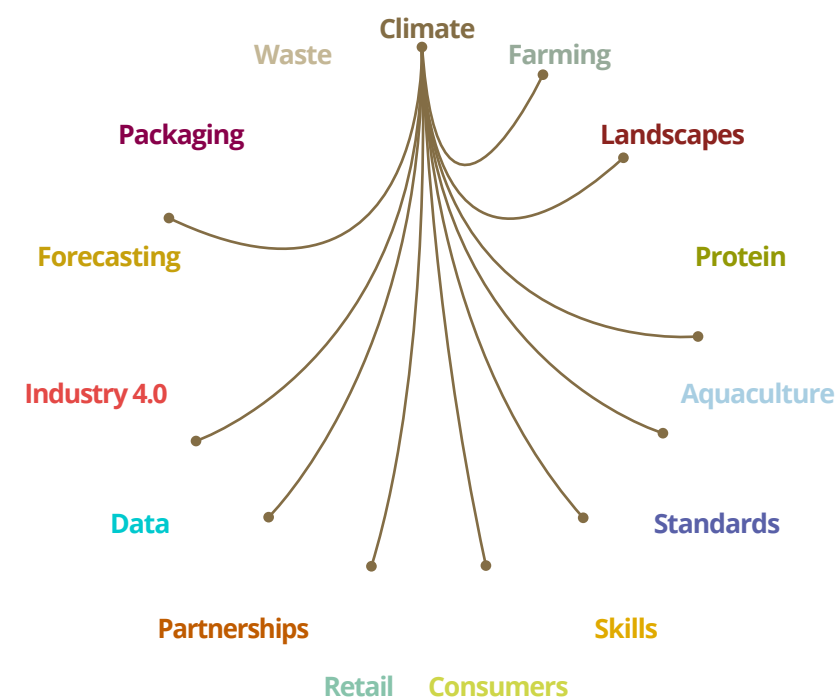
“Evidence suggests that the risk of a 1-in-100 year production shock event from extreme weather could increase to a 1-in-30 year or more in the next few decades.”

UK-US Taskforce on Extreme Weather and Global Food System Resilience



Climate risks to food chain resilience

By 2025 the food system is expected to be experiencing the ‘Perfect Storm’ of food, energy and water shortages. Climate change will affect food supply chain resilience through its impact on food safety, raw material availability, and food quality. Gradual changes to regional climate combined with unexpected and increasingly extreme weather shocks have the potential to change the way supply chains operate and impact upon the price we pay for food. Anticipating and responding to these changes will require responses across the food system using a range of new tools, technologies, business models and practices.



Climate risks to food availability, safety & quality

Supply chains vulnerable to shocks and changes in climate

Food system resilience can be examined through the lens of key food industry concerns: food availability, quality and safety. Even though some of the forecasts quoted in the infographic on the right stretch beyond 2025, the next decade will be a key period for industry and policymakers to prepare for these challenges – particularly in the agricultural stages of global and UK value chains.



Food availability

Climate change and altered weather patterns are likely to disrupt food production and sourcing locations. More frequent and extreme weather events such as droughts, heatwaves, intense rainfall and storms will affect production and transport. Where food supply is constrained and prices rise, there is likely to be a greater risk of food fraud.



Food safety

Climate change will affect food safety by altering microorganism growing conditions and their exposure to food. Pesticide usage is also likely to change as agricultural pest ranges move. The Emerging Risks Unit of the European Food Safety Authority has identified climate change as a key driver for emerging risks in food and feed safety. Despite this, the understanding of the links are only beginning to be researched in detail.



Food quality

Heat, drought and changing pest ranges are likely to impact on the technical, nutritional and eating quality of foods and food ingredients. Research has identified evidence for climate impacts on food quality across a diverse range of products including fruit, vegetables, grains and dairy products.



A variety of crops and livestock products will have current models and locations of production challenged by climate change in the coming decades. Examples include:

- **Bananas** - Half of the current global banana growing area is likely to become unsuitable for banana cultivation by 2060.
- **Nectarines** - Warming temperatures are expected to mean that certain regions can no longer provide enough "chill hours" to set fruit.
- **Fish** - Temperature changes will have a mixed effect on fisheries as waters warm across the globe. Some species will be negatively affected and others positively.
- **Wheat** - Global wheat production has been estimated to fall by 6% for each °C increase of local temperature, barring adaptation. Yields will also become more variable, creating more volatility.
- **Sheep** - Bluetongue virus, a sheep disease, is spreading into northern Europe with rising temperatures.

"Food quality is declining under the rising levels of atmospheric carbon dioxide that we are experiencing."

*Professor Arnold Bloom,
University of
California,
Davis*



Higher levels of contamination of **vegetables** from microorganisms such as E. coli and salmonella are likely due to flooding events and temperature changes.



Wheat contributes approximately 25% of the protein

in human diets and a number of manufacturing processes, such as baking, require sufficient levels of this nutrient. Researchers have shown rising carbon dioxide levels in the atmosphere inhibit the conversion of nitrates into protein in wheat growing.

"Some of the most productive agricultural land in England is at risk of becoming unprofitable within a generation due to soil erosion ... Without further action the natural environment will be severely harmed by climate change."

*Committee on Climate Change
2015 Report to Parliament*

Agriculture



Intense and disruptive storms as well as droughts and rising food prices may undermine the stability of supply routes (e.g. Suez Canal).

Logistics

"Climate change is expected to challenge the effectiveness of current food safety management systems in the near future."

*Editorial in Food
Research International
special issue on the
impacts of climate
change on food safety*



Mycotoxins are highly toxic chemical substances produced by mould that grows on crops such **maize, wheat, and rice**. With climate change they may become of increasing concern to food processors in the EU.

Processing



Increased carbon-dioxide levels have the potential to impact upon the quality of **oilseed rape** and have implications for industrial processing. Researchers predict significant reductions in the concentration of healthy unsaturated fatty acids in the crop. As a major ingredient in the food industry, this has implications for household diets.

Household

Creating a climate resilient food chain

The trajectory for climate risks to food chain resilience: Risks and opportunities on the pathway to 2025



Opportunities

Investment in new approaches to food chain climate resilience improves business and societal stability, as well as promoting better environmental performance.

- **Alternate ingredients** Crops most at risk from climate change have the potential to be substituted for alternatives with lower risk profiles e.g. almond milk (at risk from drought and pollinator declines in California) can be substituted for by peanut milk (more widely available and self-pollinating). Interest is also growing in using ingredients derived from crops tolerant to drought, such as prickly pear. There is potential to combine climate resilient traits in new crop varieties with improved nutritional qualities.

- **Food safety research & best practice** More work is needed on understanding and addressing the links between climate change and food safety. The insights from this need to be integrated into revisions of industry best practice. For example, updating guidelines on Good Agricultural Practices and Good Hygienic Practices. The food safety, fraud and quality implications of climate change will lend additional weight to improving traceability systems.

- **Climate finance** New approaches to risk transfer and investment in climate adaptation can help mitigate climate risks in supply chains. For example, insurance products are being developed for primary producers in countries and regions most at risk from climate change.

- **Climate analytics** There is potential to use the growing quantity of macro environmental data to develop business decision-support tools. For example, warning systems to help predict climate-related risks, such as food safety hazards or disease outbreaks. This data could also be used to examine longer-term supply risks to enable companies to focus adaptation efforts and work with suppliers to increase supply chain resilience.

"The food system we increasingly rely on is a global enterprise. Up to now it's been pretty robust and extreme weather has had limited impact on a global scale. But if the risks of an event are growing, and it could be unprecedented in scale and extent, how well prepared are we? Especially in the context of an international food system that over time has become increasingly efficient and therefore less resilient, the risks are serious and should be a cause for concern."

Sir David King, former UK Government Chief Scientist in a report from The UK-US Taskforce on Extreme Weather and Global Food System Resilience



Current trajectory

Reactive responses to gradually changing climate sees global food production shift to new growing regions and production systems.

- **Shifting production** As regions become more climate stressed there will be a shift in land suitability for growing certain crops such as coffee, bananas, grapes (for wine), stone fruit, etc. This shift is likely to be preempted by increased risk of crop failure and variability in yields. The changes could have significant negative economic impact on the countries affected.

- **Variety development** In addition to using new crops in food production, research will continue into the development varieties of common crops that are able to cope with climate extremes (e.g. salinification, drought, heat). For example, researchers at the University of Adelaide in Australia have bred salt tolerance into a variety of durum wheat that shows improved grain yield by 25% on salty soils.



Risks

Extreme weather shocks and new disease threats cause severe disruption to global food system and put food security at risk - particularly in developing countries.

- **Shocks to production** The food system is increasingly at risk from production shocks caused by extreme weather. Without efforts to better understand and mitigate these risks, food security would be affected - particularly in developing countries. These shocks would also have the potential to cause political unrest in import-dependant regions, such as North Africa.

- **Pest and disease crises** Novel distributions and increasing incidence of pests and diseases threaten agricultural production. Researchers have identified that climate change and its effects on plant health will increasingly threaten human populations - again, particularly in developing countries. Proper monitoring and control is also needed to lessen the impact of these crop-destroying organisms.

- **Food fraud** Criminal activity in supply chains has the potential to increase as the availability of some food types are challenged by a changing climate.

Increasing food chain climate resilience

Food safety warnings

New forecasting techniques and systems will help mitigate the food safety impacts of climate change.

New collaborative and data-enabled platforms will help industry respond to challenges. For example:

- **Horizon scanning** will look at diseases emerging in animals or other parts of the world to identify and predict threats.
- **Early warning systems** will use computer models and weather conditions to predict risk levels for mycotoxins in crops.
- **Veg-i-Trade** is a European Commission funded project on the impact of climate change and globalisation on the safety of fresh produce. It has developed a diagnostic tool for performance measurement and identification of bottle necks in horticultural safety management systems as well as guidance on risk-based sampling plans.

Climate smart farming

Agricultural production is particularly vulnerable to climate change and so warrants special attention.

Climate Smart Agriculture (CSA) could increase resilience of agriculture to climate change. CSA is defined by the UNFAO as “agriculture that sustainably increases productivity, enhances resilience (adaptation), reduces/removes GHGs (mitigation), and enhances achievement of national food security and development goals”. According to the research programme on Climate Change, Agriculture & Food Security, CSA “includes both traditional techniques, such as mulching, intercropping, conservation agriculture, and pasture and manure management, and innovative practices, programmes, and policies, such as improved crop varieties, better weather forecasting, and risk insurance”. However there may be a trade-off between resilience and agricultural yield.

Supply risk analysis

Environmental data will increasingly help support strategic decision-making in grocery supply chains.

Businesses are exploring how long-range climate forecasting and risk analysis can help them identify low resilience and adapt to future primary production conditions. For example, Sainsbury’s, in collaboration with fresh produce suppliers and academic partners, has been exploring the feasibility of using macro environmental datasets to support long term climate change adaptation. The feasibility study, funded by Innovate UK, focused on risks that impact upon stonefruit product quality, availability and cost. In another project, WRAP are working with industry partners to develop a Raw Materials Risk and Opportunity Assessment Tool to help inform business sourcing strategies and decisions. This tool includes a range of risk parameters, including the impacts of climate change on production.

Climate insurance

New financial products will be used to increase the resilience of producers and promote investment in agriculture.

The Global Innovation Lab for Climate Finance is piloting the Agricultural Supply Chain Adaptation Facility. It is a credit enhancement and technical assistance facility that aims to strengthen small- to medium-sized farmers’ and processors’ ability to make climate-resilient investments. In another example, Columbia University and large re-insurance companies are designing index insurance products that will allow banana farmers in the Dominican Republic to recover more quickly if severe winds or droughts damage crops. Swiss Re and Oxfam America have also developed a risk management framework to enable farmers in Ethiopia to improve their food and income security through climate resilience projects, insurance and microcredit.



Is your supply chain climate resilient?

The Environment Agency Climate Ready support service has developed detailed guidance on assessing and managing climate change risks in supply chains.

The guidance contains a five-step framework for businesses to understand what a changing climate and extreme weather mean for them (see below). The Environment Agency Supply Chain guidance has been shared with ASDA’s suppliers.

ASDA has developed a Climate Resilience Framework, in which the business mapped risks across their food business and own UK operational sites. Their research into food sourcing, processing or transportation, found that there is a risk to all aspects of their operations. 95% of fresh produce will be affected by changes in the climate.

“The food industry has to move from considering resilience in terms of response and move to prediction and planning.”

Chris Brown, Senior Director, Sustainable Business, ASDA

Step 1

Is climate change a material issue?

Step 2

Plan to respond

Step 3

Access risks and opportunities

Step 4

Prioritise and identify actions

Step 5

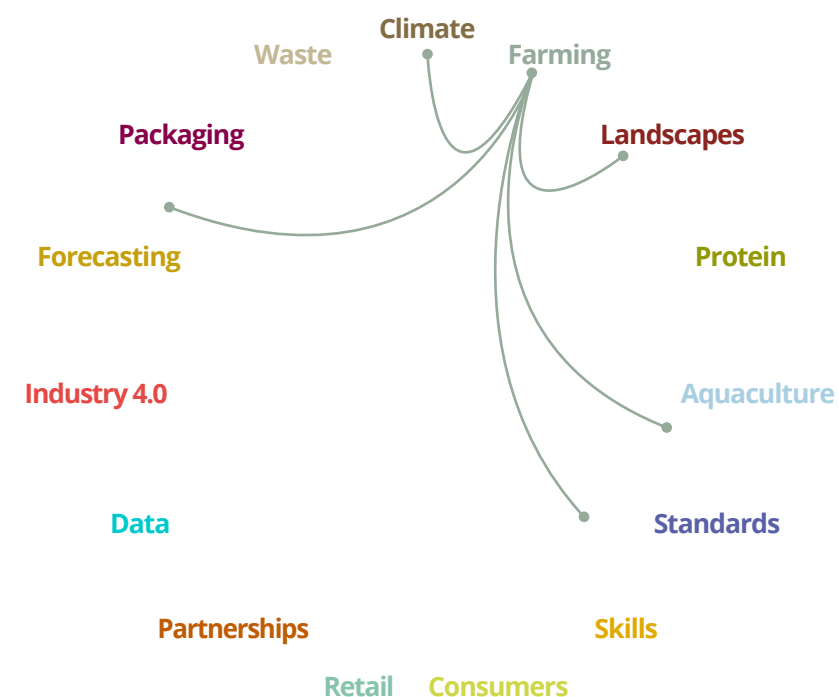
Manage your risks



Farming for the future

Agriculture will become a key area of technological innovation in the coming decade. Impacting all areas of the production system, this innovation will be driven by a desire from both industry and policymakers to reduce production costs, boost agricultural output, and adapt to a changing climate.

Likely areas of innovation include precision agriculture and the use of advanced monitoring and data systems as well as biological innovations in genomics and plant breeding. Some emerging approaches will also challenge established models of food production through the use of alternative systems such as soil-less growing and indoor farming. This topic explores these opportunities for advanced, commercial farming systems.



"The challenges facing the food industry are well documented. From adapting to the effects of climate change, to feeding a growing global population with dwindling resources, it is very clear that the degree of change that is required within food and agriculture systems, and the pace with which that change needs to be delivered, requires us to adopt new ways of doing things."

*A UK Strategy for
Agricultural Technologies*

The farm of the future

The opportunity

The world population is projected to grow by over a billion to 8.1 billion by 2025. Net expansion of cropland is estimated to overshoot UNEP’s “safe operating space” of 1,640 Mha by 2020. To feed the world’s future population, the FAO predicts that overall food production will need to be raised by 60% when compared to 2005.

To meet these demands without exceeding planetary boundaries, there is the need to get ‘more from less’. However, increases in UK agricultural productivity have trailed other countries over the last four decades, and it is now at the lower end of agricultural productivity in developed countries.

Sustainable intensification

90% of the increase in global crop production needed to feed the world’s future population is expected to come from higher yields, reduced waste, and increased cropping intensity. Sustainable intensification is defined by FAO as “increasing productivity and improving efficiency in the use of resources, against a backdrop of strong competition over a degrading natural resource base”.

Remote Sensing (RS) techniques

Aerial and/or satellite imagery used to determine yield potential, nutrient deficiencies, and stresses.



Agritech in action



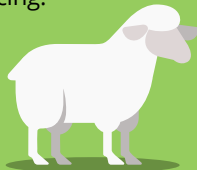
Individual livestock tracking

Satellite receivers allow tracking and storing of information on animal health status, grazing behaviour; data can be further used to understand grazing pressure and create virtual fencing.



Biomass monitoring

Mapping of plant growth and amount of nitrogen needed through location-specific crop phenology observations (study of cyclical/seasonal events and their external influences) and optical sensors for canopy status and nitrogen content.



Machine Guidance

Using satellite technology to support driver assistance, steering support, and automatic driving.



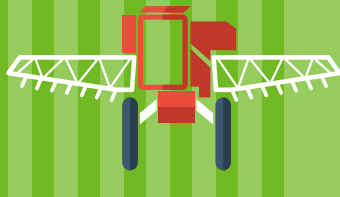
Harvest monitoring

Instant data on crops (wet and dry readings, crop density, information about yield) allows harvests that maximise yield.



Robotics

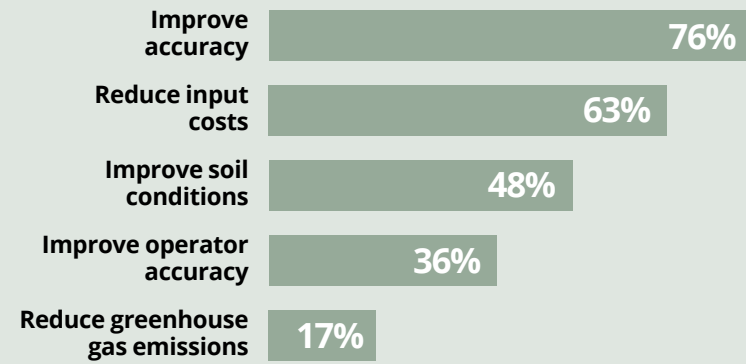
Potential applications ranging from: weed and pest management; to milking; to artificial hands capable of picking strawberries.



Variable rate application/technology (VRT)

The variable application of seeding and spraying according to accurate, specific maps of soil and plant information.

Reasons for using precision agriculture techniques*



*Based on 518 farms that use at least one precision farming technique

Uptake of precision agriculture

Precision agriculture is an emerging methodology linking management practices to site specific soil and crop conditions. Precision agriculture is used to monitor performance, react to changes in the weather, predict harvest times, and to apply precise chemical inputs. These approaches enable highly targeted, efficient management as well as providing evidence to drive further innovation. Precision techniques such as greater fuel efficiency and lower chemical inputs result in lowering greenhouse gas emissions and higher water quality. There are also economic benefits: Controlled Traffic Farming (CTF) has been able to reduce machinery and input costs up to 75%.

Not just technology: the role for integrated production methods

The benefits of sustainable intensification divide opinion, with some critics arguing it is a trojan horse for furthering the interests of ‘big agriculture’. However, while future farming usually brings to mind technological advances, innovation needn’t be technocentric. There is growing interest in integrated production methods, and we can expect them to rise in tandem with technological innovations:

Agroforestry: A system that combines trees with either arable crops or livestock pasture. Benefits include maximising space in three dimensions, reduced erosion, increasing soil fertility and better nutrient capture (reducing leaching) – increasing total farm productivity.

Integrated pest management: IPM widens pest control strategies to reduce the use of pesticides. For example, biodiversity-rich field margins provide habitats for insects to control aphids or attract birds that manage slug populations. In glasshouses, biological controls can be introduced to manage pest populations as soon as they are observed.

No-till farming: Also known as zero tillage, it is being explored in smallholder and large-scale production (for example, it is very widespread in drought-prone Australia). No-till means minimal soil disturbance, permanent soil cover, direct sowing and sound crop rotation. Although short term yields can decline, these are seen to recover and UK reports include improved soil quality, water infiltration and lower operational costs.

Organic agriculture: This system has an established certified standard for integrated production. Artificial fertilisers are banned and farmers develop fertile soil by rotating crops and using compost, manure and clover. Pesticide applications are severely restricted, and GM crops and ingredients are banned.

Fertile ground for innovation

The trajectory for farming for the future: Risks and opportunities on the pathway to 2025



Opportunities

Diversified production systems that combine the best of agri-technology with integrated production systems to produce quality, affordable food.

- **Quality food** Higher quality, nutritious produce may be supplied in larger volumes that lower the cost to households, with particular opportunities from emerging markets. Potential for savings from optimisation to be passed on to householders.
- **Efficient** Step change reductions in inputs for crop production, reducing fuel, water, and chemical inputs. Knock-on benefits would reduce run-off and enhance biodiversity from reduced agrichemical applications. Focus on waste reduction will also drive efficiency improvements.
- **Diversified production** Agri-tech and integrated production systems may be co-existing, with the latest technology used to enhance novel production systems. There may be proliferation in methods and locations of food production, with increased production around cities including for high value proteins such as fish from aquaponics. Benefits from these changes would apply to small farms as well as large scale farms.
- **Connected** Farmers in all growing regions could gain access to high-speed internet and mobile data. Standardised data protocols could provide free or low-cost access to farmers from all sectors, while apps running on existing low cost technologies (such as smartphones and tablets) could reduce upfront investment costs.



Current trajectory

Establishment of agri-technology will drive fastest rate of change for any part of the food system.

- **Technology** High value, large arable production systems will be further mechanised, with ground-based activities directed by data from remote-sensing. Supporting technologies such as GPS and drones will increase in precision and decrease in price, making them more accessible to a larger population of farmers. Output data will drive up efficiency, meaning lower inputs for the same, or higher, output yields.
- **Consolidation** There is greater consolidation in UK farming, particularly for livestock where economies of scale are driving cost-competitiveness. Within industry it is generally expected that this trend is likely to continue.
- **Combined monitoring services** Advanced weather monitoring, modelling and agronomic data, such as from The Climate Corporation (bought by Monsanto for USD ~\$1bn), will become increasingly important in informing farmer behaviour.
- **Novel production systems** These will expand in scale, with urban or peri-urban production systems becoming commonplace, although only providing modest contributors to calorific demands. They are likely to provide fresh produce, but unlikely to substitute for major food groups such as carbohydrates or proteins.

"The global community faces an important choice: expand the area of agricultural land to increase gross production, or increase yields on existing agricultural land."

The Royal Society



Risks

Greatest risks may stem from unintended consequences from adoption of future farming methods.

- **(Not) addressing food security** If sustainable intensification succeeds in increasing food production, it won't necessarily improve food security for the most vulnerable in society. Affordability of, and access to, food must remain priority policies.
- **Unequal uptake** Whether linked to regional connectivity of producers, or capital investments segregating the market, risks of disparities of uptake of technical advances which makes smaller farmers less competitive and unable to survive.
- **Technology reliance** Ownership and access to data could reside with a small number of (large) businesses, on which food production increasingly depends. There may be risk of farmers depending on technology, reducing autonomy and self-sufficiency.
- **Soils** For future farming, managing and enhancing soil structure and fertility will be critical. Sustainable intensification must avoid soil degradation in pursuit of higher yields.

Details of climate change risks to agriculture in Climate risks to food chain resilience.

Tools for change

Biological innovations

Innovations in genetic sequencing speed and cost

Historically, time and cost have been limiting factors for crop and livestock breeding innovations. New developments in the speed and cost at which genetic sequencing can occur are opening the technology up for use in traditional breeding methods, as well as the potential for genetic modification.

- **Next Generation Sequencing (NGS)** technologies can be used to generate whole genome sequences for crop species; this technology is becoming cheaper and more accessible, enabling faster development of new varieties.
- **Phenotyping methodologies** are a current barrier to greater use of NGS; the relationship between genetic variation and phenotypic differences (i.e. the physical expression of the gene) is complex, and NGS only offers one side of the picture. Imaging sensors and software for 2D and 3D imaging analyses are promising fields for developments in plant phenotyping.
- **New low-density array systems** allow swifter and cheaper genotyping of animals. Access to detailed genetic information is giving farmers the ability to make more informed decisions on breeding selection and increasing yield and efficiency, particularly in dairy cows.

C4 pathway in rice Rice is one of the critical food staples around the world, but yields are plateauing as demand continues to rise. In Southeast Asia, every hectare of agricultural land currently has to support 27 people; this is projected to rise to 43 by 2050. A global group of researchers is currently working to introduce a more efficient type of photosynthesis ("C4") in rice. This so-called carbon concentrating mechanism enables C4 species to exhibit 50% higher yields, as well as significantly enhanced water and nitrogen use efficiencies.

Coffee breeding for a changing climate

Nestlé is working with major coffee R&D organisations in Brazil and Ethiopia. Their screening programme looks for the following water-related characteristics in coffee plants: lower overall water demand, fewer and shorter irrigation cycles, less drought sensitivity, and fast recovery after droughts.

New production systems

Growing indoors...

Indoor growing allows the producer to control the environment. This enables more efficient light exposure, temperature control, and irrigation. Pest pressure is greatly reduced and dependency and risk from weather becomes a thing of the past. Produce grown in indoor farms use up to 98% less water and 70% less fertiliser than traditional farms. New innovations in lighting allow lettuce to grow 2.5x faster.

LED lights have brought multiple benefits because they don't generate heat, allowing insulated buildings, closer proximity to plants and lower energy demand.

Vertical farming, a specific system for growing indoors, makes efficient use of land restraints: crops are grown in "high-rises" in multiple levels that vastly reduce land footprint requirements. The city of Newark, NJ in the US has just provided USD \$9 million in grants and tax credits to build what will be the world's largest producing vertical farm.

...without soil

Soil-less growing takes controlling the environment to the next level. Controlling the medium in which crops are grown reduces soil-borne disease and allows for much more efficient manipulation and monitoring of nutrient availability. Soil-less growing can mean higher yields with higher water and fertiliser efficiency than traditional agricultural but energy demands can be high due to heating, cooling, lighting, and circulation requirements.

Hydroponics uses a water-based medium with bare root. Hydroponics can use up to 70% less water than conventional irrigation-fed systems.

Aquaponics is an integration of aquaculture and hydroponics into one production system. A symbiotic relationship whereby waste from fish is a fertiliser for growing plants, thus providing protein and high quality herbs from a single system. However, it currently has high start-up costs, and commercial aquaponic systems are relatively few in number. Fish species suited to aquaponics are also limited; tilapia is the most commonly used.

Aeroponics is an offshoot of hydroponics in which water is sprayed onto bare roots, rather than immersing them. It uses up to 70% less water than hydroponics.

Harnessing technology

Satellite technologies

Many precision agriculture techniques, such as tractor guidance, biomass monitoring, and livestock tracking, require satellite technology.

GNSS is a global satellite system that provides autonomous geo-spatial positioning, allowing users to determine their location with high precision. The proportion of high-powered tractors equipped with GNSS is expected to reach 50% penetration by 2023 from just over 10% in 2013.

Robotics

Automatic Milking Systems (AMS) 5% of cows in the UK are currently milked by AMS, and 20% of the cows in the EU are predicted to be milked automatically by 2020. Transponders collect data on the cows each time they pass through, allowing farmers to easily and precisely monitor health and nutrition. AMS can be complemented by other robots which manage feeding and cleaning, resulting in a dairy farm where most labour is done by robots.

Robotics in crop production Robots are currently being developed for use in many aspects of crop production, including spraying and harvest. Specialised robots such as close-range precision spraying robots allow targeted work to be undertaken and integrated into farms using precision agriculture.

Drones/Unmanned Aerial Vehicles (UAVs)

Drones and Unmanned Aerial Vehicles provide aerial imagery and data collection that is key for many techniques in precision agriculture. By flying lower, they can provide more detail than satellite imagery and aren't foiled by clouds. UAVs can also be fitted with various light sensors, allowing farmers to collect data on things like crop damage and yield potential. Costs have been declining and are expected to fall further, making this technology (and by extension many precision agriculture techniques) available to many more farmers in the future.

Many of these up and coming technologies allow farmers to collect large amounts of data in many areas, enabling a move to a "data-driven" farm. See Food chain data revolution for the connection

"It makes good business sense, if not now then certainly in the future. For example, we're doing research and development on new varieties of coffee and cocoa that are more drought-resistant and higher yielding. This is about creating shared value, not just value for shareholders."

Anne Roulin, vice-president of nutrition, health, wellness and sustainability at Nestlé



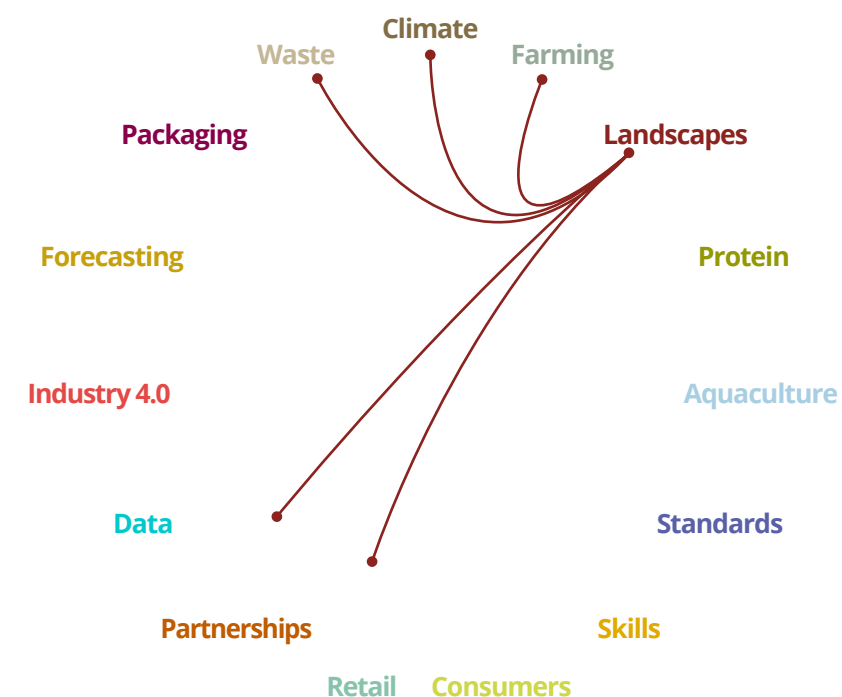
Landscape-scale opportunities

A demand-supply analysis of UK land requirements in 2030 indicates the potential for an additional 7 million hectares to meet the needs of a population of 70 million, equivalent to an increase of 35% of the UK's current agricultural land. While some of this demand can be met by more efficient production, and less food waste, the future will place higher demands on our finite land resources.

With increasing pressure on land, the optimisation of multiple functions becomes essential; whether for food cultivation, flood risk alleviation, natural habitats or energy production. One technique for optimisation is 'landscape scale' management approaches, which operate across multiple farms to pursue shared objectives.

"However, our land is a finite resource, and it is set to come under increasing pressure... as we seek to maximise economic returns, and as we recognise its potential to yield benefits in diverse areas such as ecosystem services, mitigating climate change, and wellbeing."

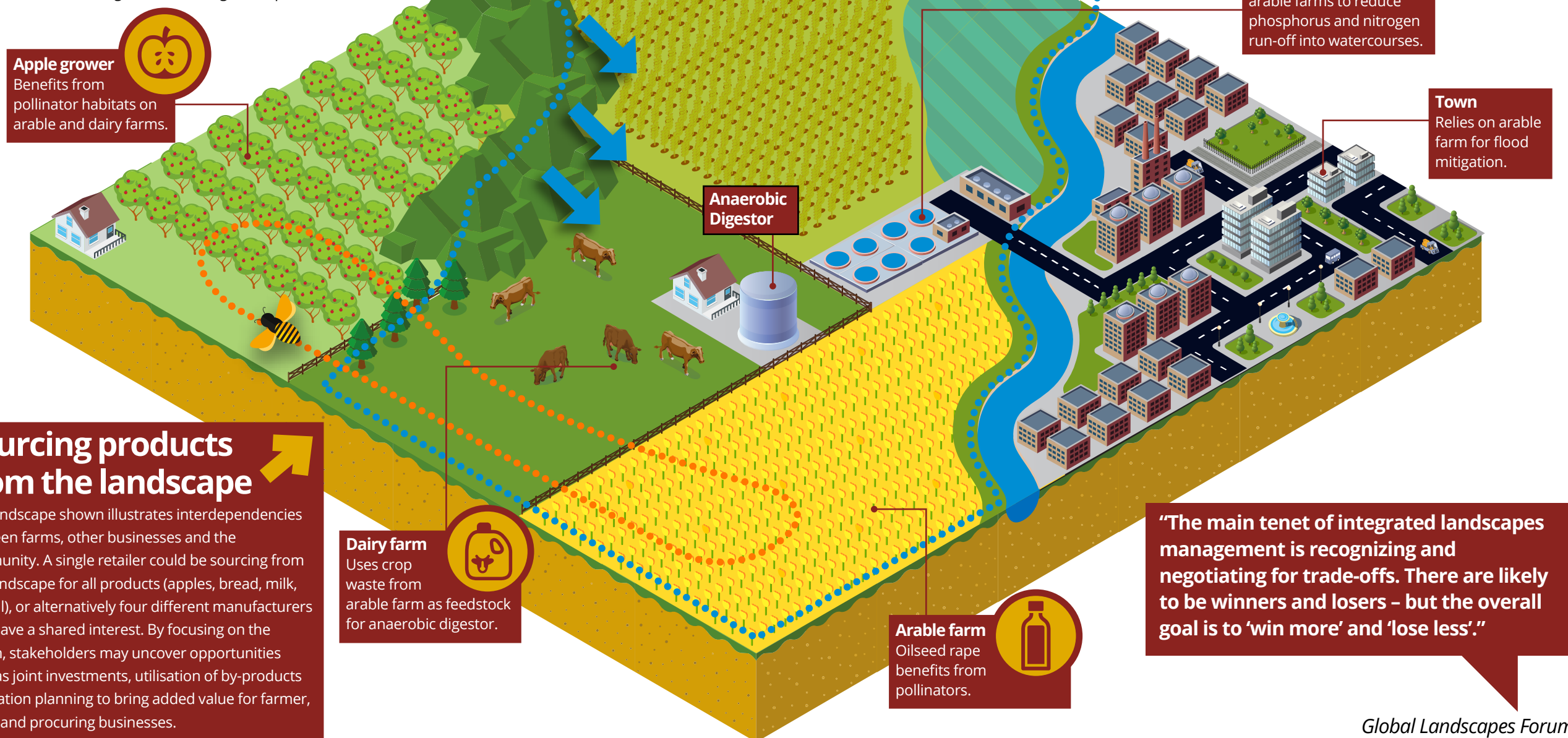
Foresight Report, 2014



Food production from a landscape system

Recognising the characteristics of the producing region, not just focusing on individual product outputs.

Landscape approaches have developed from a need to identify integrated solutions to competing demands on land uses, pressures on environmental systems and requirements from the local community. Within any landscape, there are usually a variety of land uses such as for forestry, agriculture, and grazing, as well as for recreational uses and ecosystem services such as water catchments and biodiversity habitats. Payment for ecosystem services would create a market for natural capital that could reconfigure land management priorities.



A need for methods and new markets

The trajectory for landscape-scale opportunities: Risks and opportunities on the pathway to 2025



Opportunities

Successful implementation could remodel the composition of land use patterns, with individual actors rewarded for contributing to the common vision.

- **Landscape leaders** Major sourcing businesses step up as 'land shapers', helping to positively shape landscapes by their procurement strategies.
- **Functioning market** Farmers and other land managers have clear market signals in order to benefit from management decisions that deliver greatest net gain from the landscape.
- **Greater productivity** The landscape is more productive for food and other outputs, while enhancing the natural capital.
- **Climate adaptation** An integrated approach presents opportunities to adapt to climate change co-operatively, with greater potency than any single farmer acting alone.
- **Improved relationships** Partnerships between producers and between sourcing businesses strengthen relationships that lead to further collaboration and new innovations.



Current trajectory

Progression from ambition to action, with implementation of landscape methods spreading beyond water catchments to other land functions.

- **Established methods** In ten years, a range of methods will be tested and implemented for different types of landscapes.
- **Immature markets** Emergence of markets for trading of value between landscape stakeholders – but limited to simple transactions.
- **Measurable benefits** Outcomes from early implementations, providing data demonstrating impacts on landscape stakeholders.
- **Growing momentum** A small number of food businesses roll out these methods across their sourcing landscapes, raising awareness across their producers and wider industry.

"With rising demands to produce more food from the land, and the growing crises of climate change and biodiversity loss, it is more important than ever to manage landscapes sustainably."

*Prof. Tim Benton,
Global Food Security Programme*



Risks

The practical challenges of coordinated planning of land use will always pose a barrier, and behaviours revert to short term supply and demand.

- **Complexity** Attempting to understand, define and reward competing interests of land users may not reach a satisfactory conclusion. Establishing a market can create incentives, but it is difficult to design effectively to ensure the correct signals that will generate net gains in natural capital.
- **Funding gap** Designing and implementing landscape programmes requires resources. When the beneficiaries may be dispersed (or a public good), the case for private sector investment is weak.
- **Skilled coordinators** Expertise on the ground from coordinators who understand their key stakeholders is essential but may not be readily available.
- **Regulatory environment** Regulations and tax regimes may not align with coordinated approaches, and can present barriers to development of new behaviours.

Landscape partnerships in action

Scope 4: How to grow sustainable sourcing into measurable impacts in regions and commodity systems

The US-based Sustainable Food Lab - with members including Unilever, Mars, and Starbucks - has introduced 'Scope 4' guidance for international sustainable sourcing programmes that face region-wide challenges such as water shortage or chronic poverty.

Scope 4 is described as "the space around the supply chain: geographically, in the surrounding landscape; agronomically, including livestock and other crops in rotation; socially, to account for healthcare and education; economically, to capture synergies with other enterprises on a farm as well as off-farm income; and strategically in order to take advantage of other stakeholders."

This new guidance addresses the challenges for individual businesses striving to source sustainably from a region, and the challenges from attempting to go it alone. The Sustainable Food Lab provides examples from regions as diverse as Iowa for soybeans, Ghana for cocoa, and South Africa for sugar, highlighting the need for one company to lead strategy development in a given landscape, around which others can then collaborate.

The Scope 4 guidance identified three bottlenecks to implementation:

- Lack of financial resources to fund the organising function.
- Insufficient technical and leadership capabilities within coordinating organisation.
- Unclear business case for less innovative players in the system.

The articulation of Scope 4 supported by a series of major food businesses is a significant development in the evolution of landscape approaches. Rightly it acknowledges challenges to implementation, but a series of case studies and outline of the opportunity at large present valuable evidence for programmes of regionally-focused sustainable sourcing.



Defra Sustainable Intensification Platform (SIP)

Opportunities and risks for farming and the environment at a landscape level.



The SIP Research Platform is operating at farm and landscape scale. SIP2, at the 'landscape' scale, is investigating the spatial variation in land capability and environmental risks, to see where coordinated action opportunities exist within England and Wales. The project covers seven study areas, and seeks to identify the mechanisms by which more collaborative working among farmers can be enabled.



General Mills

Purchasing as part of crop rotation.

When General Mills began to look into sustainable wheat, they realised that engaging solely with wheat growing would not be sufficient to address the issue and claim the title "sustainable". Rather they would need to involve not only the farmers' whole rotation (which includes sugar beets, potatoes, and barley alongside the wheat) but also the companies that purchase those other products in the rotation. General Mills further engaged the Nature Conservancy and state and federal agencies in a multi-player initiative whose ultimate goal is improving and maintaining the water and soil quality of their landscape to achieve sustainable production for all stakeholders.

Co-operating in water catchments

Wessex Water

Groundwater in agricultural regions can be affected by high levels of nitrates and pesticides. The common response to this is to build treatment plants and carbon filters to remove the impurities. Wessex Water has begun to take a different approach that is lower cost and more sustainable. The Wessex Water supply region is predominantly rural and agricultural, so the company depends on local farmers and land owners to manage the land. Wessex Water works with farmers across the catchment to achieve the common objectives of food production and high quality ground and surface waters. The successes of the scheme have enabled Wessex Water to cease the requirement for additional treatments at three sites, leading to cost savings for the business and benefits for farmers including optimised use of nutrients and pesticides.

SABMiller

Watersheds by nature are larger than individual farms, and any avenue for improving water quality must necessarily include all players with a stake in it. SABMiller, one of the world's largest brewers, recognised that water quality in their South Africa and Colombia breweries was a serious problem that needed to be addressed beyond their breweries. They turned to WWF and GIZ, developing a landscape approach that involved all the key players in the catchment to more successfully mitigate risks. SABMiller knows that the capital costs incurred by this project are an investment, one that is vastly outweighed by the reputational costs and supply chain risk that would be associated with water scarcity and pollution.





“Raising meat takes a great deal of land and water and has a substantial environmental impact... We need more options for producing meat without depleting our resources...”

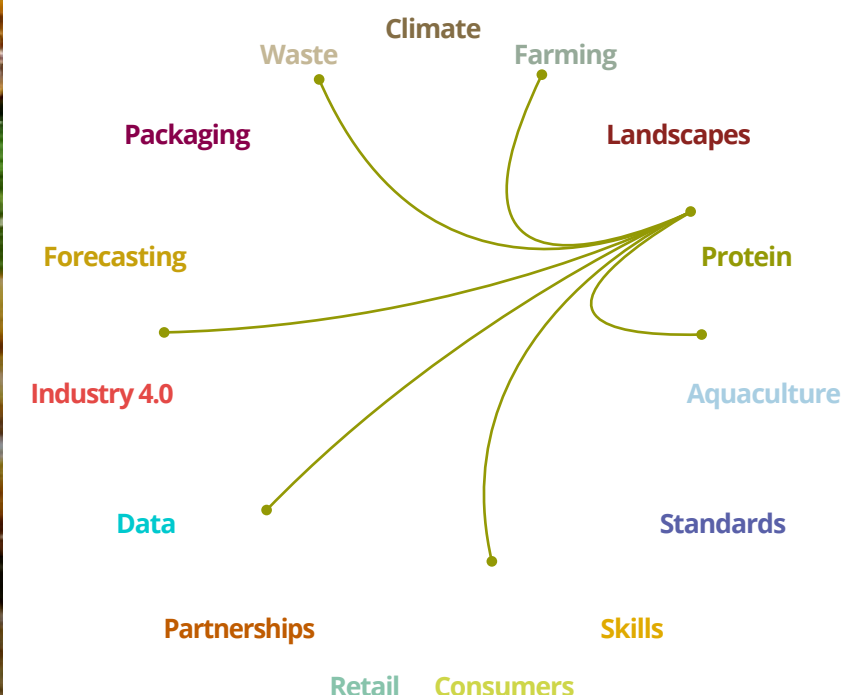
Bill Gates



Alternative feeds and proteins

Global meat consumption is expected to increase by 76% by 2050. Rising household incomes are leading to greater demands worldwide for more meat. However livestock production generates greenhouse gas emissions, causes land use change, requires 33% of global arable land for feed, and causes high water demands.

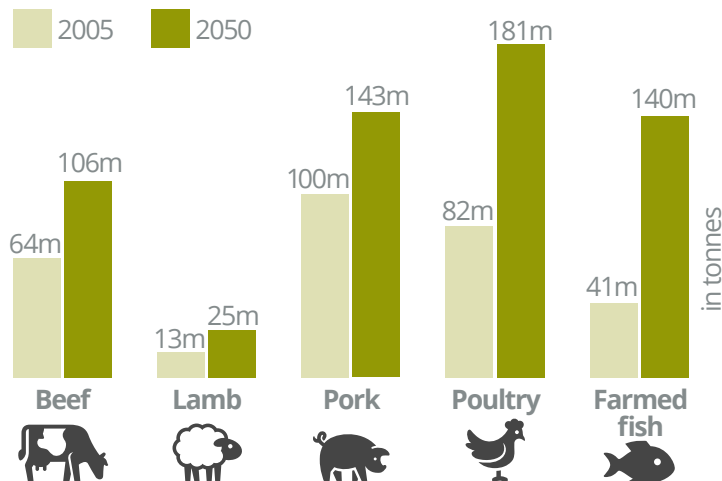
Alternative proteins are being pursued for livestock feed and as food for direct human consumption. Sources of alternative proteins range from bacteria to insects, from mycoprotein to artificially cultured meat. The next generation of proteins will depend on proving food safety, production costs, nutritional qualities, scalability and consumer acceptance.



Growing solutions

The environmental cost of meat production means there is a need to find alternative protein sources for both human consumption and animal feed, supplementing efforts to develop sustainable aquaculture systems.

Global demand for animal products



The role of the householder

Developing more sustainable alternative proteins is only the first step; consumer preferences and attitudes towards these new foods must also shift in their favour for real growth to occur.

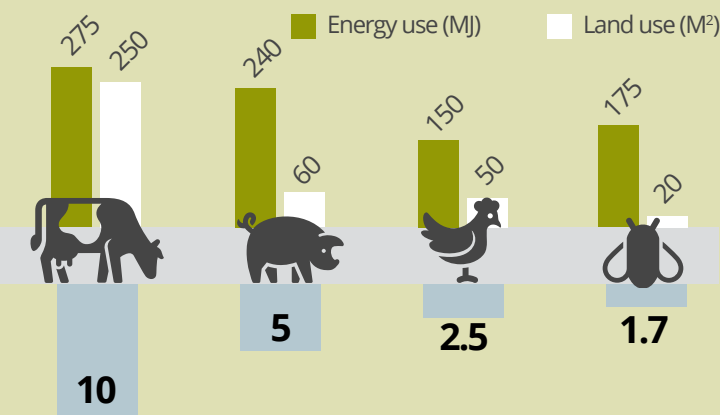
There can be a “yuck factor” for many potential alternatives, such as insects and lab-grown meat. Western attitudes towards entomophagy (the consumption of insects by humans) are typically negative – insects are perceived as unclean and vectors of disease. And similar attitudes may be found towards lab-grown meat; a 2014 study found reactions of “disgust” and “unnaturalness”.

Success of new generations of protein sources will require consumer acceptance. It has been shown that environmental concerns can play a part in changing attitudes, though recent uptake of insect protein flour in North America has been a response to nutritional benefits. Recent studies have also shown positive attitudes towards insect feed for animals; a majority of study respondents said that they would eat meat (pig, poultry, fish) raised on insect feed.

Comparing proteins

Input per kg of protein

kg feed required per kg bodyweight



Novel protein products



Human consumption

Lab grown meats



- Uses potentially 45% less energy, 96% fewer GHG emissions, and requires 99% less land than the average for farmed beef.
- First hamburger made in 2013. It cost approx £200,000 and took 2 years to create.
- Processed meat such as ground beef, pork, sausage may be feasible on a production scale in the next 5 to 10 years.

Seaweed



- Protein levels of up to 47%.
- Most types contain all essential amino acids.
- Saltwater crop; uses no fresh water.
- Seaweed meal may help increase body condition and wool production in sheep and milk production in cows

Microalgae



- High lipid (oil) content; can produce 50 times more oil than corn per hectare.
- A new study shows it may be a viable option to replace corn in cattle feed.
- Dried defatted algae could replace up to 1/3 of soybean meal in diets for pigs and chickens, replacing 10% of pig feed with algae would save 30 million tonnes annually.

Insects



- Lower land use requirements and potentially lower GHG emissions.
- High protein digestibility (86-89%).
- Up to 80% of bodyweight is edible and digestible, compared to 55% for chicken and 40% for cattle.
- Insects can be reared on various organic substrates such as vegetable waste, manures, and food waste, creating value from and reducing waste products.

Bacteria



- Can be grown on wastewater nutrient sources, without feed or sunlight.
- Methane can be used as input for high volume production.
- Up to 60% protein, with high levels of digestibility.

Animal feed



Mini factories of the future

The trajectory for alternative feeds and proteins: Risks and opportunities on the pathway to 2025



Opportunities

If well-informed consumers support the emergence of flexible, efficient production systems then future proteins can transform diets for humans and livestock.

- **Consumer demand** Changing household habits and perceptions, as well as evidence of nutritional quality as food and animal feed, could rapidly transform the nature and scale of demand for novel protein sources. More familiar but currently less popular plant-based proteins such as pulses and nuts may also see a surge in consumption, in part due to consumer awareness of livestock's environmental impact. Where demand comes, supply can swiftly follow.

- **Efficiency** In a resource-constrained world, the ideal solutions will efficiently convert low-grade inputs to high-grade protein products. The nutrient inputs to new protein production need to be drawn from low value sources, such as mixed waste streams or digestate from anaerobic digestors, and new protein could be reared using cooling water or low grade heat from existing installations. Ideally, new protein production systems could be deployed as modular units, situated near substrate sources and workable at small and large scales. Improvements in feed conversion rates across sectors will create more efficient protein both in sea and on land.

- **By-products** The value of many novel proteins extends beyond food. For insect production, in addition to protein, lipids and soil conditioner, initial research has identified high value molecules with antimicrobial properties. The process used to grow bacteria also results in clean water from food and beverage waste streams. The triglyceride oils and ingredients developed from microalgae can be used as the foundation for industrial products and fuels as well as foods. If each fraction of these proteins can be refined and sold into discrete applications, the aggregate value and efficiency of the system will drive widespread expansion and adoption.

See Unlocking new value from wastes for more details.



Current trajectory

Continued growth in global demand for livestock, and associated requirement of feed, such as soy.

Pressure on production, fisheries and land assets directly affects market for feed production.

- **Volatility** Traditional feed prices will fluctuate (as seen for fishmeal), with direct knock-on effects on the cost of meat.
- **Innovation drive** Pressure on feed resources availability will drive investment into new protein sources, with establishment of commercial insect production and the breakthrough of engineered solutions including protein from bacteria. Costs of production and feed conversion ratios will dictate which new protein sources predominate over time.
- **Novel foods** Western diets will incorporate insects to some degree, in a similar way to the spread of sushi from Japan in 2000s, but the major growth will be for feed to livestock.

"The absence of clear legislation and norms guiding the use of insects as food and feed is among the major limiting factors hindering the industrial development of farming insects to supply the food and feed sectors."

FAO 2013



Risks

Future protein and feed sources will need to operate at scale, and success relies upon a dependable, safe, balanced system to support livestock that depend on them.

- **Health risks** Real or perceived risks to human health pose the greatest risks to the emergence of new protein sources. Substrate materials used for rearing can be transferred to protein products, and in turn into the food chain - but it is vital that we avoid unintended consequences that seriously disrupt the food chain such as those that caused the BSE crisis. Risks to beware of could manifest as either another significant contamination of our food system, or over-zealous regulations that stifle investment and commercialisation of novel protein sources. Aside from direct consumption, high concentration of insects could lead to other impacts, such as allergenicity for farm workers or accidental releases to the local environment.
- **Production failures** Future reliance on intensive production systems for animal feed will expose vulnerabilities to large-scale production failures. Just as viruses such as swine flu have decimated pig populations in the past, so infections can spread rapidly and eradicate entire populations under production.
- **Burden-shifting** Unintended consequences of 'burden-shifting' such as high energy inputs (e.g. heat for insect rearing) or water usage (e.g. for microalgae) could undermine the resource efficiency of new production systems. Similarly, competition for input resources (such as for anaerobic digestors or into conventional animal feed) could negatively affect both the new and established industries.

Bringing new protein products to the market

Nutrinsic

Protein source Bacteria

Use Animal feed

Method Produces ProFloc, made from a poly-culture of natural bacteria consuming underutilised nutrients from food and beverage processors as well as biofuel producers.

Current collaboration with Miller Coors brewery utilising process discharge water.

Outputs First US production facility, in Ohio, is operational. Initial capacity of 13t/day is anticipated. 63% protein product is easily absorbed and demonstrates good feed conversion ratio (FCR) in poultry, swine, and aquaculture.

Future Plans to scale up production to 80t/day within 18 months and build additional operating plants.



Ynsect

Protein source Insects

Use Animal feed

Method Tenebrio molitor (mealworm) fed on plant based material only, to fulfill EU rules. Mature larvae are collected from a full automated farming process, slaughtered, and processed to obtain a concentrated protein meal and a fat fraction.

Outputs First small industrial scale production in France operational in 2016 dedicated to pet food market with 20,000 t/year meal capacity.

Future Products approved for sale in Europe for pet food, awaiting EU approval for insects in feed. First large scale plant aims to be built in 2017.



Solazyme

Protein source Microalgae

Use Food and Feed

Method Fermentation using *Chlorella* micro algae in a liquor rich in simple sugars and other nutrients. Mixture is transferred to larger containers under controlled conditions, before harvesting, concentrating and drying. AlgaVia whole algal product is 65% protein, and used as a food additive.

Outputs First produced range of commercially saleable products on full-scale production lines in mid 2014. Two US-based production facilities, and a third large site (100,000 mt/year) in Brazil, in partnership with Bunge's Bonsucro sugarcane mill.

Future Production in Iowa will potentially expand to 100,000 mt/year in subsequent years. Moved forward with FDA approval of high-oleic algae oil and their AlgaVia portfolio in early 2015.



Industry view

Angela Booth, Head of Alternative Proteins AB Agri

Efficiency

"As livestock become more efficient, in order to maximise the potential the feed industry has to increase the protein to energy ratio. Soy is currently so widely used because it is a very cost-effective source of concentrated nutrients, so one challenge is to improve the quality of other existing proteins to remove anti-nutritive factors and improve protein concentration. A further aspect is that protein from cereals such as wheat and maize needs to become more predictable. Currently, protein levels can range from 8% to 14%, and this variability needs to be understood so we can manage production accordingly. For other existing sources – such as rapeseed – we need to improve usage, with processing that delivers higher nutrient value."

Alternative proteins

"This topic should be called 'new generation proteins', as the industry is always looking for improved protein sources and some may be achieved by applying new technology to existing sources. There are a number of potential new sources we can use: fungal, bacterial, algal and insect, as well as continuing to seek additional synthetic amino acids which can be used to supplement existing proteins. For all of these, the challenge becomes how to scale up to large-scale production that is price competitive. For example, to use algae we still need to understand: which species to use; optimal growing conditions; and then to calculate costs such as light, water usage, pigmentation removal, drying and so on."

2025 view

"In ten years time we will see a different feed landscape. We have already seen significant changes in aquaculture, moving away from fishmeal to vegetable and cereal proteins. Two factors for future changes will be firstly competition for substrates, and secondly the level of mechanisation to enable scaling up – both of which will determine cost competitiveness. On the down side, one of my worries is the state of legislation in the EU, which is restricting our ability to compete. The legislators are trying to fit new generation proteins into existing legislation, but instead we need new legislation that recognises future sources, and unlocks the wave of further innovations in the field."

A novel protein becomes mainstream

Quorn

Protein Source Mycoprotein

Use Human Food

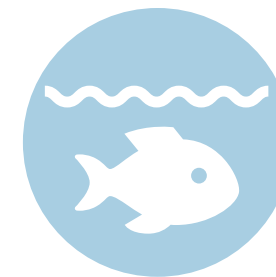
Method Mycoprotein is derived from the fungi *Fusarium venenatum* using a natural fermentation process and wheat-derived glucose syrup. The resulting dough-like paste is mixed with egg albumen and water to bind it, then mixed, shaped into products such as Meat-Free Mince, Chicken-Style Pieces or Fillets, steam-cooked and rapidly frozen for texture.

Outputs Founded in 1985, Quorn Foods currently

produces around 22,000 tonnes of mycoprotein per year and is sold in 16 countries worldwide. Quorn has provided over 3 billion meals across the world and demand is rising; it expanded into Germany, Italy and Spain in 2015, and in the US demand is up 30% on last year.

Future Quorn Foods are currently investing £30m in its Billingham plant to double its production capacity to nearly 40,000 tonnes, which will support continued growth in the UK, USA, and European markets.



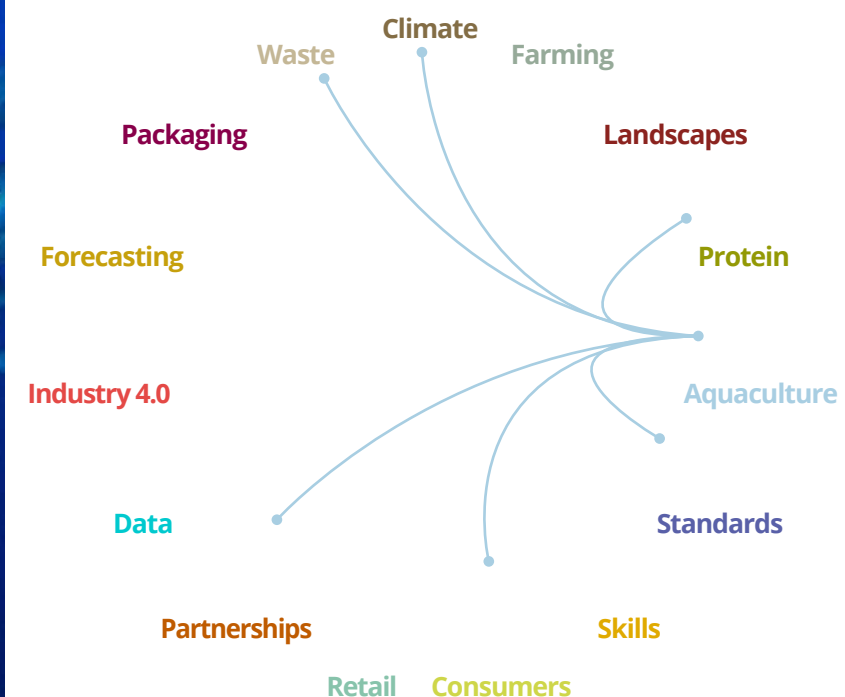


Aquaculture expansion

Aquaculture has become the fastest growing animal protein sector and in 2014 global output overtook beef. By 2030, almost two thirds of fish for human consumption could be produced by the sector. Aquaculture has the potential to contribute to healthy sustainable diets and economic development due to the nutritional qualities of its products and the potential for efficient, low impact production. The development and adoption of innovative systems could also relieve pressure on sensitive natural habitats on land. However significant technical, commercial and policy challenges will need to be addressed in the coming decade to fully realise the potential of this increasingly important global protein sector.

"It is highly unlikely that wild capture fisheries will be able to produce higher yields in the future. For aquaculture the opposite is the case. No other food production sector has grown as fast over the past 20 years... It [the industry] must now prove that large-scale fish farming is possible without placing unacceptable demands on the environment."

World Ocean Review



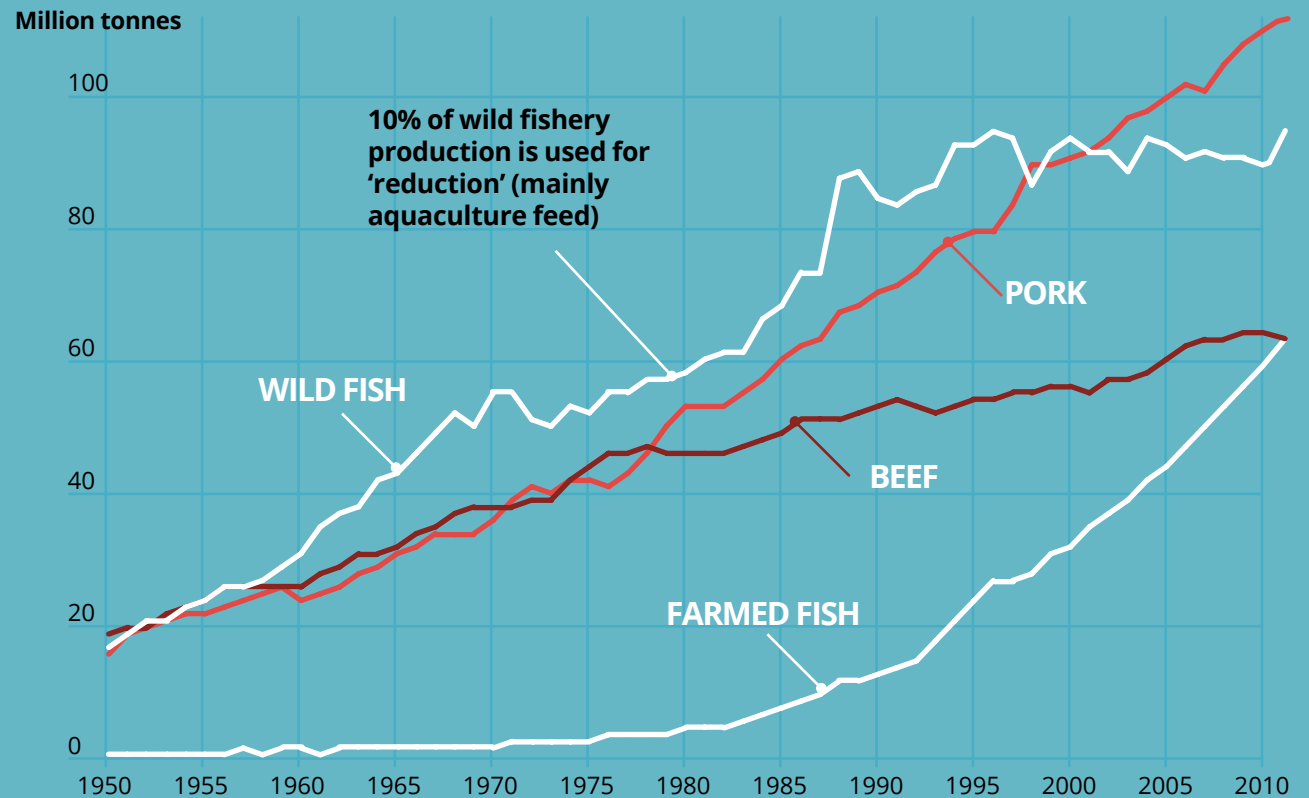
The blue revolution continues

A global protein sector of increasing economic and dietary importance

Aquaculture is the farming of fish, shellfish and water-based plants. It is an extremely diverse sector, encompassing a range of systems, species types, and production intensities. Global trade and production is on the increase, and while this has the potential to result in environmental and social benefits a number of technical, commercial, and regulatory challenges need to be addressed. In addition to fish and shellfish, 24 million tonnes of algae (mainly seaweeds) are farmed globally by the sector - currently worth USD \$6.4 billion. Food producers are exploring the potential of using this ingredient in new food and non-food household products.

Fish trade & production

Fish is one of the most internationally traded foods. The majority of aquaculture-produced fish consumed in the UK is sourced from countries such as Scotland, Norway (salmon) and Southeast Asia (warm water prawns and freshwater fish such as tilapia). Farmed fish output is continuing to grow rapidly and recently overtook beef production. China dominates production, contributing 59% of global supply. According to The World Fish Center, the majority of the increase in global production in the next decade will come from South and Southeast Asia. India, Indonesia and Thailand in particular will increase their production volumes.



"Ensuring successful and sustainable development of global aquaculture is an imperative agenda for the global economy. Investments in aquaculture must be thoughtfully undertaken with consideration of the entire value chain of the seafood industry."

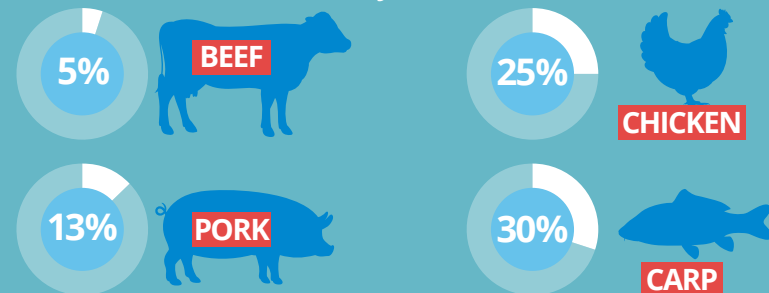
UNFAO Fish To 2030: Prospects For Fisheries And Aquaculture

Benefits of aquaculture

Fish and algae are nutritious and their health benefits are likely to drive increased demand in the future. Hundreds of millions of people already depend on fish for their main dietary protein. Fish are also efficient

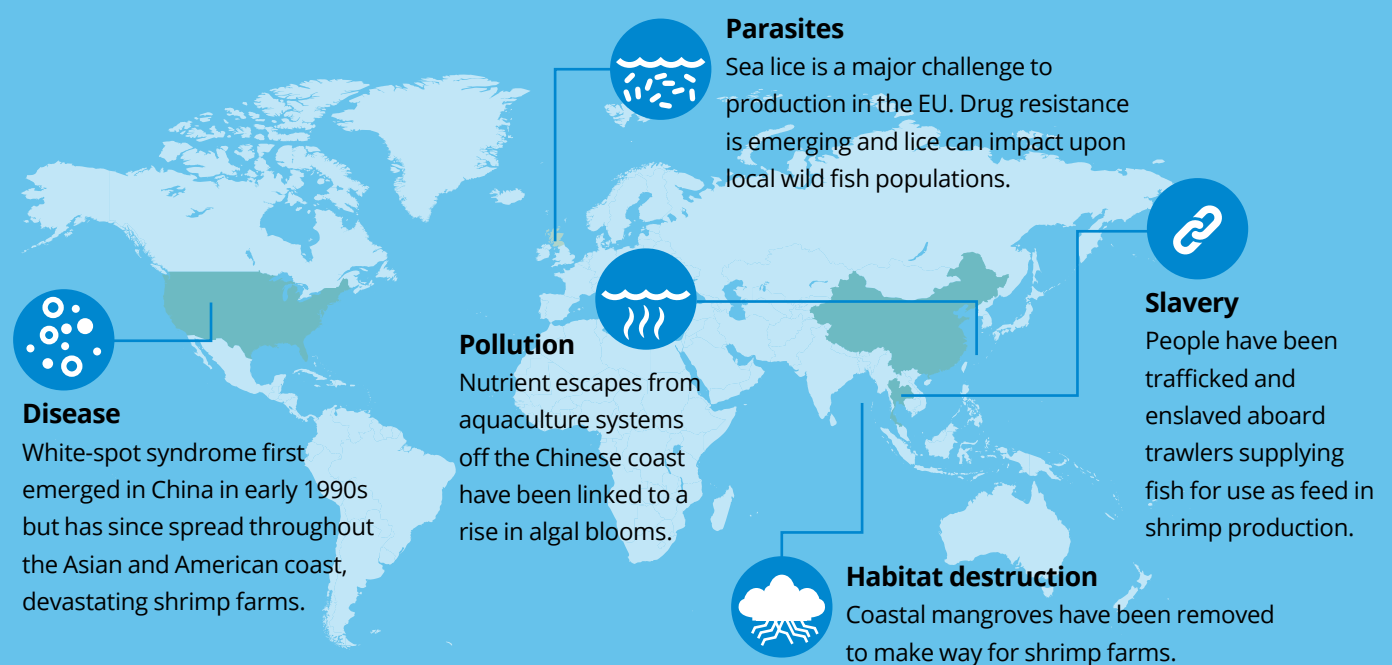
converters of protein, making them attractive from a production point of view. Aquaculture therefore has the potential to support sustainable economic development and nutrition security.

Protein Conversion Efficiency (%)



Challenges

While aquaculture systems have many potential benefits, they have also been associated with a range of negative environmental and social outcomes. These issues are more likely in jurisdictions with a weaker regulatory framework.



Off the hook - a long term protein solution?

The trajectory for aquaculture expansion: Risks and opportunities on the pathway to 2025



Opportunities

Production system innovation and increased household acceptability of new fish and plant species creates a more diverse, sustainable sector.

- **Novel production systems** New land-based and offshore systems have the potential to increase the sector's resource efficiency and reduce pressures on coastal and land habitats.
- **Plant-based products** Algae and seaweed derivatives have the potential to be increasingly used as product ingredients and protein sources.
- **Circular economy** Aquaculture has the potential to be a key element of a future circular food economy. Research by Zero Waste Scotland into fish, beer and whisky value chains identified a range of opportunities for cross-sector innovation. For example, the processing of brewing by-products into higher nutrition fish feeds and the extraction of highly refined protein compounds from fish wastes, for use in human food supplements.
- **Disease monitoring** Improved systems for identifying and responding to disease outbreaks could be promoted both in developed and developing countries.
- **Consumer preferences** Through education and product development, a wider range of fish species should be promoted with consumers. This provides a more diverse market for a range of aquaculture products.
- **Scaling standards** To achieve sustainable growth in conventional aquaculture systems in the short to medium-term there is potential to encourage greater use of, and improvements to, relevant sustainability standards.

See case studies on next page and dedicated topics addressing Alternate feeds and proteins and Unlocking new value from wastes.



Current trajectory

Steady reduction in fishmeal usage and increased sector output in Asia. Novel production systems remain niche solution.

- **Wild caught fisheries eclipsed** The growth already seen in aquaculture over the past 20 years will continue such that by 2025 more of the world's fish demands will be met by aquaculture than from capture fisheries.
- **Asian expansion** The majority of the increase in global production in the next decade will come from South and Southeast Asia. India, Indonesia and Thailand in particular will increase their production volumes.
- **Fishmeal reduction** The trend in continued reduction in wild-caught fishmeal will continue as alternates are found.

"In recent decades, diseases have emerged in aquaculture at a rate which far outstrips that observed in terrestrial systems."

*Professor Grant Stentiford,
Centre for Environment,
Fisheries and Aquaculture Science*



Risks

The nature of aquaculture systems exposes them to important risks - however these can be mitigated.

- **Disease** Disease has always represented a significant threat to aquaculture. When fish are grown in high density populations of low genetic diversity there exists a strong possibility of a disease sweeping through the system. Increased intensification and globalisation could put the sector at increased risk from disease transmission.
- **Water quality** Many aquaculture systems are known to be in regions sensitive to ocean acidification and other impacts of climate change. As the density of aquaculture farms increases along coastal regions, nutrient efflux may also lead to significant algal blooms, diminishing water quality. There are signs this is beginning to happen in some key growth areas of China.
- **Climate change** Aquaculture will be impacted by climate change. For example, ocean acidification could negatively affect organisms, such as shellfish, that produce a carbonate shell.

Aquaculture system and product development

Mara seaweeds

Mara is a Scottish company capitalising on the growing global demand for seaweed as a health food ingredient. The company is working with researchers to trial the commercial application of a land-based aquaculture production system. The Scottish Government has identified potential for the growth of seaweed cultivation and its use in Integrated MultiTrophic Aquaculture (IMTA). See example below from Loch Fyne.



Scottish Aquaculture Innovation Centre

The Scottish Aquaculture Innovation Centre is overseeing research into new techniques to reduce the incidence of sea lice in farmed salmon – a major constraint on production that costs the industry £30m per annum. One project is developing a vaccine that will enable the commercial farming of wrasse – a fish that cleans the salmon of lice.



Loch Fyne IMTA

Loch Fyne are trialling the first large scale Integrated Multi Trophic Aquaculture site (IMTA) in Scotland. In an IMTA system various species are farmed alongside each other to create a balanced ecosystem. Even though some crops will yield less than if grown alone, IMTA systems are designed to create greater overall output. Species grown at Loch Fyne include salmon, mussels, oysters, queen scallops, sea urchins and various edible seaweeds.



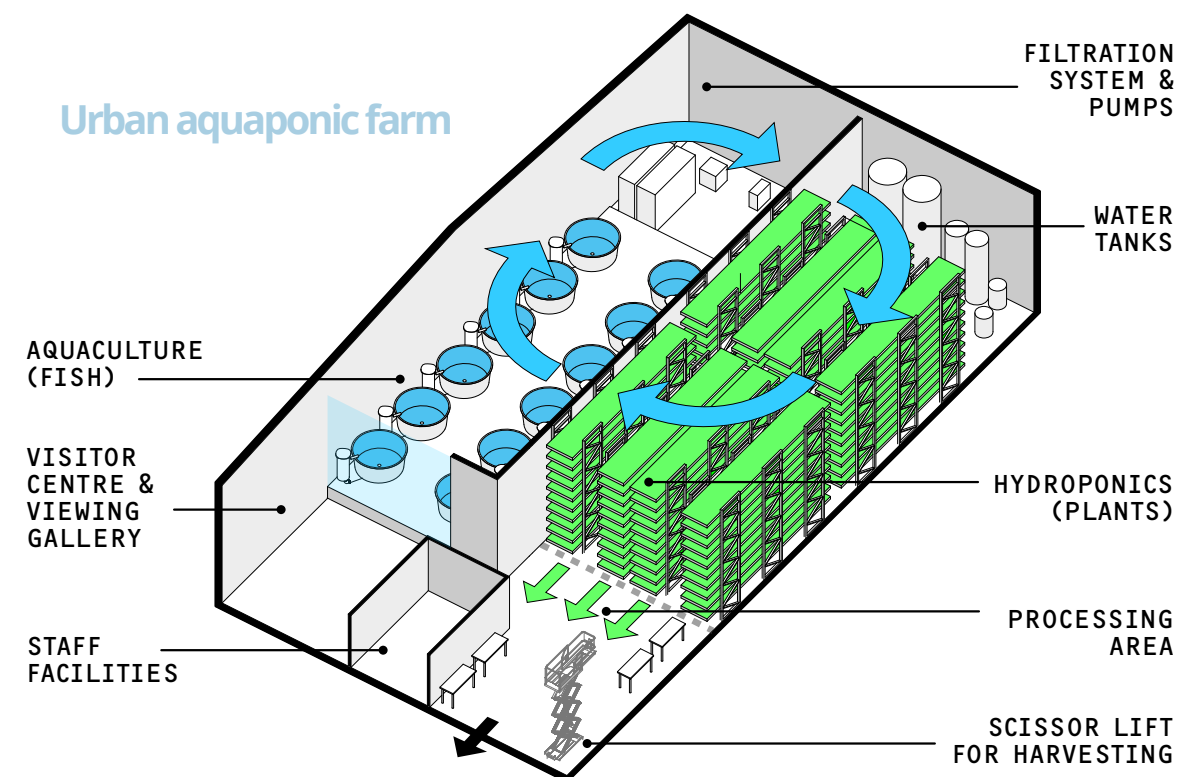
Calysta FeedKind

Calysta is a US biotech firm with offices in the UK developing FeedKind protein, a high protein feed ingredient that is an alternative to fishmeal and soya protein concentrate in livestock diets. Calysta's naturally occurring microorganisms utilize methane as their sole source of carbon and energy. They are grown in a patented bioreactor, then dried and pelletised. The first large-scale FeedKind production facility is targeted to open in 2017.



Recirculating Aquaculture Systems

Urban aquaponic farm



According to a detailed review of recirculation aquaculture systems (RAS) technologies by the University of Stirling, they have the potential to: minimise water consumption; control culture conditions; allow waste streams to be fully managed; and increase biosecurity. Economic sustainability remains the greatest challenge for long-term adoption for table fish production. An analysis of different Atlantic Salmon production systems estimated land-based RAS are almost 30% more costly than inshore cages, per kg of fish.

To make the economics more favourable, some start-up enterprises are exploring the potential to produce multiple high value products nearer to customers and consumers. GrowUp Urban Farms is building the UK's first commercial-scale aquaponic urban farm in London. They are converting a 6,000

square foot warehouse into a controlled environment aquaponic farm capable of hydroponically producing 20 tonnes of salad on a footprint of less than 200m², as well as 4 tonnes of Tilapia fish.

"I see particular significance for land based fish farms utilising water filtration and re-circulation technologies which have several genuinely positive environmental aspects."

*Scott Johnston, Technical Controller
Grimsby, Young's Seafood*

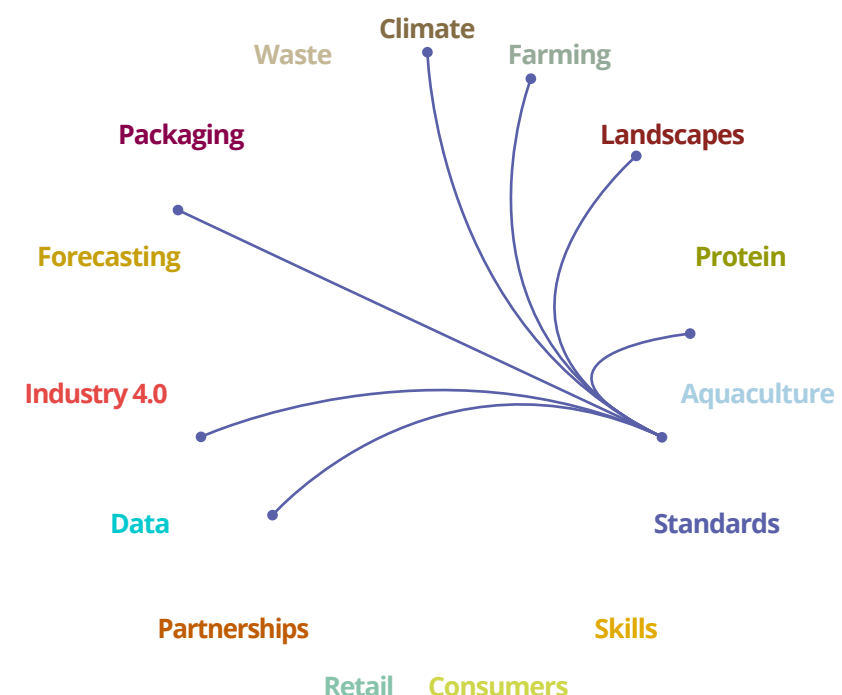


Scaling sustainability standards

Over the past decade private sector sustainability standards and certification have become the dominant method of defining, delivering, demonstrating and creating demand for more sustainable products - particularly addressing issues in agriculture, fisheries and forestry. However the proliferation of different schemes, combined with the costs of implementation and questions over their impact, means new approaches are beginning to be developed. These will use innovations in data collection as well as completely new models of measuring sustainability outcomes.

“Most sustainability standards are not set up to drive scale change in a way that would allow all the world’s output of a commodity or all of a supermarket’s products to be certified. To achieve this level of scale change we need a new way of working. One that links markets (developed and developing); producers (big and small); policy makers, civil society and campaigners to deliver a whole landscape approach to managing commodity.”

Mike Barry, Director of Sustainable Business, Marks & Spencer



Today's standards

459

Number of eco labels operating globally in 25 industry sectors

\$31.6bn (USD)

Estimated trade value of top 12 sustainability standards initiatives

10.5m

Hectares of land managed under major standards

What is in a standards system?

This topic explores the current use of private sector sustainability standards in food and drink supply chains. There are four components of these standards systems. How these are delivered influences the cost, credibility and impact of the standard. Identifying opportunities to increase the efficiency of these components, and in some cases finding completely new models of delivery, will be a key challenge for the food industry in the next ten years. Of particular interest will be finding new methods for verifying sustainability standard outcomes and providing sufficient supply chain traceability.



Standards and performance criteria

A standard contains a set of practices or performance criteria. These are core to a standards system. The effectiveness of standards at delivering sustainability outcomes are assessed through 'monitoring and evaluation' work.



Assessment processes and requirements

The dominant model of ensuring compliance is the use of audits (e.g. certification, verification and surprise audits). The frequency of these, and who conducts them, is standard specific. Self-auditing can also have a role to play.



Traceability & chain of custody

Different Chain of Custody models are available, from those that provide high levels of traceability ('identity preservation' and 'segregated supply') through to models such as 'book & claim', where the certificate is de-coupled from the physical product.



Claims, labels & certification marks

About two thirds of standards have a consumer facing claim. However, the past ten years has seen growing appreciation of standards as a useful business-to-business tool (e.g. to deliver sourcing commitments).

Challenges facing the current standards model

A number of challenges are hindering the current model of sustainability standards from delivering more widespread and transformative environmental and social outcomes. These include ...

Evidence of impact. Measuring the impact of standards is challenging. While benefits for individual producers, society and the environment have been identified in evaluation studies, evidence of widespread change is weaker.

Cost and complexity. Certification can be out-of-reach to smaller businesses due to the technical and investment requirements. Administration can be inefficient, with producers answering the same questions for different customers.

Limited reach. According to WWF, the 'bottom 25%' of food producers cause about 50% of the environmental impacts and only supply 10% of the market. Certification has not proven to be good at reaching the worst performers.

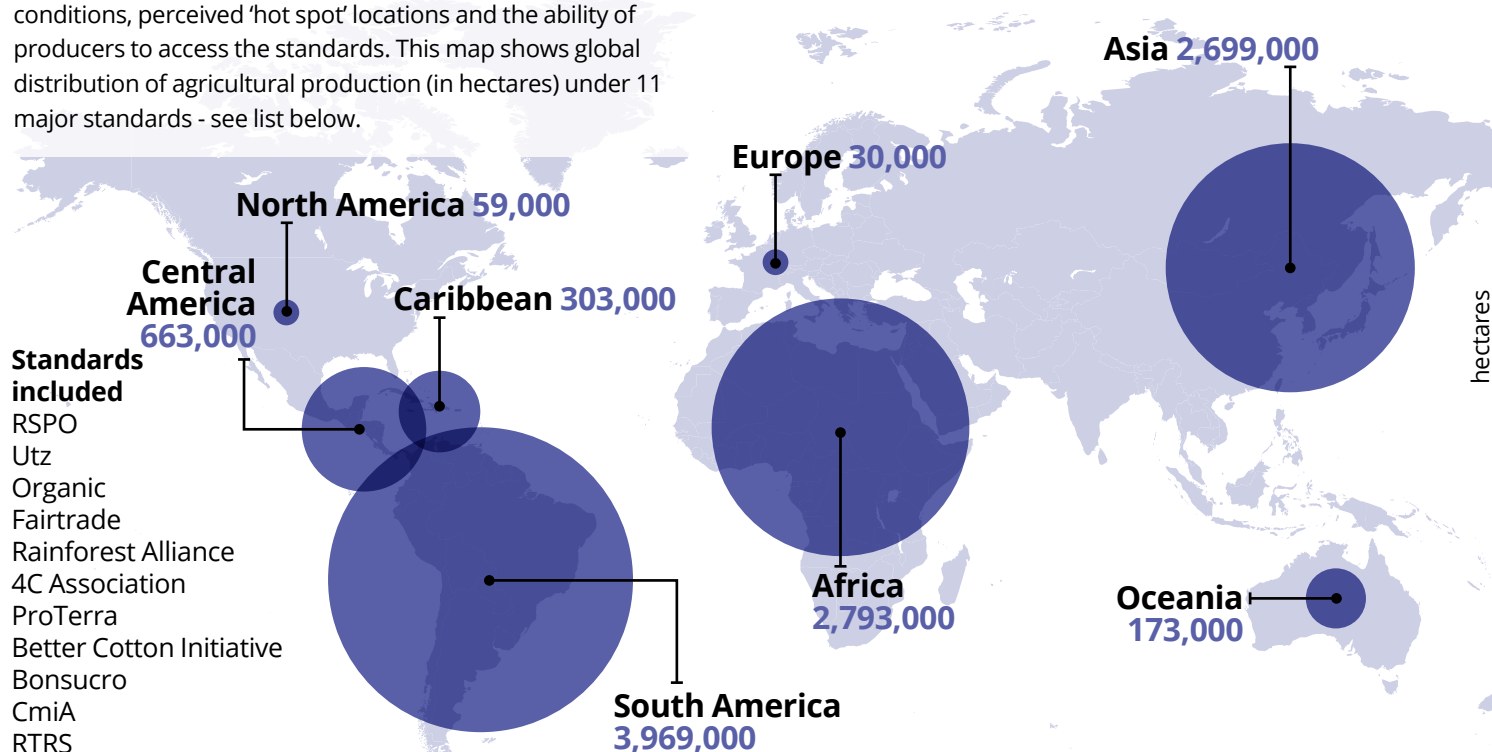
Data inaccessibility. In many cases the certification process itself has not evolved much since it was first developed decades ago; auditors still go out on site and record findings in paper-based systems which are hard to access.

Capacity gap. There is a shortage of agricultural training capacity needed to increase knowledge of better management practices. This is slowing in the adoption of better management practices on-the-ground.

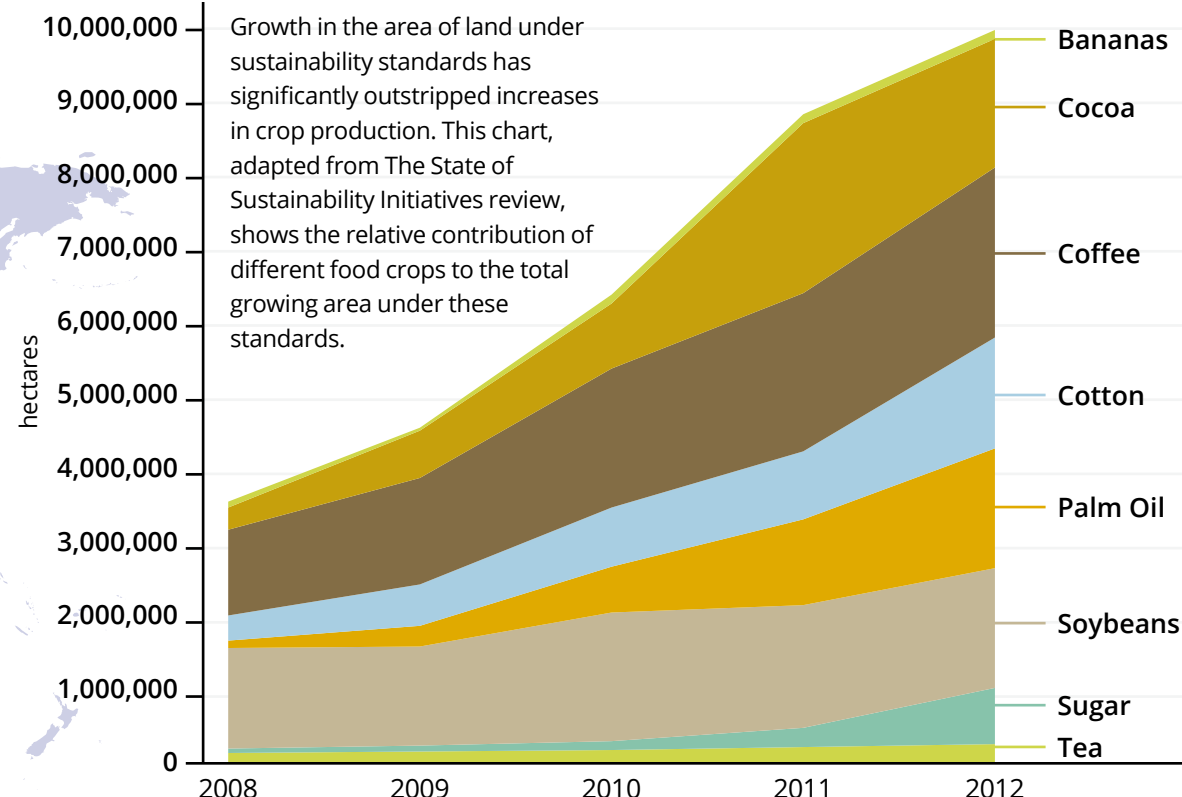
Growth in sustainability standards

Standards-compliant production has grown significantly, but is concentrated in certain locations and commodities

There is a concentration of production due to biophysical conditions, perceived 'hot spot' locations and the ability of producers to access the standards. This map shows global distribution of agricultural production (in hectares) under 11 major standards - see list below.



Area of food crops under standards tripled between 2008 and 2012



Upping the standard

The trajectory for scaling sustainability standards: Risks and opportunities on the pathway to 2025



Opportunities

Sustainability data and business model innovation unlocks new possibilities for businesses to encourage and demonstrate improvements in sustainable agriculture, forestry and fisheries.

- **Relevant** To encourage adoption, standards more explicitly demonstrate their effectiveness in addressing core business needs (e.g. risk reduction, productivity), while at the same time delivering fundamental economic, environmental, and social outcomes.
- **Cost effective** Reductions in certification and chain of custody costs can be achieved through standards convergence, creation of shared certification platforms and the use of new technologies that aid verification and traceability processes.
- **Outcome based** A shift to more 'outcome-based' standards has the potential to empower producers with the flexibility to adopt practices that are more locally relevant and can be judged on performance, not practices. Such an approach will also provide supply chain customers, households and policymakers with more compelling and inspiring evidence of change. While measuring outcomes has historically proved expensive and challenging, new data collection technologies and landscape-scale monitoring has the potential to open up new opportunities to innovate in this space.
- **Sector transformation** Sustainability standards aren't the only tool in the sustainable food system toolbox. They will need to be complemented by increased adoption of a broader set of supplier relationship management programmes, as well as stronger regulatory and public policy tools. For example, the certification of whole regions (so-called 'jurisdictional approaches') has the potential to increase the uptake of standards. A broad set of measures will help drive sector transformation through reaching the 'bottom 25%' of producers who contribute a significant proportion of negative environmental and social impacts.



Current trajectory

Single sector initiatives continue to dominate and total area under coverage expands. Increasing interest in standards from policymakers and in emerging markets.

- **Expanded hectares** Growth in markets for standard-compliant products continue to grow, reaching 20-30 million hectares of major commodities.
- **Concentration** Single sector initiatives continue to dominate production volumes, with new commodities covered by new standards. Alongside this there is potential for further concentration of standards in commodities and regions deemed to be the 'riskiest' and where producers have the capacity to meet the requirements.
- **Emerging markets** Increased interest in sustainability standards by households and businesses in emerging markets e.g. China, Brazil and India. As a result, sustainability standards are increasingly viewed as a 'minimum requirement' for accessing export markets.
- **New audiences** Policymakers and investors show increased interest in sustainability standards and how they can help deliver their objectives.

"Transformation of sustainability standards will require new approaches that are appropriate for operating at scale, that adapt and integrate new technologies, that are streamlined, and that create new value."

Patrick Mallet, ISEAL Innovations Director



Risks

Lack of progress on demonstrating impacts and loss of household confidence stalls the adoption of sustainability standards.

- **Credibility loss** Sustainability standards could suffer a significant loss in credibility if pressure groups highlight serious transgressions or question the scale of impact that standards are achieving.
- **Trade barrier** The World Trade Organisation could rule that sustainability standards are a Technical Barrier to Trade - and this seriously hinders further use of this model for operationalising sustainability in international trade.
- **Lower demand** Growth in emerging market demand for commodities, with lower sustainability requirements, could mean adoption of standards is much less attractive in some producer countries in the short term.

Enabling sector transformation

Web 3.0 Chain of Custody

Organisation Provenance.org

Challenge Households, regulators and businesses are demanding increased traceability in supply chains to provide greater assurance that products have not been adulterated and have not been associated with poor social and environmental practices. Current Chain of Custody models used in certification schemes are costly and concerns have been voiced over their potential to be circumvented.

Solution Provenance is a UK organisation that proposes to use Web 3.0 technology to make supply chain traceability faster, more efficient and more robust. Their software uses decentralised 'blockchain' databases - a system originally developed to enable the creation of digital currencies, such as Bitcoin. The technology creates a digital paper trail that is almost impossible to tamper with. The approach, which is set to be piloted in a tuna supply chain, has the potential to revolutionise the way that grocery businesses guarantee a chain of custody in a cost-effective manner.

Landscape partnerships

Organisations Alliance for Water Stewardship (AWS) and Forest Stewardship Council (FSC)

Challenge Environmental processes happen at a scale that transcends farm or supply chain boundaries. However the majority of sustainability standards focus on business-level interventions that aren't tailored to local conditions and do not recognise shared interests with other resource users.

Solution Sustainable natural resource management requires integrated, landscape-scale solutions to reconcile competing demands, and multiple pressures on local social and environmental systems. To address these challenges the AWS standard supports watershed level collaboration: it has advanced-level requirements to engage in collective action to tackle shared water challenges. Similarly, the FSC forest management standards have requirements to assess impacts beyond the boundaries of the certified entity. The adoption of landscape-scale approaches also offers the opportunity to collaboratively measure sustainability outcomes at that scale.

Building local capacity

Organisation Utz Certified

Challenge While there is a good understanding of what sustainable production looks like in agricultural, forestry and fisheries systems, a lack of investment in producer training capacity is slowing the adoption of better management practices and sustainability standards.

Solution As part of a five year € 18m programme funded by the Dutch ministry of Foreign Affairs, Utz has partnered with development donors to create training for coffee farmers on how to deal with the adverse impact of climate change on coffee production. The training is now a mandatory element of its Code of Conduct. This means that potentially over 150,000 coffee farmers will benefit from increased knowledge on climate change.



Transaction validation

Organisation Marine Stewardship Council (MSC)

Challenge There are acknowledged to be high levels of mislabelling in the seafood industry and there is growing pressure from households for greater traceability. The existing MSC Chain of Custody system means that tracebacks are done manually and potentially useful information is not easily accessed by businesses, policymakers and consumers.

Solution The MSC Online Transaction Solution (MOTS) aims to improve chain of custody integrity and reduce Chain of Custody costs. The tool, which is being piloted in China with 15 companies, works by providing a centralised database that captures purchase and sale transactions information across the supply chain. The intention is that this will enable auditors to validate transaction volumes, species, suppliers and customers, before an onsite audit. The ultimate aim is to undertake a global roll-out of the tool to more than 3,000 companies handling products in more than 34,000 sites.



Satellite data + crowdsourcing = verification

Organisations World Resources Institute and The Forest Trust

Challenge The monitoring of standards compliance across large areas of land is expensive and the potential remains to miss problems during audit visits due to unrepresentative sampling of locations to inspect.

Solution The use of satellite and other remotely sensed imagery offers the potential to increase the quality and cost effectiveness of verifying standards compliance. Remote sensing can be used to monitor a range of parameters relevant to sustainable land use, such as land cover, agricultural productivity, pests and diseases, carbon stocks, water availability, water quality, forest cover and species diversity. The World Resources Institute has developed Global Forest Watch, an interactive online forest monitoring and alert system. The open data source provides near real-time information on suspected forest loss and also facilitates the crowdsourcing of new information on forest loss via web and mobile apps. Corporate members of The Forest Trust publish their supplier maps so that NGOs can check how effectively company policies are being implemented. Through the combination of 'radical' transparency and remote monitoring, verification can be more credible and robust.

“The industry predicts 109,000 new staff will be required over the next ten years to replace retiring staff - even though the total number of people employed in the sector will continue to dip as a result of increasing automation, new technology and efficiency gains.”

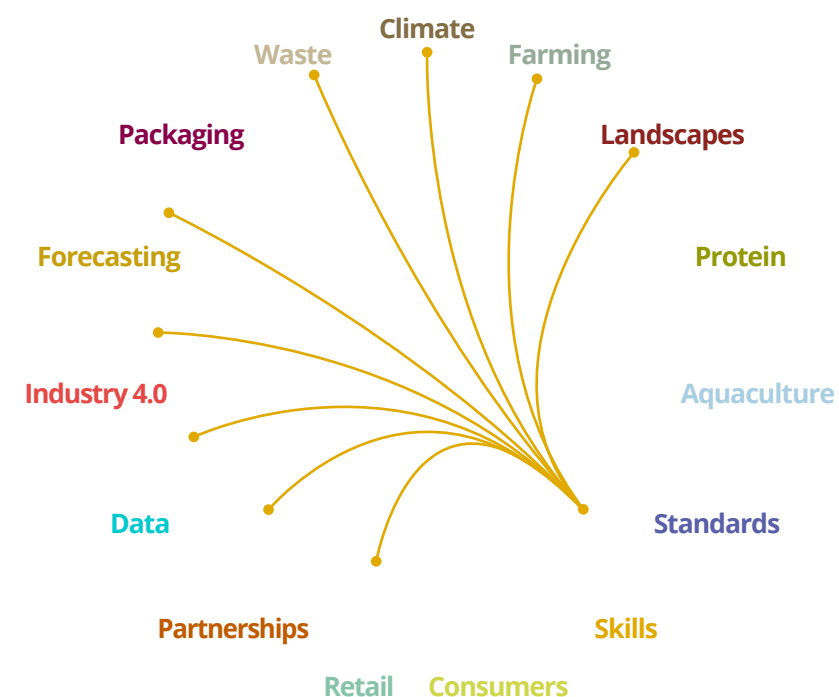
National Skills Academy
for Food & Drink, on food
manufacturing



Skills for future food challenges

The food industry is the UK's largest private sector employer with 3.7m jobs in 200,000 firms. Concerns are high in the agricultural and manufacturing sectors over a shortage of workers, particularly the unavailability of the advanced skills needed for rapidly evolving workplaces. However, this fear sits alongside expectations of greater automation leading to *less* employment - perhaps indicating a move toward fewer, more skilled employees.

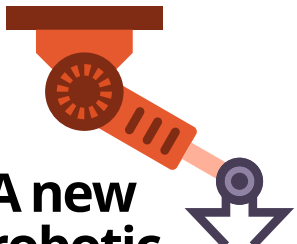
There is agreement that more needs to be done to attract new younger talent to the industry. Concerted efforts are needed to enhance the public image of food production and to establish clearer entry points, particularly through schools and colleges.



Attracting new talent to the food sector

The demand profile for talent varies between farming, manufacturing, hospitality, and retail. Increasing penetration of technologies is reducing demand for low-skill roles, but the sector as a whole seeks to improve its image to attract the best recruits for the future.

	Agriculture	Manufacturing	Retail & catering
			
	“There remains a serious skills shortage in our sector, and we need to ensure that industry has the talent it needs to remain competitive.” <i>Meurig Raymond, NFU President</i>	“Manufacturers will need to replace 28% of their current workforce by 2022, and we’re facing a skills gap, particularly in engineering and food science.” <i>Angela Coleshill, Director of Employment, Skills, and Corporate Services, FDF</i>	“The skills gap in the hospitality sector is the largest... and the most common reason is workers being new to their role.” <i>People 1st, State of the Nation</i>
 The demand	WORKFORCE 430,000 94% work in microbusinesses (<10 employees). The average age is 55, with only 12% aged 25-34. Surveys show 40% of training is informal on the job, with lack of time cited as the main barrier to skills development. Farmers themselves forecast greater professionalism required by 2030, and over a quarter expect labour shortages in the next 15 years. The National Federation of Young Farmer’s Club have a mission to develop skills for their 25,000 members and so equip the next generation of farmers with the technical skills needed.	WORKFORCE 390,000 Employees across the sector in over 8,000 businesses. Forecasts are for 109,000 new jobs required by 2022 (compared to 2012), although the total size of sector is expected to contract due to automation & efficiency gains. Employers need abilities in STEM (science, technology, engineering & maths) subjects, with 64% struggling to recruit people with the appropriate skills. Budget constraints have reduced graduate scheme places, leading to concerns over future managers developing internally.	WORKFORCE 2,700,000 With 1.1m in retail and 1.6m in catering, the demand profile varies across the sector. Employers are generally looking for workforce flexibility, as well as stronger ‘soft skills’ such as communication and teamwork. Ten-year net employment growth of 4% is estimated in the retail sector by 2022, and for hospitality high recruitment needs to reflect rapid staff turnover. There is evidence of significant competition for positions - 200 applicants per vacancy at a new Costa Coffee branch, and over 1,500 applicants for 40 roles at a new Lidl store.
 Entry to the sector	Agriculture suffers from poor perception among young people, more than 80% of whom think farming is outdated. Other barriers include ownership or access to land; a third of young people surveyed believed they needed a family connection to break into the sector. The Future of Farming Review proposed the need to create land partnerships and to assist older farmers in better planning for exiting their farms.	Established mechanisms are needed to bring more varied talent to manufacturing. Through its ‘Feeding Britain’s Future’ programme the IGD is focused on inspiring 5,000 school children to follow careers in the sector. A new National Skills Academy for Food and Drink scheme will provide career advice to 5,000 young people, deliver ten new Trailblazer Apprenticeship standards, and develop industry Kitemarks for training provision.	According to the UK Commission for Employment and Skills, the number of students having a part time job has dropped from 42% nine years ago to 18% today. At the same time lack of apprenticeships and desirable restaurant jobs has led to a lack of a pipeline of talent wanting to be chefs. In 2015 job postings rose by a massive 61% but those looking for catering roles only increased by 8.5%.



A new robotic workforce

35% of existing UK jobs are at risk of automation in the next 20 years, including replacing human labour on farms, in catering and in assembly activities such as food processing in factories. While this is likely to lead to a smaller workforce, the sector will need employees with the skills to maintain and work alongside automated systems, creating new positions that require a different, or expanded, skill set.

Attracting talent

Agriculture and food manufacturing sectors have both identified the need to appeal to future workforce.



Ensuring a thriving food economy

The trajectory for skills for future food challenges: Risks and opportunities on the pathway to 2025



Opportunities

Food sector successfully establishes an identity that attracts the best new talent - and provides clear entry points and opportunities to progress.

- **Robotic help** An increasing use of robots on farms for the back-breaking, time-consuming, mundane tasks could free farmers up to focus on innovative solutions and activities for their business.
- **Joined up thinking** The creation of a universal 'one-stop-shop' for UK businesses may help identify skills programmes from farm to fork. A network of practical sites develops for interested parties - e.g. demonstrator farms/centres of excellence; open factories; proven e-learning courses.
- **Diversified recruitment** Employers could look beyond young talent, recruiting diverse entrants which leads to greater retention, lower recruitment pressures and associated development of skills for the job.
- **Enabling farm entrepreneurs** Assistance could include desirable exits for retiring farmers, land partnership for new farmers, innovative financing, and mentoring for new entrants joining larger, consolidated agricultural businesses.



Current trajectory

Significant new entrants to agricultural sector replacing older farmers, and emergence of higher portion of skilled workers in manufacturing. New minimum wage places pressure on cost base in retail and catering.

- **Clearer sector image** Active efforts to reposition the UK's largest employment sector succeed in shedding out-dated and unclear image of food production.
- **Flexible workers** There will be some acute shortages, leading to a scramble to fill them from contractors and universities stepping in to provide technical services.
- **Smaller workforce** Gradual reduction in aggregate number of employees in the sector, as automation and efficiencies reduce labour demands in agriculture, manufacturing, retail and catering; 35% of all existing UK jobs are at risk of automation by 2035.
- **Varied training opportunities** Whether in-house, online, apprenticeships or centres of excellence, the next ten years of training will be far more varied and rich than in the past.
- **Minimum wage increases** Legislation on minimum wage significantly affects cost base of labour intensive sectors, particularly catering and retail.

"Food lacks the unified voice with which to address government, research funders, universities and the education system that other sectors - such as automotive or pharma - have developed."

Leading Food 4.0 Report by National Centre for Universities and Business



Risks

The loud messages from industry aren't heeded, and the skills gap directly affects food quality, cost and ability to innovate, resulting in missed opportunities for Gross Value Added to UK Plc.

- **Understanding engagement at home** Future skills in the food industry will benefit from sound knowledge and engagement with food in the home. The recent trend for less time cooking and fewer home skills may pose a risk for future talent entering into the industry.
- **Agricultural productivity** Mismatch between the advanced agriculture techniques available with the know-how in the workforce may lead to a productivity gap from UK farming. This is exacerbated by continued lack of access to land, curtailing opportunities and ambition of new entrants.
- **Food quality** Acute shortage of skills could impact on food quality and business growth leading to higher costs.
- **Avoiding investment** Budgetary pressures in food businesses could lead to reduced investment in training to protect short term performance. Declining development opportunities for staff may reduce productivity, staff retention and attraction of new quality candidates.

Programmes for developing UK skills

Business-led programmes

While smaller businesses in the sector can struggle to provide training, the largest companies have extensive staff development programmes.

The Industry Skills Partnership brings together 50 food and drink manufacturing companies as well as a range of trade associations to collaborate on designing effective employee training. It is supported by £2m of BIS funding and £1m of industry funding.

In-house training is also filling gaps identified in the market. The major retailers have established in-house training academies - from 2004 to 2012, Tesco delivered 7,000 apprenticeships, before increasing this to a further 10,000 over the subsequent two years. Within food service, Whitbread (owner of Costa Coffee) is aiming for 6,000 apprenticeships by 2020, with apprenticeship levels that are externally recognised.

Many food businesses are extending this pro-active support for skills to their supply chains. For young people under 25, programmes such as M&S's Farming for the Future and McDonald's Progressive Young Farmers extend training and support opportunities into agriculture. Sainsbury's is changing perceptions of agriculture through a new specialist apprenticeship scheme with Staffline. The aims are to secure quality supply from UK producers in the long term.

At the other end of the value chain, support is also being extended to help householders gain skills in food preparation and nutrition. Tesco is investing almost £5m into the Children's Food Trust network of school cooking clubs, giving children the skills to cook meals at home and make healthy food choices. WRAP's '10 Cities' programme similarly offers free cookery classes to the public across the UK.



Skills of the workforce are critical across many of the other topics covered, and in particular for Consious food choices and Food chain data revolution.

Expertise from universities



As technical demand increases, universities can provide expertise to fill skills gaps, but this is in early stages. Food 4.0 reported that "only a few universities have a clear sense of the research, innovation and educational needs of the food economy. Conversely many, if not most, food businesses do not have a strategic and long-term relationship with universities".

Nestlé has partnered with the University of Lincoln as a follow on from its 'Fast Start' school leaver programme to provide paid positions to work part time whilst studying for a school degree. Another good example of collaboration starting to happen comes from the University of Nottingham, which has produced a capability statement that is structured to help the food and drink industry navigate and better access the university's expertise so that its knowledge can be applied in helping to address challenges faced by industry.

Going online



Online resources create options for more flexible training and skills development. High levels of online services by parts of the farming community present e-learning opportunities, and The Farmers Weekly Academy and ARTIS e-learning platform both provide courses that earn CPD credits for farmers.

Within manufacturing there are fewer options, although The National Skills Academy in Food and Drink has its Online Academy for manufacturing, and food hygiene and safety courses are available from a number of providers. Gamification of training is a growing trend adopted to make content more engaging, such as Waitrose's approach to food safety and hygiene legal compliance training. More broadly, Massive Open Online Courses (MOOCs) provide widespread availability, and Open University's FutureLearn is recognised as a leading provider with courses available on nutrition and food security.

Centres of Excellence



Spanning the whole food supply chain, new centres are springing up to inject needed skills. "To deliver a world class agricultural industry requires a pipeline of basic and strategic research that feeds through to inform both the training of our students and our advisory services."

Examples include the Centre of Excellence in UK Farming (CEUKF), seed-funded by Waitrose in 2011; £12m funding for the new Centre for Agricultural Informatics and Sustainability Metrics (AIMS) at Rothamsted Research; and the National Centre of Excellence for Food Engineering (NCEFE) at Sheffield Hallam University (operational in 2017) which includes a 4-year MEng degree and 3-year BEng. A new Centre for Innovation Excellence in Livestock (CIEL) has the support of over 80 companies and 30 industry bodies for its bid to attract government funding, led by the ADHB.

Food Enterprise Zones



Technology and consumer interests are seeding the opportunities for new levels of food entrepreneurship. One government scheme seeking to nurture this trend is the creation of "Food Enterprise Zones" (FEZs) in England. The government expects new FEZs will create 10,000 new jobs and significant investment by promoting place-based enterprises and creating much needed links between producers and processors. Local Development Orders will make business start-ups and expansion easier and faster. Eleven FEZs are planned in England, with three of these in Lincolnshire.

FEZs demonstrate the importance of place-based enterprise, a theme explored in more detail in the *Landscape scale opportunities* topic.

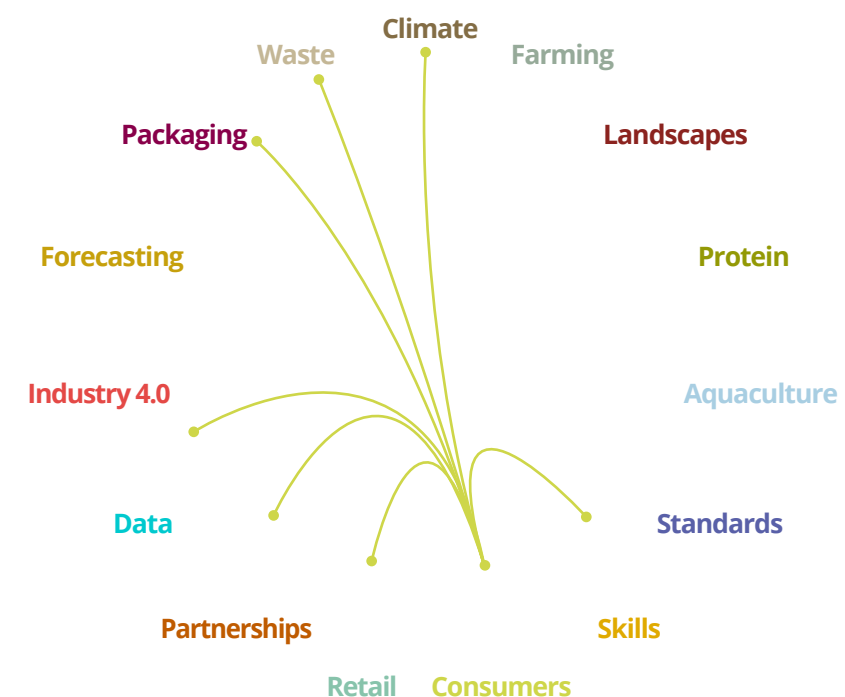


Conscious food choices

In the UK, household engagement with food has been steadily increasing with more sustainable, ethical and healthy choices arguably becoming more aspirational and associated with improved quality and taste. This is where product transparency and storytelling can play a positive role against other issues and any scandals that might reach household consciousness. There are real challenges beyond sustainability and transparency to face between now and 2025, including access to food and the relationship between health, food and nutrition. Solutions to these challenges may need to be found at a societal level, not just a personal level.

"Three things remain constant: Britons' culinary curiosity, their love of good food and their desire to eat healthily."

The Waitrose Food and Drink Report 2014



The changing landscape of consumer choice

The landscape of what motivates and drives consumer choice is complex and personal. Some of the key influencers are price, quality, trust and transparency, socio-cultural influences, and more recently health and sustainability.

Sustainability

Sustainability and broader ethical considerations motivate a minority, with Millennials far more likely than older people to consider these in their purchasing. Ethical concerns have proven resilient to recession, and are likely to continue to grow in importance even during a time of expected increases in food prices. Reducing food waste at home has been motivated more by financial benefits than by sustainability concerns, but as a generation schooled in recycling become householders, sustainability could become a greater driver.

Health

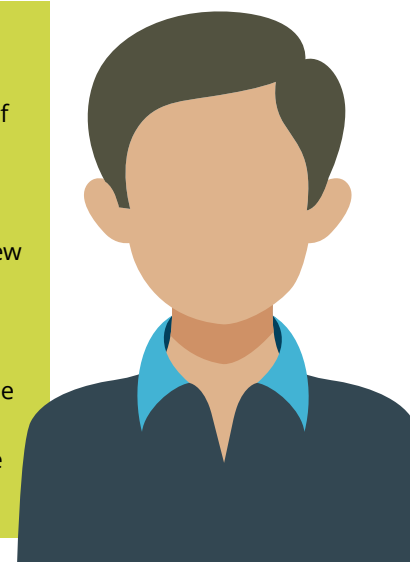
We are heading towards a health crisis in the UK, with both an aging population and rising obesity rates putting additional pressure on resources. Food and nutrition can play a valuable role but cannot on their own solve these challenges. Concentrating on the individual alone is not enough to make changes in food consumption and behaviour. Businesses and government will need to take a greater role in helping people eat more healthily - including reformulating products and changing public procurement standards.

With an increasing proportion of eating occasions taking place out of home, it will be important that healthy, sustainable choices are available and affordable in all channels, from restaurants to workplace catering.

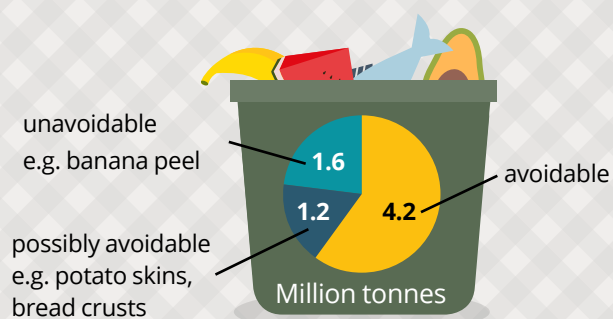
Quality

Consumers are increasingly looking for quality in terms not just of taste, but also of provenance and safety. However, food scandals and lack of transparency mean they do not always trust food. Food manufacturers and restaurants can use new technologies in areas like supply chain monitoring and active and intelligent packaging to reassure and inform.

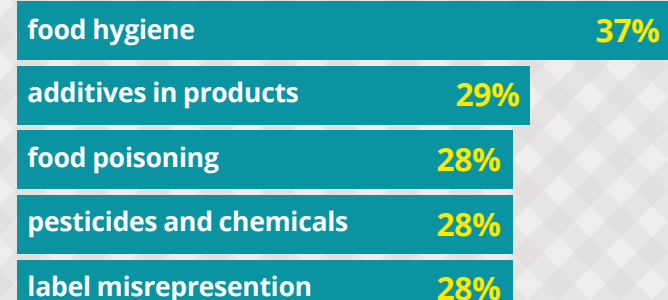
Concerns about food quality and hygiene are greater for out of home occasions, which are likely to increase versus in home consumption to 2025.



Total household food waste:

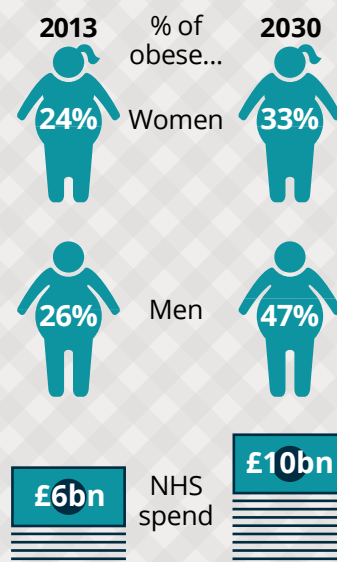


Consumer concern about food safety issues out of home



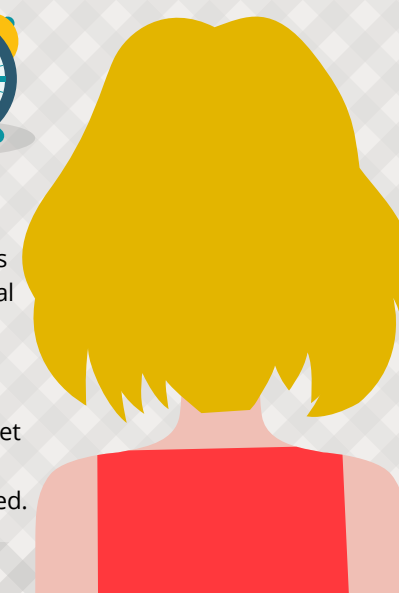
Obesity issues

Obesity affected 24% of women in 2013, a figure which is projected to rise to 33% by 2030. Similarly, the percentage among men is expected to rise from 26% to 36%. The correlating NHS spend on obesity will grow from £6bn to £10bn.



Meal time preparation

The average time it takes to prepare the main meal has reduced from 60 minutes (1993) to 32 minutes (2013). This downward trend looks set to continue as time continues to be pressured.



Prices

For UK consumers as a whole, price is the most important factor influencing product choice, ahead of quality, taste and health. The continuing growth of retail discounters will ensure that price will continue to play a key role. Significant price increases in a core category like meat, as a result of increased demand from a growing middle class in China, will affect consumption, particularly in lower income households. Increasing price volatility in staple foods will cause some reappraisal of food choices. By 2025 people could be spending an increased proportion of their income on food, which is likely to constrain their ability to buy high quality food. However, relative price stability or price reductions in foods such as fruit and vegetables could challenge historic perceptions that healthier foods are more expensive.

Food trends

Flexitarian eating (cutting down on meat eating) is likely to continue to increase, motivated by health, price and the personal taste of younger consumers. A growing minority are seeking diets that reflect very specific food concerns, from 'gluten-free' to 'longevity enhancement'; these interests will spread and new themes emerge, requiring highly tailored food solutions. "I want this, and I want it here and now" will shape behaviour, as people will expect technology to enable mobile ordering and the delivery of all forms of food to home or other locations at precise times.

In an increasingly connected, interactive world, consumers will expect food companies to seek out and address their opinions and wishes continuously, as well as assist them with food preparation, recipes and advice.

On the menu: positive sustainable diets

The trajectory for conscious food choices: Risks and opportunities on the pathway to 2025



Opportunities

Consumers become increasingly engaged in food, led by strong public procurement policies

- **Product innovation** There is an opportunity for food and drink companies to make it easier for consumers to make more sustainable and healthy choices. There is potential to create new products and services with sustainability and health values that an increasing proportion of the UK population are calling for.
- **Consumer engagement** There is an opportunity and need to increase consumer engagement in food sustainability and health. For example: the promotion of better portion control to reduce food waste and overconsumption; increased accessibility of product information; and increased consumer acceptability of new crop and livestock breeds that are more climate resilient. This could build in the successes of consumer campaigns, such as 'Love Food Hate Waste'.
- **Choice editing** The big challenge of societal health has to be tackled at a societal level. Public procurement policies that require healthy and sustainable meals can have a knock on effect throughout the supply chain as suppliers change to meet procurement requirements. This also helps to normalise sustainable diets and choices. Government should promote dietary guidelines that position healthy choices as sustainable choices.



Current trajectory

Convenience and price continue to drive consumer preferences. Food waste levels continue to fall

- **Flexible choices** Eating out will continue to increase as choice and availability rises whilst still being a convenient and easy option. Choices based on specialist diets continue to remain niche in terms of market size but increase in terms of consumer awareness. Food prices will continue to be a major influencer and driver of the diets consumers choose.
- **Aging healthily** The aging population continues to put pressure on health systems but could be an opportunity for food companies to meet their individual health needs through nutrition.
- **Ethics 'built in'** Brands will still need to entice and delight consumers, rather than seeking to educate them, even as consumers are more aware of the complex and varied sustainable and ethical concerns within food and food production. Sustainability and ethics will be an expectation, rather than a nice to have and this will be reflected in more healthier choices and responsible advertising.
- **Managing out waste** Food waste will likely continue to become less socially acceptable. It is also likely to decrease as food becomes both more valued and more easily managed and planned through interconnected platforms, devices and appliances preventing waste.

"As shoppers begin to recognise the links between health and sustainability, new opportunities will open up for food businesses. For example, innovations that meet the specific health needs of the individual, while enhancing the natural environment and reducing food waste."

Dr Richard Swannell, Director, WRAP



Risks

Food system under pressure from growing inequality and worsening dietary health.

- **Food inequality** The low food prices of 2015 are unlikely to last to 2025 with high levels of volatility in prices being more common, and some food categories becoming more expensive. When volatile prices are at their peak, it may make it more difficult for consumers to access high quality, healthy and sustainable food, especially low income households. This could have a serious knock on effect to consumer health and wellbeing.
- **Nutrition deficit** The compound impacts of food inequality, rising obesity and an aging population will put a new focus on nutrition. The resulting burden on the health service means that the government may have to make an intervention.

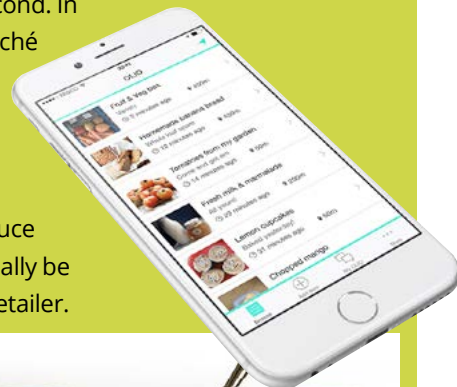
Making sustainable diets easy and appealing



Reframing waste

Making good use of food that would otherwise be wasted is creating opportunities for entrepreneurs and larger companies. In the UK, OLIO is a platform that enables neighbours and local businesses to connect easily to share surplus food. The hyper-local focus is designed to deliver social benefits around increased interaction, as well as financial benefits to those who can share the cost of food.

Rubies in the Rubble make award-winning chutneys and jams from left over fruit and vegetables, emphasising great taste first and sustainability second. In France, Intermarché celebrates and promotes 'Inglorious Fruit and Vegetables', misshapen produce that would normally be rejected by the retailer.



Timesaving technology

Technology can help solve the contradictions arising from our growing interest in food and cooking, our desire for real and healthy food and the diminishing amount of time we spend on food preparation at home. Gousto is a UK home delivery service designed to save time while helping to improve cooking skills. A weekly menu based around healthy, organic, high welfare standard foods is delivered in exact ingredient portions to make cooking easy and eliminate waste. This saves shopping and food preparation time, while ensuring a healthy, sustainable meal.

EatWith is a platform enabling people to connect with chefs who will cook a meal or offer a supper club in their own home. Launched in 2010 it is available in 150 cities, involving over 500 chefs.



USA and Swedish government health recommendations

Mixed fortunes in bringing health and sustainability together in government recommendations.

The intersection of health and sustainability and the importance of a holistic view of health beyond pure nutrition have begun to be communicated. In the UK, for example, the WWF Livewell plate demonstrated that by making small changes, you can eat a healthy, balanced and sustainable diet for a "positive difference for ourselves and for nature". These people and planet positive approaches are starting to be implemented in government recommendations.

The Swedish government's advice can be summed up with their introductory statement "Eat greener, not too much and be active", three simple ideas that together would not only be better for health but also for the planet. The holistic links are explicitly addressed: "When it comes to food, it's easy to concentrate on individual nutrients or foods to the exclusion of everything else. But all aspects are interlinked, so it's important to maintain a holistic

approach."

In the USA, the federal Dietary Guidelines Advisory Committee is responsible for recommending the content of dietary guidelines to the US government. In 2015, their recommendations included defining a healthy dietary pattern as "lower in red and processed meat". They define a "sustainable diet" as one "lower in calories and animal based foods [that] is more health promoting and is associated with lower environmental impact than... the current U.S. diet". After consideration, the US government decided against including the goal of sustainability as "a factor in developing dietary guidelines". While sustainability will not officially enter US dietary guidelines in 2015, its promotion by the Advisory Committee and inclusion in the conversation demonstrates a movement towards linking health and sustainability that is likely to continue to grow.



"It's our job to be competitive in all aspects and at all ends of the market. That includes the opening price point in any category in the market."

Dave Lewis, CEO Tesco Plc

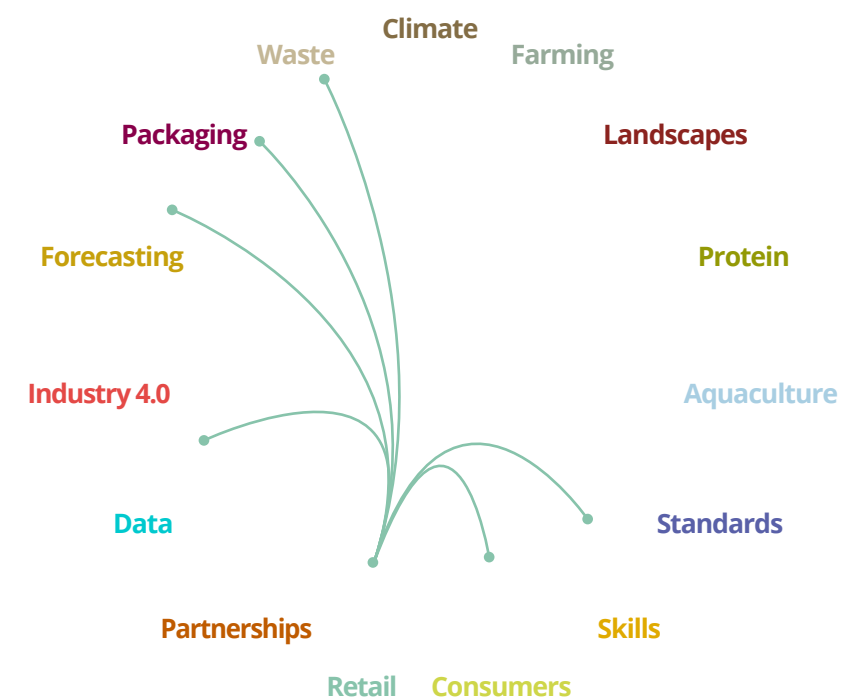


Redefining grocery retail models

Since the 2008 recession householders have been spending more at the value-end of the market, leading to an erosion of profitability at the 'Big 4' supermarkets. As the dominance of the Big 4 weakens, price sensitivity is increasingly driving retailer strategies and behaviours.

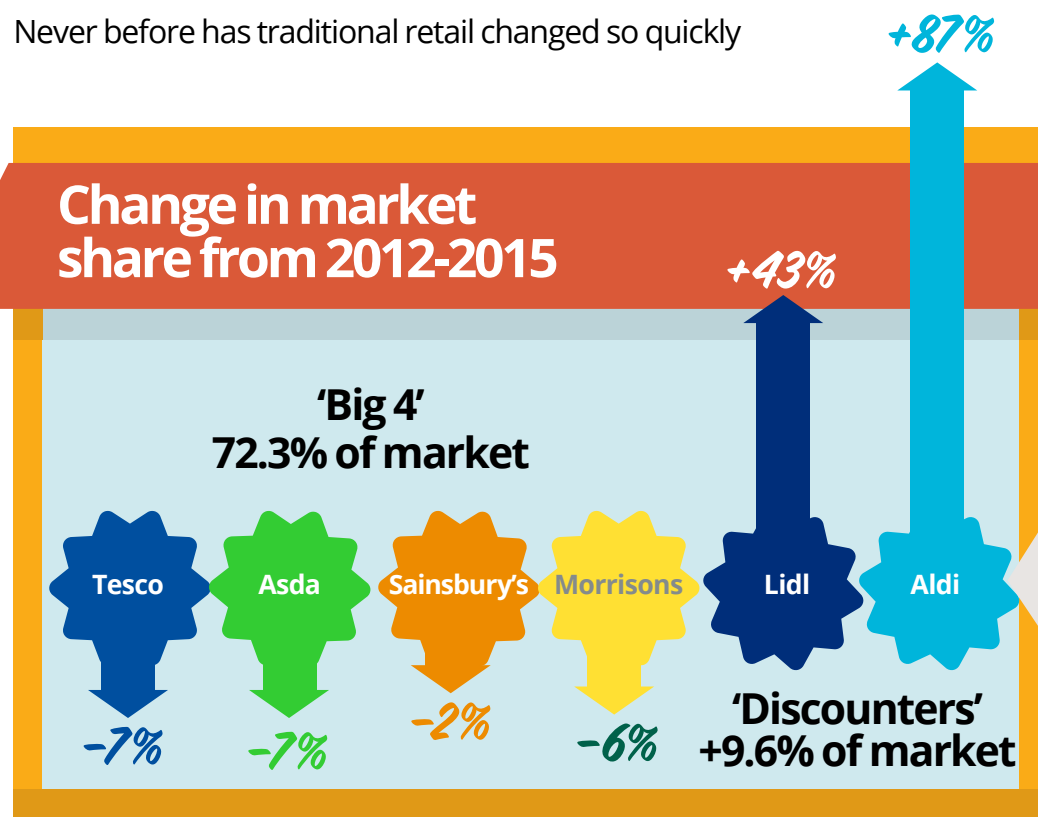
This trend is unlikely to slow and alongside an increasing prevalence for smaller, more regular shops carried out locally will re-shape traditional retail. On-line sales and delivery platforms will accelerate this by allowing smaller disruptive innovators to compete.

Retailers' relationships with suppliers is changing and becoming more balanced. This will lead to the need for closer relationships, longer contract terms and greater collaboration.



The changing face of retail

Never before has traditional retail changed so quickly



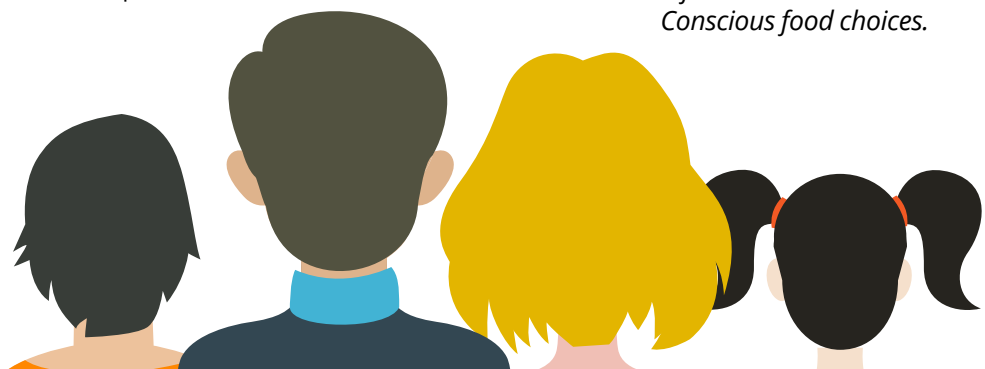
Disruption of retail

The change in market share of discounters has gone through the roof in three years, with a rapid growth in new stores and changes in shopper buying behaviours. For many new entrants, online and mobile technologies have provided the means to reach the market. 'Challenger brands' are emerging around convenience or around specific issues, like locally sourced food. One emerging player is FarmDrop which started as a fresh produce click & collect offer but last

year raised nearly £750,000 to fund expansion; they now deliver the same day direct to customers.

Established retail players are also entering the mainstream food market, such as Amazon. Their model allows consumers to order groceries and products from local restaurants and stores for same day delivery all under AmazonPrime membership.

More detail on the household's influence on retail in Conscious food choices.



New ways of buying

Vertically integrated supply chains allow for more direct control of costs and quality, as well as improved traceability, as seen in Morrison's operating model. ASDA's subsidiary IPL simplify the supply chain and reduce cost. These approaches will be increasingly adopted as they allow the grower and retailer to have a closer relationship.

Collaborative groups such as Tesco's Supplier Network or Sainsbury's farming groups accelerate pure commercial activity and drive

sustainability benefits. These will be increasingly essential in a future of climate change, resource competition and increased scrutiny.

Over the next few years the trend will move towards fixed and longer contract terms to encourage greater collaboration and investment in quality and efficiency. Cross border buying alliances will be more typical in the UK, following the commonly seen continental model.

Win-win for consumers

Households are hugely benefiting from lower prices as well as a never before seen choice of delivery options and convenience of shop.

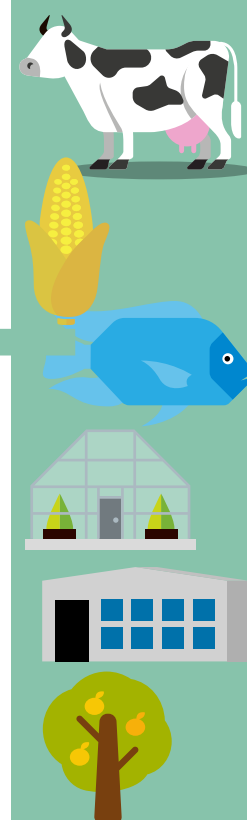
Short term-ism danger

Unless checked, the current razor sharp focus on price from some major retailers could lead to dilution of sustainability programmes which in turn would increase supply chain risk, future costs and possibly alienate consumers.

Power to the producer

The supply chain has undergone significant change. Coupled with more legislative oversight and the need to secure volume in the light of increasing overseas competition for food, this is re-shaping the balance of power between retailers and suppliers. The Grocery Code Adjudicator has also grown in strength leading to a greater focus on compliance.

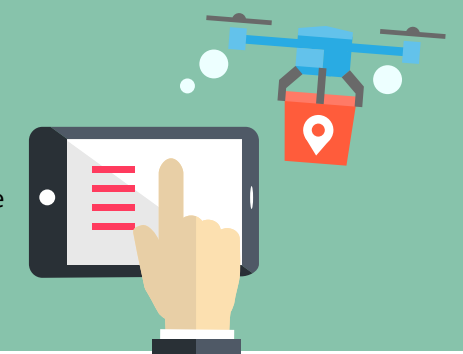
Consolidation amongst producers has increased and will continue leading to fewer but far larger players, who have a bigger voice both in negotiating with their retail customers and in influencing action and activities across the supply chain. In the future, it is conceivable that brands will bypass retailers, and sell directly to consumers through their own online platforms or via other third parties.



Looking ahead to 2025

Whilst it is highly unlikely that the 'Big 4' will have lost combined dominance by this date, their market share is forecast to continue to be eroded by the continuing, though slowing, rise in 'discounters' and 'pound shops'. To drive scale, consolidation is highly likely, particularly across European retailers, such as seen with Ahold and

Delhaize, and by 2025 this trend could affect UK retailers. Further expansion from disruptive innovators is expected, taking advantage of growing consumer desire for differentiation in the areas of local sourcing, sustainability and transparency, and powered by omnichannel and new methods of delivery or collection.



Significant change on the horizon?

The trajectory for grocery retail models: Risks and opportunities on the pathway to 2025



Opportunities

Closer relationships across the food system will improve the consumer offer whilst at the same time driving efficiency and innovation.

- **Integration** Food producers could develop closer, longer term, more collaborative relationships with retailers. These closer relationships, possibly partly vertically integrated, may stabilise price fluctuations and lead to greater transparency for consumers as well as create an environment for innovation and joint investments. Efficiency may increase and the need to manage natural resources over the long term will be recognised.
- **Consumers drive innovation** The growing desire for healthier, more sustainable food, especially amongst Millennials, growing consumer demands for greater transparency, and pressure from new, disruptive entrants to the market mean that product ranges will become more healthy and sustainable over time.
- **Increased efficiency** If a more joined up marketplace is established and there are closer relationships between growers, processors, and retailers, this could lead to the wider use of innovations such as 'whole crop purchase' arrangements, allowing crops to be used across multiple product categories and supply chain partners (e.g. loose produce, ready meals, soups and sauces), increasing crop utilisation, and reducing waste.
- **Start-ups** Competitive pressure in the market place drives food entrepreneurship, alongside new production methods and connectivity might lead to new food start-ups thriving outside the 'traditional' grocery sector.



Current trajectory

Different market dynamics emerge: shoppers seeking ever greater convenience, and traditional retailer models under pressure.

- **Less 'Big 4' power** The 'Big 4' will continue to lose market share and value as they seek to compete with the discounters contrary to their standard business models. Smaller, more regular, shops carried out locally or picked up through click and collect points will increase in popularity further adding to retailers' cost base.
- **Obsession with price** The narrow focus on price may compete with the pursuit of greater sustainability, and so less opportunity to mitigate future costs, whilst the discounters continue to innovate. The food production sector will become increasingly consolidated into fewer companies with more power and smaller players will decrease in numbers.
- **Convenience** Consumers might be able to order and collect their shopping same day at a location of their choosing and have greater transparency on its origins and values.



Risks

Significant re-shaping of the retail environment occurs, with the danger that a singular focus on price leaves some retailers open to losing further market share to the discounters and disruptors.

- **Sector realignment** Traditional supermarkets could lose the loyalty of a significant number of shoppers, resulting in the loss of market share by the 'Big 4' and the potential for further consolidation in the UK market or the acquisition of UK retailers by European or international retailers. Increasing volumes of available product and supply chain information and new consumer-facing technologies could leave unprepared retailers exposed to reputational and brand risk in an era of ultra-transparency.
- **Loss of supply volumes** Sole focus on price and margins, characterised by transactional relationships with suppliers, could lead to a loss of suppliers or to supply volumes taken up by overseas retailers. There could be potential for suppliers and disruptors to seek direct sales relationships with consumers, by-passing established retailer channels.
- **Greater producer power** Increasing demand for good quality food in overseas markets provides producers with the opportunity to have a greater ability to set buying terms, and to be selective over the customers they choose to supply.
- **Race to the bottom** On-going price-driven retail competition may lead to short-termism and a lack of available capital to invest in forward thinking innovation and to build longer-term, more strategic partnerships to improve the resilience of the supply base. Knock-on effects include the progressive loss of suppliers to competitors prepared to co-invest and collaborate with them.

"Amazon is feared precisely because profit is not the measure of its success. It is only growth."

Adam Leyland, Editor at the Grocer

Evolving consumer demands drive new channels

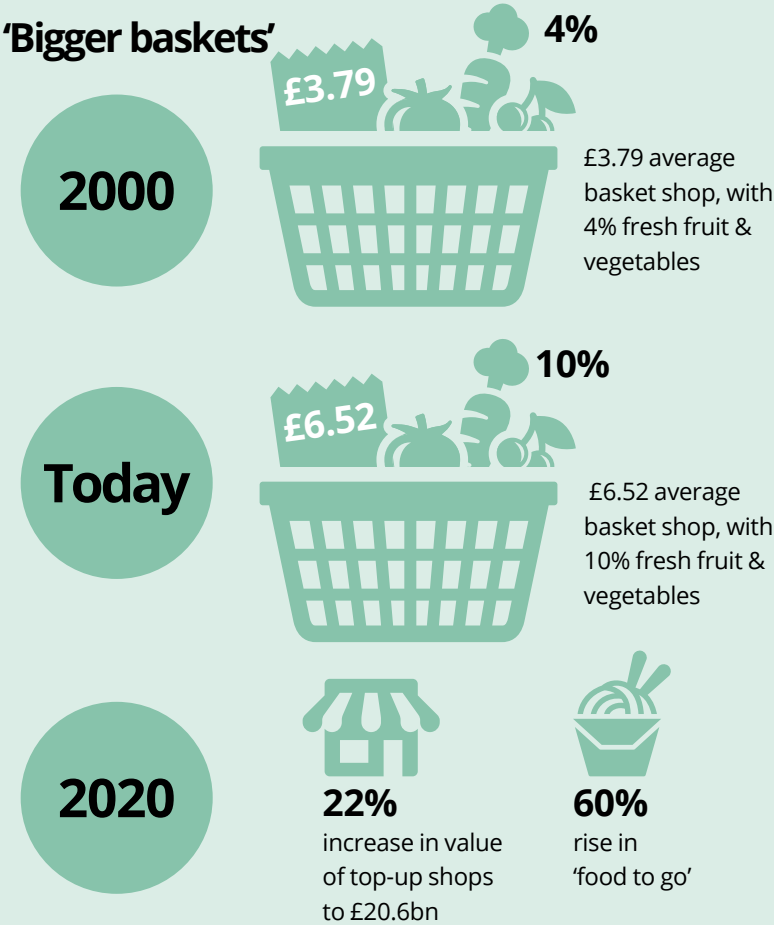
Traditional shops are out

Consumers want to buy what they want (whether food or non-food) when they want, with multiple delivery or collection options. Diversification into selling food-to-go is a key growth area for traditional retailers. This is beginning to transcend the allegiance previously given to loyalty schemes or brands in favour of convenience and immediate gratification.

Big trolley shops are less popular and are being replaced by more regular, smaller basket shops. In fact 2015 marked the year when each of the 'Big 4' publically announced the closure of stores and innovations to keep the bigger formats alive.

The purchasing of fresh fruit and vegetables from smaller stores has risen from 4% of all shops in 2000 to 10% in 2014. Alongside a further increase in sales of fresh food, this rise indicates a lesser need to then carry out a shop at a larger store.

These trends towards top-up-shops are expected to continue, further negating the need to travel to a large out-of-town superstore.



Technology is in

The internet of things is having a profound effect on shopping behaviours with 19% more consumer spending year on year across technology channels and shop formats including laptop, mobile, tablet, small store, large store, or destination shops.

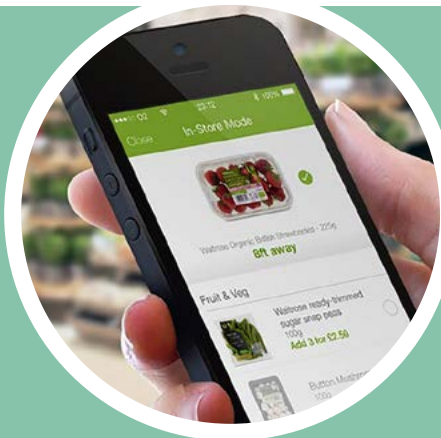
Across all products, an omnichannel shopper spends 30-67% more cash per visit than an average shopper pushing a trolley around a store, though this trend is heavily skewed towards non-food items.

Only 20% of shoppers carry out the majority of their food shopping online, versus 80% for music and film purchases. For traditional retailers, picking and delivering food on-line through grocery home shopping is often less profitable than from a store, and when online rises to over 10% of a store's sales this often leads to duplication of facilities through a 'dark store'.

Waitrose is one year into a five year vision to adopt a true omnishopping experience. They are now using an application platform to coordinate technology across channels such as mobiles, in-store kiosks, and e-commerce. Phil Curnow, practice lead of system design and development, said that "If we're going to compete, and we're going to win, we have to make that investment" into the technology.

Retailers are also investing more attractive shops with a natural feel, such as Marks & Spencer's 'living wall' concept and Albert Heijn's concept stores, which use technology such as iBeacon to allow customers to ask for help, find products, or even self-check out. These are designed to attract and gain greater shopper loyalty.

More detail on the influences of technology can be found in Food chain data revolution.



Omnichannel shoppers spend 30-67% more than traditional shoppers

Instant gratification demanded

Food also benefits from greater innovation on delivery and collection with the number of click and collect points rapidly rising, whether in store, from transport hubs, or from a special parked vehicle location. The time slots for home delivery are shrinking, leading to more shopper convenience and greater immediacy and accuracy of delivery times.

Click and collect has emerged as a key on-line opportunity for supermarkets for general merchandise as well as food as it utilises existing store space and staff. The ability for consumers to pick up according to their own schedule and location is driving innovation such as ASDA's acquisition in 2015 of technology to allow their customers to collect shopping from stand-alone, temperature controlled Intelligent Pods in under 60 seconds. ASDA now has over 600 click and collect locations and plans to increase this to over 1,000, including through petrol filling station forecourts, by 2018. This trend will continue, though likely with a charging model for lower value purchases as seen with John Lewis in mid-2015.

Delivery technology is supporting the move towards instant gratification with the emergence and growth of drone deliveries. Amazon's so-called 'Prime Air' is currently trialing this method in the US with aircraft up to 25kg. While currently it is mired in technological and regulatory concerns, it is expected to be viable within the ten year timescale.





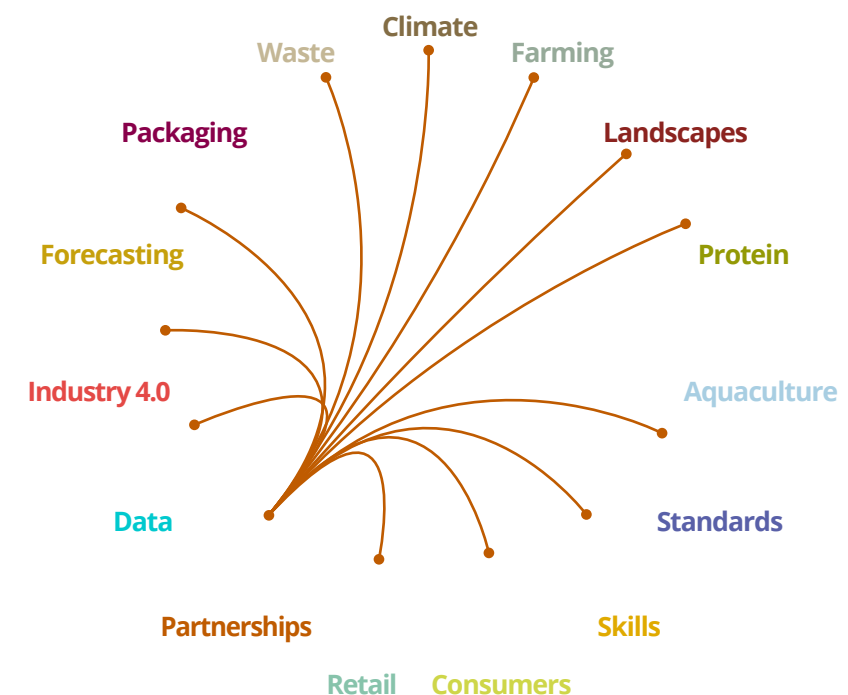
"As sustainability issues become increasingly complex, global in nature and pivotal to success, companies are realizing that they can't make the necessary impact acting alone."

Joining Forces: Collaboration and Leadership for Sustainability. MIT Sloan Management Review



New partnerships & collaborations

Collaboration has become one of the most prominent concepts in sustainable business over the past decade, however there remains significant potential to create business value and a more sustainable food system from working together: fewer than 30% of managers say their companies are engaged in successful sustainability partnerships. The scale and complexity of delivering a step change in sustainability outcomes required in the food system necessitates interdisciplinary approaches. If properly scoped and nurtured, future food partnerships have the potential to increase productivity, mitigate risk and create opportunities for the development of new products and services.



The business case for collaboration

Creating tangible sustainability and business value by working together

Since the WRAP *Grocery Futures* report was published in 2006, 'collaboration' has become one of the most promoted concepts in sustainable business. In particular, much attention has been paid to high profile collaborations such as the increasing number of multi-stakeholder roundtables. However, collaboration takes many forms and needs a lot of work to do well, so practice lags behind intentions despite success stories such as the supply chain management movement 'Efficient Consumer Response'.

According to a recent business survey by MIT Sloan, fewer than 30% of managers say their companies are engaged in successful sustainability partnerships. Much potential therefore still exists to exploit the benefits of collaborating with internal or external stakeholders such as NGOs, researchers, customers, suppliers or competitors. Collaborations between sectors are becoming of greater interest as the circular economy agenda intensifies. The diversity of opportunities and business benefits are explored in the graphic, right. This shows how collaboration can deliver clear business benefits in terms of improved productivity, reduced business risk and greater market share.

"Corporate sustainability is moving steadily from the old model — comprised primarily of ad hoc or opportunistic efforts that often produced tense relationships with the public sector — towards strategic and transformational initiatives that engage multiple entities."

Joining Forces: Collaboration and Leadership for Sustainability. MIT Sloan Management Review

Linking collaboration to core business objectives

Lower cost of technology development

By pooling resources it is more cost effective to develop mutually beneficial technologies or intellectual property.

Staff retention and personal development

Improve employee engagement and retention through working with trusted partners to create a more enriching environment, such as social or environmental NGOs.

Increase efficiency of supply chain management

A range of opportunities exist to identify mutual benefits across the value chain e.g. waste mapping and reduction.

Transform markets

Through multi-stakeholder collaboration, best practice and definitions of sustainable production can be established across whole industries.

Support product and business model innovation

Partnerships enable full exploitation of the growing spectrum of technologies and ideas.

Improved market orientation

Partnerships help businesses respond to increasing product complexity and rapidly changing consumer demands.

Access new markets

For example, unlocking value in waste by-products through partnering with researchers and potential customers – often in different non-food sectors.

See Unlocking new value through wastes.

Increase productivity

Return on equity or capital

Grow market

Manage risks

Improve asset performance

Organisations can work together to improve asset use, increase profitability and also deliver environmental and social benefits.

Secure raw material supply

Enter into longer term contracts with producers that also have sustainability requirements.

Avoid first mover disadvantage

Properly managed collaboration can enable coordinated, sector-wide improvements in product sustainability. However care is needed to avoid anti-competitive behaviours.

Manage critical natural resource risks

e.g. water stewardship through improved governance and co-operation between multiple resource users.

Materiality assessment

Using 3rd party expertise and credibility to identify and communicate the most important sustainability issues to address.

Monitoring & verification

For example, NGO monitoring of sustainability commitments on-the-ground.

The building blocks of collaboration

The Consumer Goods Forum identified some guiding principles for successful collaborations in their report on Future Value Chain 2022. These were as follows:

Put the consumer at the center Consumer education and communication is key for success.

Keep it simple Don't over-engineer solutions and demonstrate tangible benefits quickly.

Plan upfront for success Engage with multiple stakeholders and develop a compelling business case.

Create a sound model Ensure strong governance, leverage new technologies and reward participants.

Making better connections

The trajectory for new partnerships & collaboration: Risks and opportunities on the pathway to 2025



Opportunities

Secure sector-wide understanding of the benefits and opportunities for creating food partnerships of the future.

- **Collaboration best practice** Businesses, policymakers and other key stakeholders (e.g. social enterprises, NGOs) will work together to overcome the remaining barriers to collaboration (e.g. intellectual property, sustainable commodity production, competition law, geographical diversity); develop and share proven practices; and develop and promote new and novel enterprise models that support their mutual interests and deliver collective benefit and impact.
- **Brokering local collaborations** An increase in location-specific collaborations could be driven by a focus on realising the benefits of landscape-scale approaches to ecosystem service management and a desire to create a circular food economy. To catalyse these relationships, a location-centric digital platform could be created that maps assets, waste streams and resource needs. Examples of potential benefits include management of water quality within a catchment; increasing the value of by-products; and joint investment in infrastructure, such as renewables.
- **Farm-to-fork collaborations** Whole supply chain collaborations may be able to identify multiple resource efficiency, sustainability and commercial opportunities. For example, through collaborative demand and supply planning and climate risk management. This can improve resilience, drive open innovation across the supply chain, and enhance the relationships between suppliers and their customers.



Current trajectory

Challenge of creating more resilient primary production systems is focus of efforts.

- **Engagement on sustainable agriculture** The challenges of helping millions of farmers adopt better management practices and more climate smart approaches will be the focus of increasing collaboration between a wide range of businesses, NGOs, donors, and policymakers. There is likely to be consolidation and/or alignment of initiatives in this area.
- **Supply chain partnerships** With increasing global competition and a desire to secure supplies of quality raw materials, food and drink supply chains will continue to become increasingly about partners working and long term planning. With this there will be an increase need to select partners carefully and use best practice in managing these relationships.
- **Courtauld 2025** The new agreement builds on successes of the past decade to help consumers further reduce avoidable food waste and businesses realise efficiency savings along supply chains. The new agreement will help businesses report collectively and credibly on progress in reducing whole-life impacts outside their operational boundaries.
- **Structured funding** There is continued growth in research funders encouraging interdisciplinary collaborations to tackle complex problems; for example, Innovate UK and the Agri-tech Strategy.

"In our experience, successful Consumer Packaged Goods collaborations that involve two or three separate initiatives in a category deliver a return that's equivalent to a profit uplift of 5 percent to 11 percent in the affected category, through a combination of increased sales and reduced costs."

"Six steps to successful supply chain collaboration," McKinsey & Company



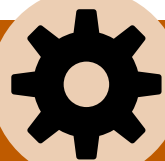
Risks

Poorly scoped and delivered collaborations put the credibility of participants at risk and exposures business to regulatory fines.

- **Credibility** With the growth in collaborations, participants might become far more selective about those they engage in. Demonstrating that genuine outcomes are delivered and that there is a clear business case would become more important. Increased scrutiny by NGOs and consumers would mean collaborations will need to demonstrate this to external stakeholders.
- **Collusion** As collaborations begin to tackle fundamental societal problems and have much stronger links to strategic issues, the risk of straying into anti-competitive areas would need to be mitigated more than ever.

Creating business value from partnerships

Encourage better land and building asset use



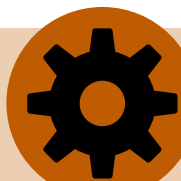
Partners Various including Blake Morgan, National Trust, and the Soil Association.

Context Land prices are a major barrier to entry into land-based enterprises. At the same time many agricultural assets are underutilised.

Aim of collaboration Help landowners identify and parcel out land and buildings on which 'land entrepreneurs' can establish new, independent businesses. This will also deliver a diversified landscape and community benefits.

How it worked Purposefully brought together both sides (representatives of land owners and tenants) to find the common ground, and develop a straightforward process.

Value chain waste reduction



Partners Greencore (own-brand food manufacturer), Sainsbury's (their customer), as well as packaging, fresh produce, and meat ingredient suppliers. Convened by WRAP.

Context Food waste is high on industry and stakeholder agendas and offers opportunities to reduce costs.

Aim of collaboration To reduce food and packaging waste during the production and distribution of sandwiches.

How it worked 1,700 tonnes of waste reduction now being targeted through 17 projects; improving supply chain relationships; and increasing knowledge and environmental awareness of staff.



Raw material security



Partners Muntons, a malt and malted ingredient company, partnered with Dewing Grain, a grain merchant.

Context Winter malting barley sowings have been in sharp decline in recent years and this represents a worrying trend to the malting industry.

Aim of collaboration Secure long term supply of quality winter barley and farm sustainability data which can be shared with downstream customers.

How it works Three year added value contract developed for barley growers in return for undertaking and sharing analysis of crop production carbon footprint.



Achieve cross-sector packaging reductions



Partners Brands, retailers, and manufacturers formed the Seasonal Confectionery Working Group (SCWG), facilitated by WRAP.

Context The Easter egg topped a consumer poll on too much packaging. However packaging was seen as important element of brand value or 'gift-worthiness'.

Aim of collaboration Identify and act on opportunities to optimise packaging.

How it worked Through the work of the SCWG Easter egg packaging was cut by 25% and, in some cases, by as much as 50%. The SCWG members have continued to make changes around chocolate eggs, as well as other areas, such as Christmas selection packs. Members successfully overcame concerns over Competition Law.



Improving beef production efficiency through better data sharing



Partners Researchers, government, farmers and processing industry in Northern Ireland.

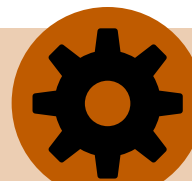
Context Carcase grading data is useful for a wide range of industry actors but was not collected digitally or in a shareable format.

Aim of collaboration Create and promote the use of an online tool for sharing and benchmarking carcase quality data. The ultimate aim to improve beef production efficiency and long term breeding.

How it worked BovIS system developed and successfully rolled out. All farmers surveyed say that the system is useful or very useful for informing management and breeding decisions. Sector using data to identify breeding strategies and identify trends.



Cool Farm Tool

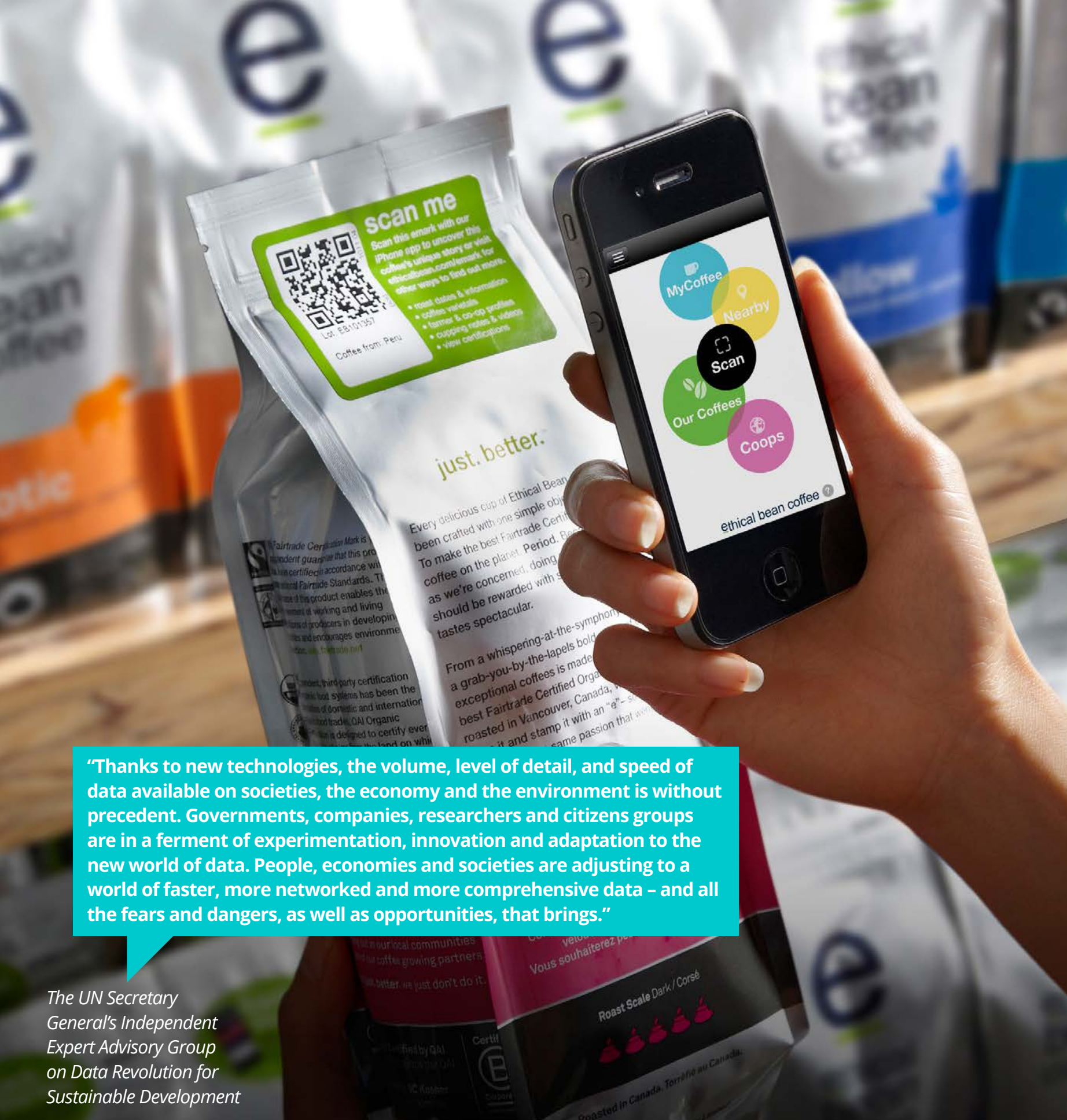


Partners 22 members spanning food business, researchers, standards setters, and NGOs. UK-based members include Tesco, Marks & Spencer, and University of Aberdeen.

Context Agricultural sustainability has been identified as a priority issue for food and drink companies. Understanding and addressing issues such as greenhouse gas emissions, biodiversity impacts, and water stewardship is technically challenging.

Aim of collaboration By working together the group can share the costs of developing a standardised, scientifically robust, credible, and farmer-friendly approach to measuring changes in key farm sustainability indicators. The group can also share experiences of addressing these issues in a pre-competitive space and use their combined influence to access new sources of funding.

How it works Companies contribute a membership fee and in return can use the tool to support their sustainability work with farmers and growers. For example, PepsiCo have used the tool to quantify a 34% reduction in potato crop related greenhouse gas emissions.



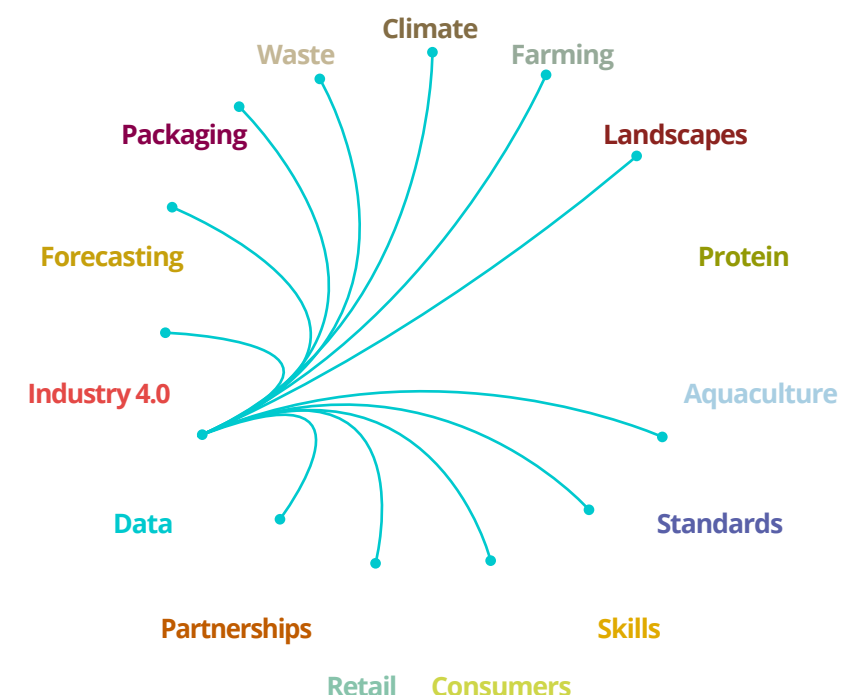
Food chain data revolution

The 'data revolution' is affecting every aspect of the food system, from the farmer that can access real time weather and market information to households being able to find, research and share their opinions and preferences on the origin of their food and the places they dine.

Data has the potential to fundamentally change the way the food system operates by enabling informed decision making throughout the value chain. However to equitably realise the potential of this opportunity for the entire sector, new relationships, standards and technologies will be needed. Without engagement in these areas the promise of the revolution may be stifled by a lack of interoperability between systems supporting communication up and down the supply chain.

"Thanks to new technologies, the volume, level of detail, and speed of data available on societies, the economy and the environment is without precedent. Governments, companies, researchers and citizens groups are in a ferment of experimentation, innovation and adaptation to the new world of data. People, economies and societies are adjusting to a world of faster, more networked and more comprehensive data – and all the fears and dangers, as well as opportunities, that brings."

The UN Secretary General's Independent Expert Advisory Group on Data Revolution for Sustainable Development

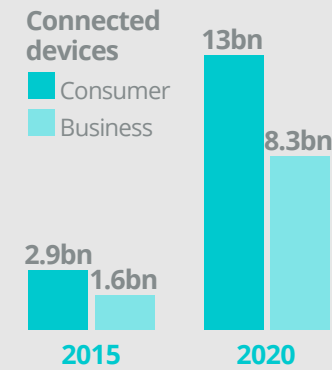


The vision of data-based decision making

Unlocking information to support the food system revolution has been promoted as being the biggest opportunity to face agriculture since the Green Revolution. However, it's not just on farm that data can create a more efficient and productive system.

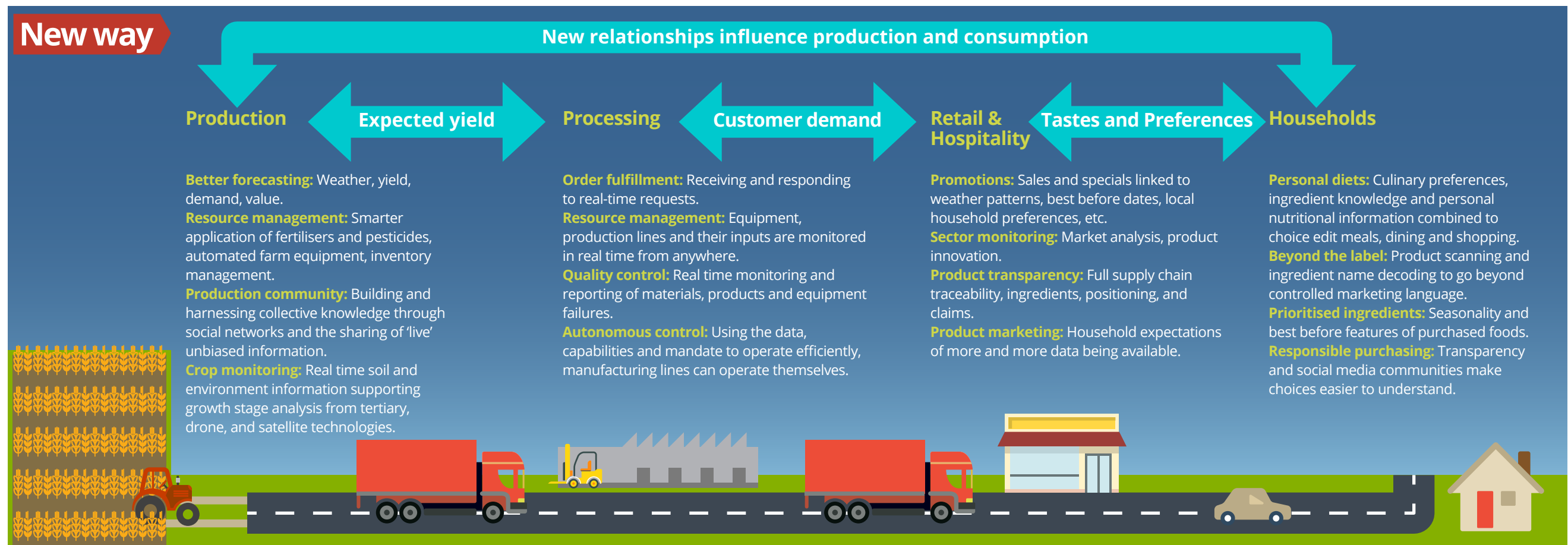
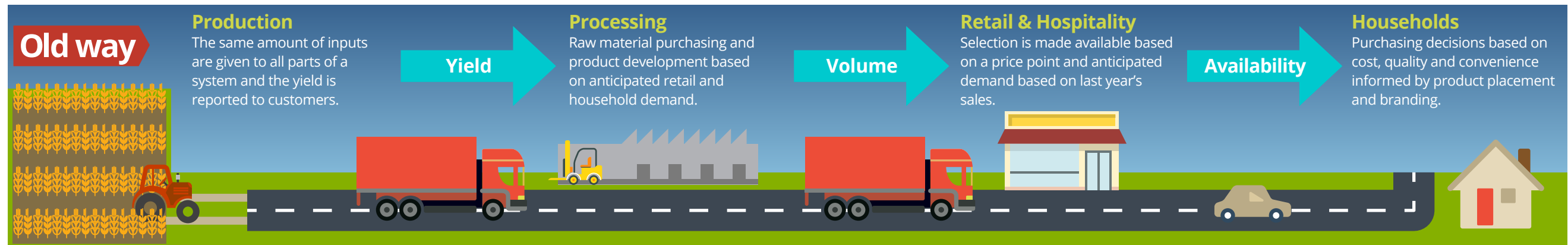
Data-enabled technologies come of age

Exponential growth in the number of data-enabled technologies used by society will enable the collection, sharing and use of data throughout the food system.



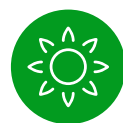
What is 'big data'?

There remains no universally accepted definition for what big data refers to, but it is typically characterised by information that is of such a high volume, velocity and variety to require specific technologies or analytical methods in order to gain value from its storage.



Better for everyone or better for business?

The trajectory for the food chain data revolution: Risks and opportunities on the pathway to 2025



Opportunities

Global data commons that is provided in a universal format for widespread use.

- **Supply chain transparency** Disclosing data throughout the supply chain would improve brand trust and loyalty whilst significantly reducing the risk of food fraud.
- **Global standard** There is no single system in place that has support from all parts of the food system from farm to fork. A new standard developed concerning the legal, technical, privacy, and statistical standards would promote the sharing of data as a global resource.
- **Healthy and sustainable diets** Information could influence consumption patterns, as households rapidly adopt tools enabling them to understand their food choices in terms of both nutritional value and sustainable production.
- **Equal access to data** Open access to technologies (e.g. satellite imagery) supports all supply chain actors to collect, store, access, and share their data in a meaningful way.
- **Waste reduction** Improved forecasting and monitoring can allow better use of resources and reduce waste.



Current trajectory

Product and supply chain transparency is becoming the new normal for businesses.

- **Clear labels** Product labels describing the origins and contents of food stuffs will be written clearly on product labels, apps, and websites to help households understand the relevant attributes of the food they are buying.
- **Increased focus on food fraud** The increased risk of food fraud in increasingly complex supply chains will contribute to higher expectations and controls on traceability.
- **Training** A major focus for businesses will be ensuring staff and their customers are able to access, utilise, and understand the tools and data they have access to and appreciate how data can support their roles.
- **Intuitive household apps** Mobile applications aiming to simplify open data for households are likely to be mainly from a health perspective but could also link to sustainability, depending on demand.
- **Agriculture apps lead the way** Producers are likely to make the greatest use of mobile technology and open data enabling them to have access to necessary information.
- **Asia-Pacific agricultural growth** Applied data technologies in agriculture will grow most quickly in this market as farming systems rapidly modernise.

"A full 90% of all the data in the world has been generated over the last two years."

SINTEF



Risks

A surge in data protectionist activity amongst government and private bodies could widen the gap between the haves and the have nots.

- **Privacy** Concerns throughout the system, from confidential business information to households, could result in regulatory changes restricting the use of certain technologies.
- **Cyber attacks** Cloud-based data storage or datasets may be unavailable, corrupted, or destroyed if not adequately protected.
- **Private datasets** Closed systems may produce unfair advantages for certain companies, sectors, countries, or regions that restrict the use of data and profit from the generation of that data from third parties.
- **Small farmers could be disadvantaged** Technologies, such as sensors, and software may present new capital and skill requirements that are beyond the reach of small enterprises.

Realising the potential of free and open data

Harnessing the information and knowledge we have of the world and how seemingly distinct variables influence our food system is leading to significant funding for organisations that can unlock this potential.

Three particular areas are the focus of the innovative organisations and businesses seeking to capitalise on big data: making data available, improving accessibility to support new research, and being understandable for those making decisions from the citizen to the CEO. Initiatives to find or provide solutions to these issues are working across the value chain, from producers to households.

New skills will be needed to work with newly available data. See Skills for future food challenges for more details.



Key Issue:
Data Availability

Making existing statistics and data available to the public or third parties to create new value.

Why Public and private organisations have traditionally collected and analysed information for their own purposes. By opening up data to the public new applications and knowledge can be gained to further food system efficiencies and innovation.

Trends It is increasingly common to support Open Data frameworks and many governmental bodies are seeking to capitalise or stimulate new innovations through these initiatives.

Barriers Privacy concerns (e.g. personal health records) and who pays for digitisation are the principal issues.



Key Issue:
Data Accessibility

Providing data in a format that can be used by everyone in a way that does not require access to proprietary systems.

Why Datasets are typically stored in 'in house' systems where unique software is needed to access or interpret the information.

Trends New global standards are starting to be developed, such as [GS1](#), however governments have taken the position that any change must be stimulated, and resolved, by industry.

Barriers Global data standards take a long time to develop and often are marred by red herring issues that delay their adoption leading to many companies moving ahead with their own supply chain standards.



Key Issue:
Understanding of Data

Novel analytical tools that simplify large volumes of data to make it accessible to relevant decision makers.

Why Data is varied and increasingly unstructured making analysis and interpretation of information difficult. New ways of engaging and illustrating cross cutting relationships are needed as demand for data-based decisions increases.

Trends Business tools are moving away from being both data collection and analysis tools. Instead a new breed of tools are developing that allow for multiple datasets to be combined to visualise data across a range of metrics. Household applications are becoming more user friendly, reducing the technical knowledge needed for use.

Barriers Requires good quality data in the right format in order to be meaningful.

Innovation: Blue Number Initiative

A collaboration between the International Trade Center, GS1, and the UN Global Compact to produce a global register of farms and growers.

Aim Improve product traceability from farm to fork using a single communication and technology standard.

How it works A unique ID is provided for all farms. Producers can voluntarily report on their compliance with Good Agricultural Practices (GAP) and any associated sustainability certifications they had.

Funders Private and public sectors
Outlook Platform development and pilot across organisations and countries to reach one million farmers by 2019.

Issues Addressed



Innovation: Centre for Agricultural Informatics and Metrics for Sustainability (AIMS)

Consolidated internet portal to all publicly available and pre-competitive industry data relevant to the whole food system.

Aim Maximise the availability and sharing of data among stakeholders in the food system.

How it works Global data repository with basic analytical and data visualisation capabilities to support high level sophisticated analyses.

Funders UK Government.
Outlook £12 million has been allocated to the development of the AIMS Centre and the promised platform.

Issues Addressed



Innovation: Global Open Data for Agriculture and Nutrition (GODAN)

Network and support organisation to aid the liberation of data.

Aim Agricultural and nutritional data should be available, accessible and usable for unrestricted use.

How it works Provides policy and institutional support to policymakers and organisations.

Funders UK (DFID), US, the Netherlands Government, the Open Data Institute, FAO, CTA, Centre for Agriculture and Biosciences International, CGIAR and Global Forum on Agricultural Research.
Outlook Focus on building partnerships, projects and infrastructure to illustrate how open data can support agriculture and nutrition.

Issues Addressed



Innovation: Good Guide

Household friendly mobile application consolidating scientific and publicly available information about products.

Aim An intuitive mobile and web application for households to make informed choices about the products they purchase.

How it works Provides product reviews and scientific ratings for over 250,000 products in food, personal care, household and child-rearing areas.

Funders UL Information & Insights (private).
Outlook Public engagement and promotion of resource to drive further industry disclosure.

Issues Addressed





"The constant pressure on costs in the food industry means it has a long history of innovating, so is likely to embrace Industry 4.0 quickly and enthusiastically... the need for traceability right through the production chain has already ensured that machines are interconnected and archiving data. Industry 4.0 should enhance this."

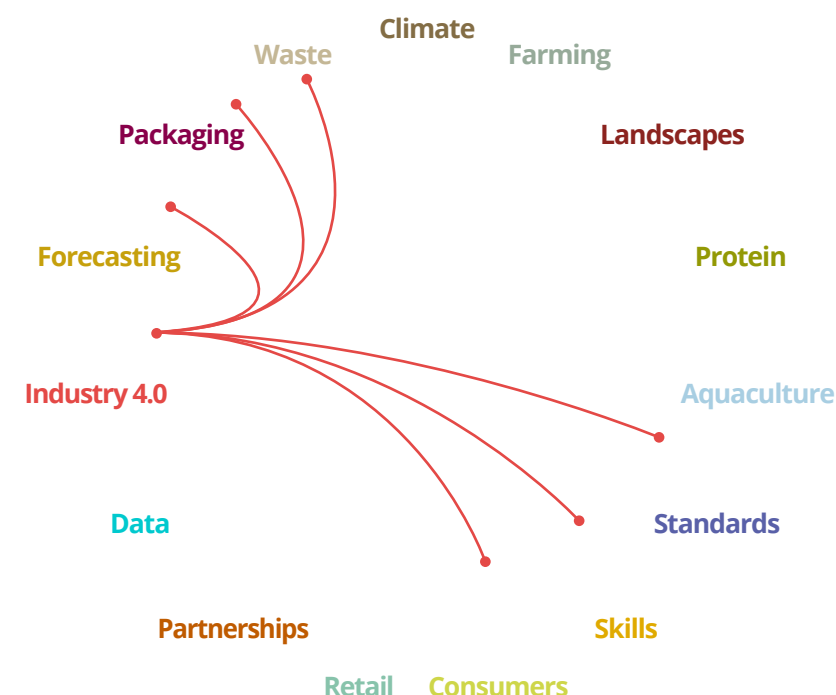
Jeremy Shinton, Mitsubishi Electric



Industry 4.0 in the food system

The rise of digital industrial technology is heralding in the fourth industrial revolution. Since the term was coined in Germany in 2011 to describe the revolution taking place to enable autonomous factories there has been rapid progress to develop and deploy these new technologies across the industry.

Despite a slow start for the food sector adopting the technologies that drive Industry 4.0, there are signs that a rapid expansion is underway as food businesses recognise the revenue opportunities for new products and services that can be delivered. However to deliver this potential the sector will need to ensure the labour force transitions its skill set to match the requirements of these new facilities.



The smart (empty) factory

Factories of the future have the opportunity to increase manufacturing profitability and reduce food waste through intelligent equipment that can talk, and respond, to the real world conditions they operate in.

Internet of services

Automated communication and control of requests based on specified conditions such as:

- Customer requests and forecasting
- Parts and service requests

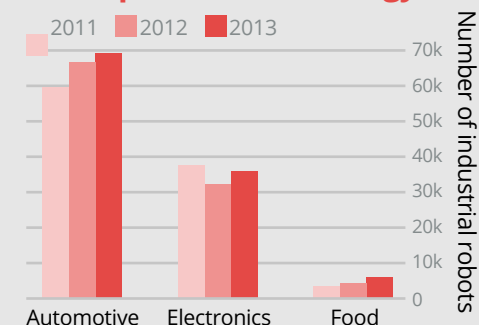
Internet of things

Connected devices influencing and responding to each other such as:

- Equipment control
- Cleaning and sanitation
- Order fulfilment

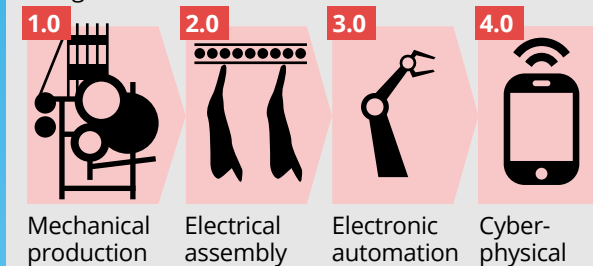
Renewable Energy

The food sector is beginning to adopt smart technology



Cyber-physical systems: the driver of Industry 4.0

Equipment collects, processes, responds to and sends commands to itself and other machines without any human engagement. In effect, these merge the 'real' and the 'virtual' worlds.



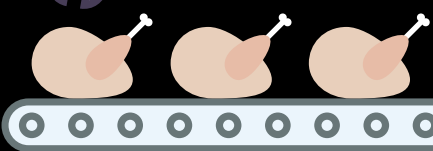
Delivery

Sensors

Material-specific intelligence and tracking eg [KiMs](#)

Prioritised sorting

Recognising and using materials based on their quality and freshness eg [Dairymaster](#)



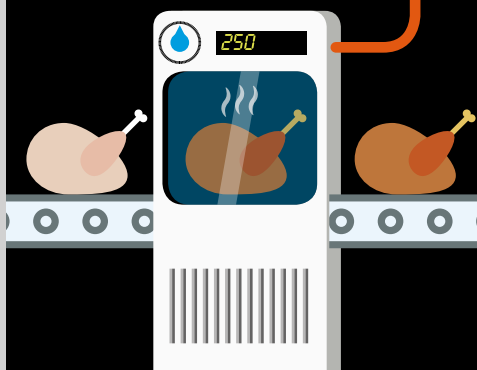
Stock control

Ordering, receiving and tracing inputs eg [Mydibel](#)

Cooking

Precision cooking

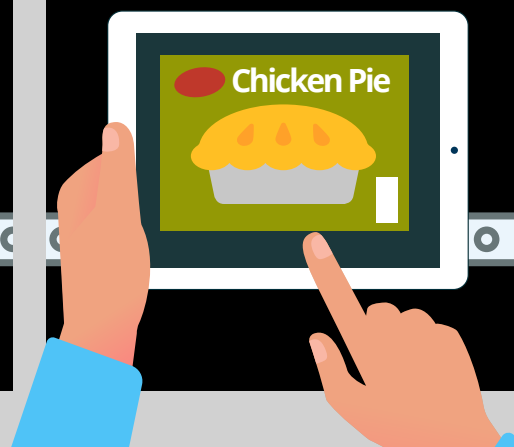
Cooking with the right ingredients, at the right time, using good energy. New technologies will present new opportunities for personalisation eg [Hershey's](#)



Packing

Custom orders

Meals and products are made on demand linked to customer requests and intelligent batch prioritisation eg [Starbucks](#)



Storage



Bespoke labels

Clear, stylised and traceable product labels and packaging eg [Diageo](#)

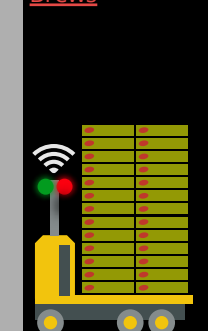
Temperature control

Self regulation of environment based on product needs eg [Winmate](#)



Picking and packing

Auto-robotics driven handling eg [Constellation Brews](#)



Route optimisation

Ordering, receiving and tracing inputs eg [Papa Johns](#)



Increasing profitability through added value products and efficiency

Safe and hygienic

Automated testing, sorting, monitoring and handling of food products and equipment to ensure minimum standards are always met.

Automated

End-to-end processes are implemented and decisions are made based on data generated by the equipment on itself and shared with other equipment and processes.

Minimal maintenance

Equipment can self diagnose, correct, and order replacement parts from manufacturers when faults are likely.

Efficient

Energy use is optimised to production demands and responds to and automatically plans for peak supply times.

Zero Waste

Food and material waste minimised through smart ordering, prioritisation, storage and disposal.

Personalised

Products, packaging and distribution channels are all tailored to customer requirements.



Manufacturing better value

The trajectory for Industry 4.0 in the food system: Risks and opportunities on the pathway to 2025



Opportunities

Integrated systems create an efficient production process leading to reduced food waste and significant improvements in energy and resource efficiency.

- **Just in time processing** Custom ordering, batch production and logistics networks would ensure that quality food is produced when and where it's desired.
- **High value personalised products** Complete customisation and ordering systems can create competitive differentiation and more valued products and services.
- **Zero waste factories** Inputs and processing are optimised to minimise losses whilst outputs are automatically connected to new markets.
- **Creative workforce** Reduction in manual labour requirements would open up new opportunities to focus on innovation and value adding activities.
- **Data standard** A global standard provides for the mechanisms and protocols needed to ensure the end-to-end system functions to its full potential.

See dedicated topic on Food chain data revolution for full supply chain opportunities.



Current trajectory

Factories will adopt ad-hoc smart engineering and software as new capital equipment and facilities are needed.

- **High tech workforce** The image of a factory worker will change to highly skilled engineers managing factory equipment.
- **Infrastructure for automation** New factory designs and investments will be developed in collaboration with technology partners to model the entire factory processes in cyberspace before ground is broken.
- **IT investment** Factories will move away from spreadsheet and paper-based factory management as new computer systems are implemented capable of joining the internet of things.
- **Central control systems** As the benefits of automated production systems stimulate greater investment, a new demand for controls and centralised plant systems will be adopted to enhance the efficiency of the end-to-end process.
- **Rise of new entrants** New business models and areas of expertise will open the door to new entrants in the sector.

"The real benefits to businesses of Industry 4.0 are not cost reductions but new business models around product personalisation, choice and service innovation. We know customers are prepared to pay more for customised products and the internet of services opens the door to new revenue models by providing direct customer benefit – this is where the real opportunity lies."

Mike James, ATS International



Risks

Skills shortages in the workforce and security issues could threaten the viability of autonomous factories.

- **Skills gap** The promise of the fourth industrial revolution in the food sector may inevitably lead to different skills being required by businesses. The changing workforce requirements will need careful planning to avoid unintended consequences.
- **Communication breakdown** Factories may be entirely self sufficient in themselves, but if the inbound materials they receive are not able to integrate with them there is a potential for production shut downs.
- **Security** It might be necessary for systems to be able to share information, and allow control of factory equipment, outside of company walls. Lack of adequate security protocols may therefore leave manufacturing processes exposed to sabotage by external parties.
- **Master of nothing** Equipment manufacturers could develop products and ecosystems that are self contained and do not support interoperability with those created and serviced by other businesses.
- **Conflicting business models** Harmonisation of technology and engineering sector business models might fail to materialise which would stifle roll outs and lead to low adoption.

Differing approaches and applications

Industrie 4.0 (Germany)

Leader in promoting and investing in the Industry 4.0 concept and application.

Policy Focus

- Providing applied research and development funding to facilitate the rapid deployment of Industry 4.0.
- Cement Germany's reputation as a global manufacturing engineering leader.
- Maintain manufacturing labour force through equipment manufacturing and service exports.

Key Activities

- Budgeting of €200m for applied research and development in:
 - Cyber-physical systems and their use in manufacturing and logistics.
 - IT systems architecture and standardisation.
 - Robotics.
 - Context-based resource use.

Challenges

- Global standardisation of systems architecture and IT communication standards.
- Infrastructure capabilities of companies and communities to support new technology (e.g. Broadband).
- Training and employee capabilities in firms to embrace cyber-physical systems.
- Dependent upon universal acceptance of approach to data standards and harmonisation.

Industrial Internet Consortium (US)

Not for profit industry-led consortium to promote the rapid deployment of 'industrial internet' technologies.

Policy Focus

- Development of common systems architecture (e.g. Communication standards, data extraction and storage).
- Industry harmonisation on approaches to data transfer and interoperability.

Key Activities

- Development of industry use cases and examples of real world application of technology.
- Reference architecture and frameworks for interoperability.
- Contribute to global standards development.
- Foster collaboration amongst members.
- Enhance confidence in data security approaches.

Challenges

- US-based initiative that will need to cooperate with, and support, global governmental bodies with differing goals.
- 'Top-down' approach to standards development is at odds with Germany's view that Industry 4.0 can only be successful with 'bottom-up' approaches.
- Not every manufacturer may agree with approach and separate efforts may be developed by competitor businesses.
- Potential conflicts of interest between software companies and company users.

Action Plan for strengthening UK manufacturing and supply chains

Food and drink sector is the largest employer of manufacturing jobs in the UK and is considered well placed to benefit from Industry 4.0.

Policy Focus

- Preparing industry through trials and toolkits.
- Engagement and education on business benefits.
- Research and development of new technologies.
- Reshoring of high skilled jobs to grow manufacturing sector.

Key Activities

- HVM Catapult Reach programme to develop small scale pilots and toolkits demonstrating the effectiveness and opportunities of smart technologies on factory floors.
- Use of Horizon 2020 programmes to deliver a demonstrator facility to engage UK businesses on the products and services available to them.
- Working with the British Standards Institution to identify where and how standards can help facilitate change.
- Direct funding and support through Innovate UK to small and medium sized enterprises.

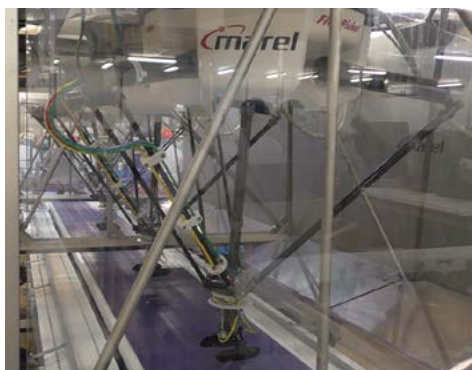
Challenges

- Industry 4.0 technologies could impact on employment levels within the sector.
- Speed of transition is behind other nations.
- Businesses will need to work with universities and training providers to upskill and transform the labour-force.

Industry 4.0 in Practice: Cargill

First robotics plant in UK food sector opened in 2015.

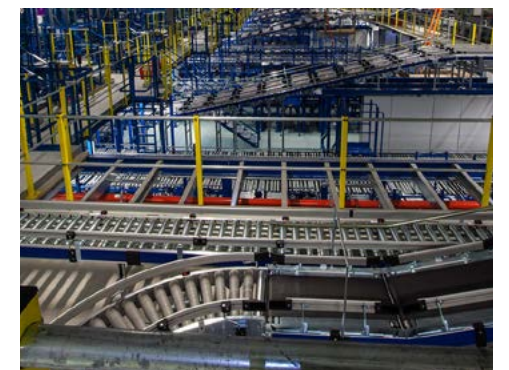
In June 2015 Cargill became the first UK processor to open an automated cutting and deboning factory to replace manual knife work by workers. The new technology will enable the facility to process 10,000 birds per hour and incorporates a number of technologies to enable the smart line management of production line machinery.



Industry 4.0 in Practice: Ocado

Automated order fulfillment.

Ocado operates the only state of the art automated distribution centres in the UK grocery sector. Its systems enable more than 1.4 million items a day to be picked, bagged, and sent to customers with minimal human handling. Routes for product collection and delivery van distribution are all designed and communicated through its IT systems.



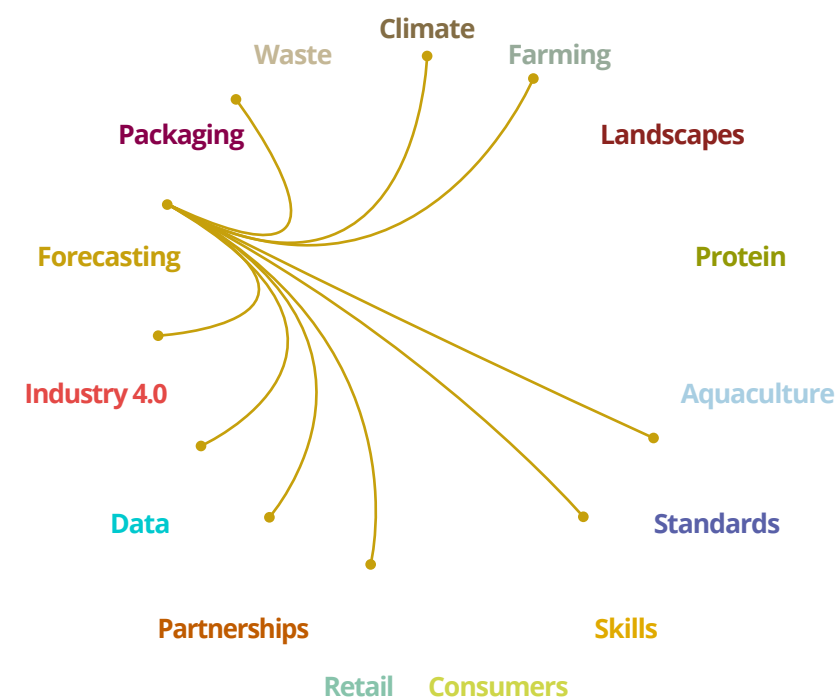
“Product forecasting still proves highly problematic for retailers and this ‘inaccurate science’ is further complicated by the seasonality of goods, weather patterns, consumer trends and calendar events, from designated holidays to sporting fixtures and national events.”

Global Food Security



Intelligent supply and demand

Perishable goods are in high demand and have lower storage potential, resulting in large quantities being wasted. While some of this waste is due to poor storage and management, a significant proportion of waste results from businesses developing their own forecasting models without sharing their assumptions up and down the supply chain. Increasingly, harnessing ‘big data’ can be combined with new platforms that enable more accurate demand models for decision-making; these methods are proving that significant cost and food waste savings are possible. To realise the full benefits of these new platforms, a collaborative culture needs to be forged with suppliers and customers to create a system-level solution.



Collaborating for efficiency

There are a myriad of reasons why businesses struggle to work together to supply the right amount of food at the right time. Finding a solution therefore requires greater collaboration and data sharing throughout the supply chain.



Up to 1/3
of UK retailers and suppliers
do not use weather data in
supply planning

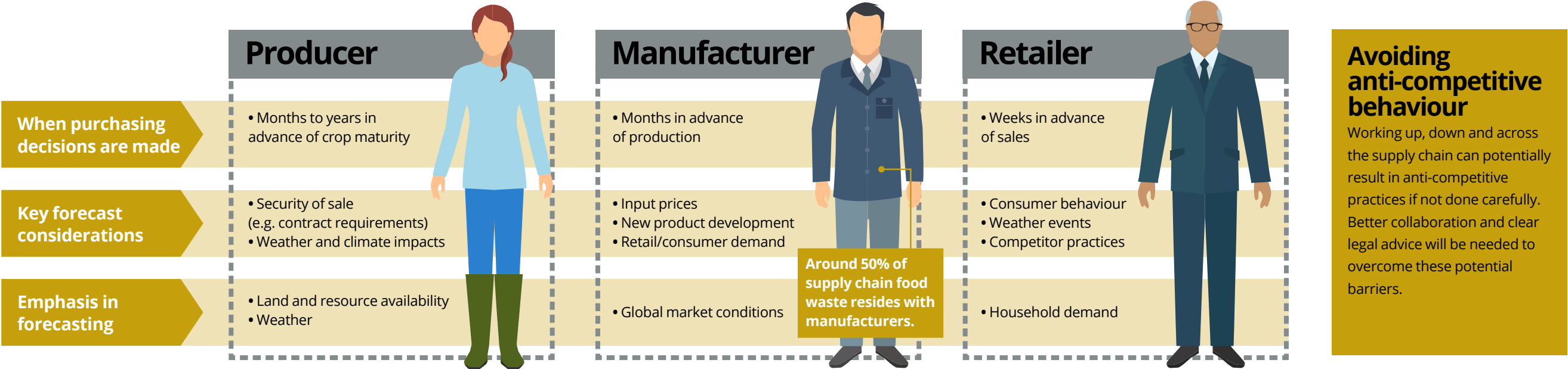


> £6.5 bn
Cost of waste to UK food
manufacturers and grocery
and hospitality retailers



8m
tonnes
food waste

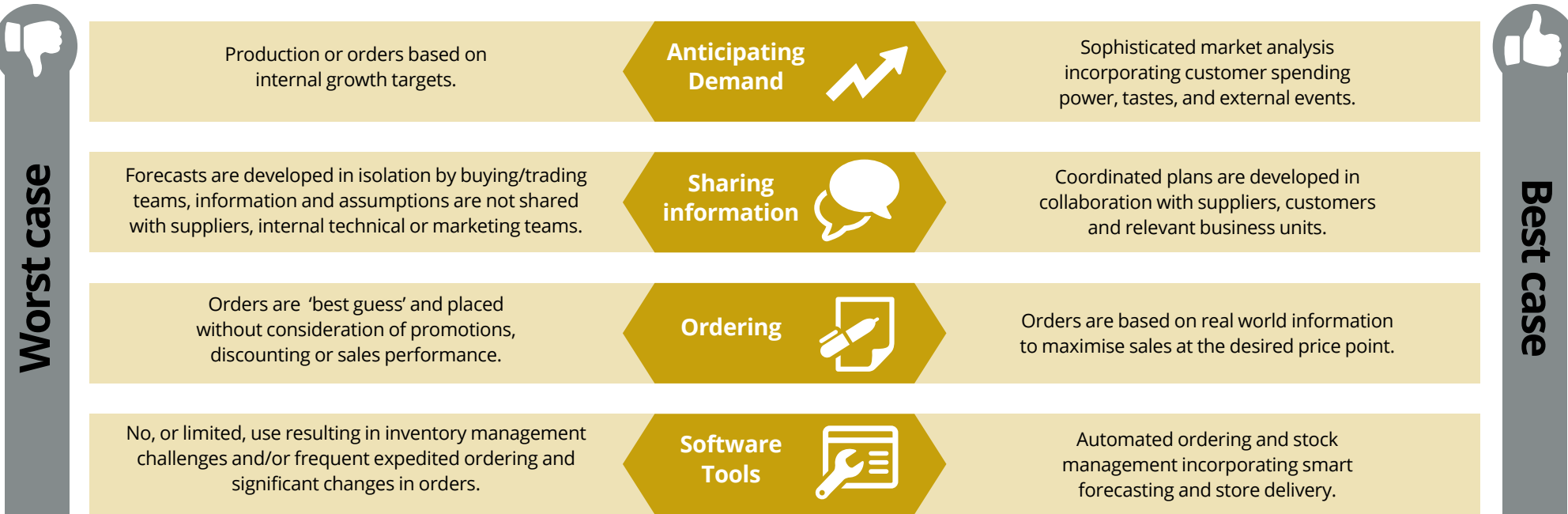
Challenges aligning demand forecasting from farm to store



Balancing lean practices with risk

It is impossible to predict each and every factor that will contribute to consumer demand in the same timescales throughout a supply chain. Production systems will always have a significant delay between when they make growing decisions and the sale of the grown output. Implementing a more intelligent system through the sharing of assumptions and forecasts can play a crucial role in minimising significant volumes of unnecessary waste, however if companies become too focused on the models they could find themselves exposed to high prices or additional waste when unexpected events occur, such as changing market conditions, weather events, strategy reviews.

Collaborating up, down and across the supply chain



The evolution of supply chain collaboration

The trajectory for intelligent supply & demand: Risks and opportunities on the pathway to 2025



Opportunities

Farm to retail collaboration leads to overall waste reduction and cost savings for all.

- **Efficient production** Short production runs could become a thing of the past if manufacturers can plan in advance for orders and find optimal distribution loads and routes.
- **Perpetual stock** Product shortfalls may no longer be an issue if stock is ordered and supplied in line with expected demand based on real world conditions (e.g. weather spells, sporting events).
- **Customer loyalty** This could result from company reputation, linked to product availability and dependency, leading to a better performance rating for supply contracts or household purchases.
- **Producer engagement** Better visibility of supply requirements from retailers and hospitality at the farm level could provide advance warning of crop and varietal requirements.



Current trajectory

The gap between those businesses that have advanced forecasting systems and those that do not will close.

- **Sophisticated models** New algorithms incorporating ever widening datasets will enable buyers to make informed decisions using real time sales statistics combined with wider market data.
- **Cost savings** Reduced excess inventory and stocking of products at the points in time they are desired by customers maximises profits and reduces product discounting and food waste.
- **Risk mitigation** Incorporation of external factors into ordering systems to allow for real time adjustments based on expected or unexpected events (e.g. regulations, food safety recall chilling effects).
- **Internal forecast sharing** Businesses will continue to build relationships and data harmonisation between procurement and sales teams to improve overall company forecast accuracy.

"The easy availability of high-powered software...makes it possible for companies of all sizes to predict, model and shape demand in a more accurate, detailed and timely fashion than was feasible for even the largest, wealthiest corporations a few years ago."

Foodlogistics.com



RISKS

Focus remains on retail and manufacturer models reducing benefits to producers.

- **Technical solution dependence** If supplier relationships or internal information silos are not addressed the risk could remain that information is not acted upon or understood by all affected parties.
- **Inaccurate forecasts** A single significant event that results in stock not being available due to a data processing or communication error could undermine faith and trust in automated systems.
- **Shifting burdens** Enhancing inventory management and forecasting capabilities in manufacturing and retail partnerships could lead to greater short term waste burdens at the producer level. Alternatively, unaligned forecasting systems used by manufacturers and retailers could result in excess risk and waste for manufacturers.
- **Long term contracts** If flexibility is not built into multi-season supply contracts, the forecasting models that are used to predict demand may be out-dated by the time production actually takes place leading to further overproduction or promotion activities to move stock.

Delivering smarter supply chains

The functionality that drives intelligent systems

Improving forecast capability involves a number of business changes, from attitudes related to data sharing internally and externally to putting the processes in place to drive permanent change. Besides these company-specific challenges, it is essential that companies move away from isolated data management and towards software solutions that are able to address the multitude of variables that can deliver more accurate forecasting. Below are some of the key functionalities present in the systems used by companies of all sizes that have successfully improved their performance.

	Why it is important	Functionality
 Weather information	Weather events directly affect production and consumption patterns.	- Integration with weather services. - Forecast algorithms.
 Holidays and events	Major events increase or decrease purchase of certain products.	Custom calendar functionality to modify day and hour supply.
 Promotion management	Increase or decrease in supply requirements.	Real-time ordering system interface.
 Top-down material price shocks	Assess company-level profitability risks.	Cross category aggregation and dashboards.
 Sales and supply team data exchange	Mutual understanding needed to maximise profitability.	- Intuitive user interface. - Interface with sales systems.
 Demographic trends	Directly affect household purchasing choices.	Market population/store catchment-level data integration.
 Menu cycles	Reduce food waste from over purchasing.	- Calendar functionality. - Fresh food date codes.
 Fresh product shelf life	Minimising transport and processing time for perishable goods to increase shelf-life.	Product life data.

Tesco

Tesco is the one of the world's largest retailers, managing tens of thousands of products throughout its supply chain. From 2007 – 2013 Tesco's analytics team grew from five to fifty. Tasked with applying advanced modeling to supply chain problems they continually review data internally to predict demand. To create a more efficient supply chain, this could be extended to the provision of this information back to suppliers and ultimately producers.

Some examples of the team's work includes:

- Consumer demand predictions based on weather forecast and store location, credited with reducing excess stock, and reducing out of stock for 'good weather items' by a factor of four. So far the team has saved Tesco £6m/year.
- Simulated performance of distribution depots and fed in demand forecasts to show where stock could be optimised. Saved £50m through reduced stock levels.
- Built algorithms to calculate discounts for produce near the end of shelf life (previously done by store managers). Saved £30m of previously wasted stock.

Applied functionality


Weather information


Sales and supply team data exchange


Fresh product shelf life

JJ Food Service

JJ Food Service is an independent food wholesaler and distributor for the UK catering industry with a turnover of nearly £200 million. Its 60,000 customers are spread across quick service restaurants, traditional retailers and education establishments, and servicing the needs of its customers requires over 1 million sales orders and 55,000 purchase orders to be processed each year. Underpinning its growth has been a promise to respond to customers in real time if they are able to deliver a product at the specified date and location desired. In the past, the company found that its ability to deliver this promise was being challenged by a lack of centralised information on orders and purchases. After reviewing the systems and processes used by the business, they sought to implement a forecasting system that would increase data automation, improve forecasting and replenishment systems and enable them to manually intervene in special situations (e.g. holidays, events).

Key benefits:

- 15% reduction in on-hand inventory.
- 50% reduction in order processing time.
- Orders are automatically filled to optimise distribution (e.g. full pallets, lorries).
- Shelf life and category characteristics are considered for fresh items.

Applied functionality


Holidays and events


Promotion management


Menu cycles


Fresh product shelf life

"Food brand [and own brand] owners and packaging companies need to understand consumer acceptance of new technologies and if necessary develop communication strategies to support the product launch."

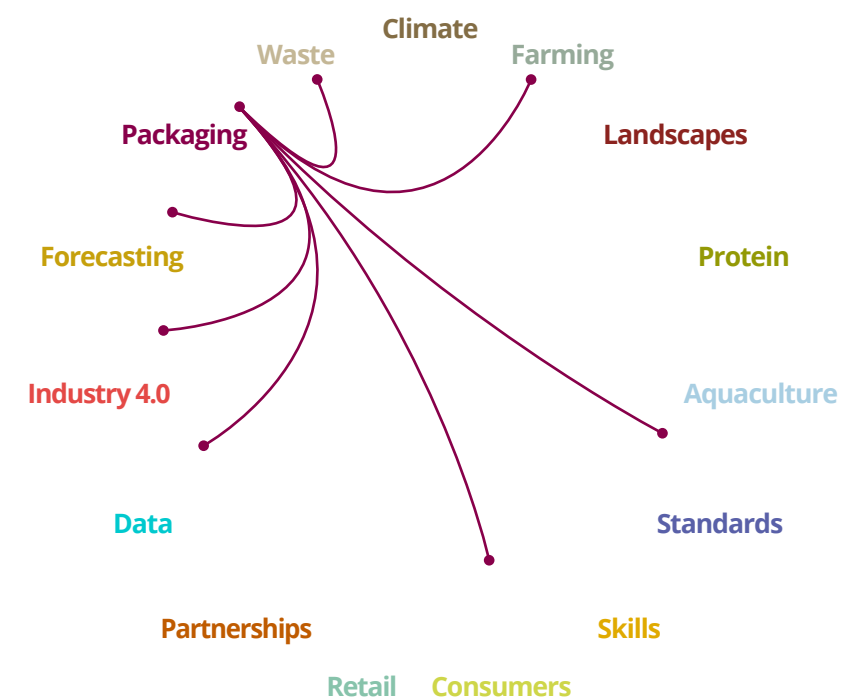
RMIT University



Active & intelligent packaging

Packaging has historically been viewed as a necessary cost for moving products through supply chains and engaging with households at the point of purchase. For more than twenty years it has been a subject of concern for governments and waste authorities as they have battled to reduce waste, but new forms of packaging have the potential to change this and address the 15 million tonnes of food and drink wasted in the UK each year.

For years we have been on the edge of a packaging revolution and we're now at the point where new innovations are becoming cost effective and value-adding.



Unpacking innovation

The global market for active and intelligent packaging, currently at USD \$13.75 billion, is expected to grow to reach USD \$21.41 billion by the end of 2019.

Recyclability is still king



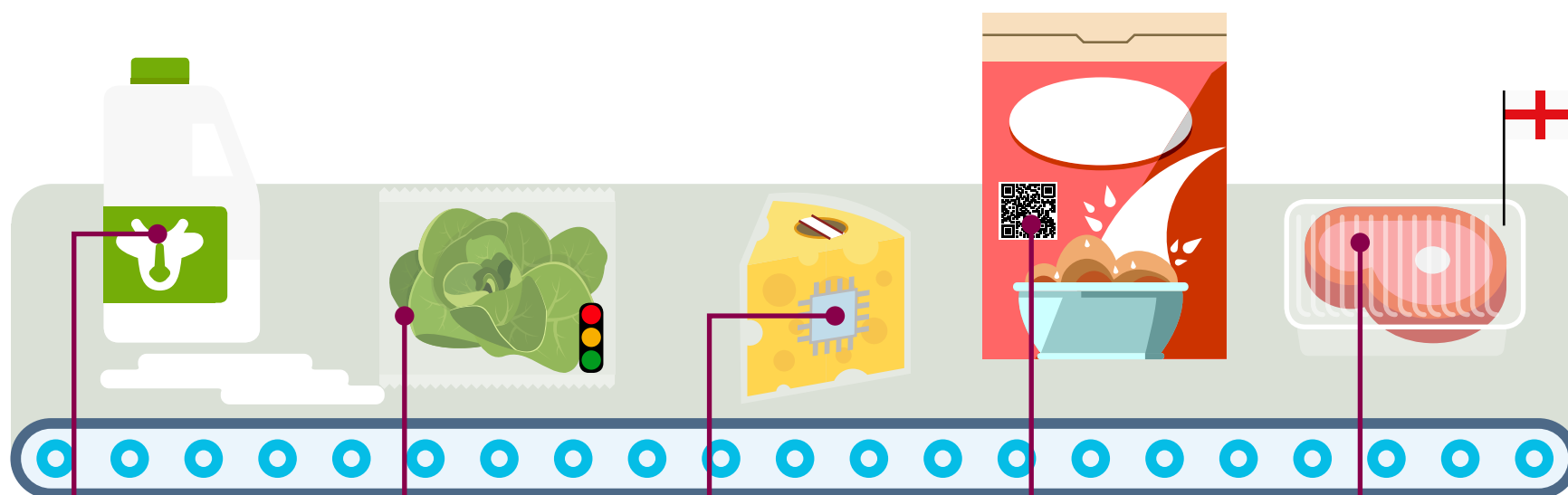
162kg
packaging
waste

65%
Recycled



In the UK in 2013, 162kg of packaging waste was created for every person, around 35% of which was not recycled. Manufacturers and retailers can help increase recycling rates further through design changes and communication combined with improved collection systems by waste management bodies.

35%
Not Recycled



Packaging diagnostics



What is it Packaging that is able to detect leaks or breaches.

Technology Smart sensor tags and labels that extend to the cap are able to transmit data on damage caused by seal-breakage; plastics that change colour on detecting the presence of oxygen within; use of nanotechnology materials.

Barrier Currently technology is primarily applied in bottles and packaging with caps, seals or lids.

Future Diagnostic technology could extend to include more types of packaging, extending its practical application to more products and its usefulness to households.

Freshness indicators



What is it Packaging that reacts to certain chemicals and atmospheric changes within the package, signaling the freshness of the food inside.

Technology Dye-based technologies that respond to bacterial decomposition; high viscosity media reserves; radio-frequency identification (RFID) sensors that detect ethanol.

Barrier Cost, trust, and concerns around liability are the primary obstacles. However, stock management practices will also need to evolve.

Future Effective technology could revolutionise "use-by" dates, reducing food waste in stores and the household.

Temperature monitoring



What is it Alerts or indicators if a temperature threshold has been exceeded on either end of a supply chain.

Technology Temperature sensing RFID tags, scanning thermometers, databars.

Barrier Price and accessibility; current technology for temperature monitoring along supply chain requires a data logger that is only read at destination. New printed electronics (with RFID tags) can be slow to produce.

Future Real-time data and remote monitoring across the supply chain requires a supportive system.

See the Food chain data revolution.

Product information



What is it Technology is used in the packaging, or on the food itself, to relay product information.

Technology A range, including integrated computer software, printed electronics, augmented reality, databars and RFID tags.

Barrier Minimal public understanding on how to use technology; recyclability of electronic components.

Future Consumer demand and food safety issues will continue to push the interest in greater understanding of where products have come from. Marketing teams will increasingly use technology to boost brand engagement in stores and at home.

Product traceability



What is it Used to identify, track and trace goods throughout the supply chain journey.

Technology RFID is used to automatically and wirelessly capture and transmit data; databars providing source of good tracking (e.g. Global Trade Item Numbers, or GTIN).

Barrier Standardisation of technology across the supply chain; data protection concerns.

Future RFID tags could become more widely adopted; M&S rolled these out to 100% of its chilled food ten years ago. New technology means that RFID can be electronically printed into tags, eliminating the need for separate RFID tags.



Active Ability to monitor, report on and respond to the environment it protects



Intelligent Adding value to supply chains through the storage of, transmission of or linking to information

Packing technology: a new love with an old issue

The trajectory for active and intelligent packaging: Risks and opportunities on the pathway to 2025



Opportunities

Societal perception may be shifted from packaging being a burden to one that enhances their food experiences.

- **Food waste reduction** Around half of avoidable UK household food waste (worth £5.6 billion in 2012) is due to food “not being used in time”. Wide adoption of technologies, such as freshness indicators and packaging diagnostics, could contribute to a reduction in food waste. For example, in the domestic kitchen environment, technologies such as smart fridges or freezers could inform on which foods are near their use-by date and need to be eaten first.
- **Packaging assets** Packaging with electronic components become valuable to businesses, and may increase incentives to develop more and better ways to recover and reuse it.
- **Smart meets sustainable** Packaging performance is optimised using materials and technologies that are responsibly sourced and recycled at their end of life.
- **End of the barcode** The rise of radio-frequency identification (RFID), databars and invisible watermarking technologies could eliminate barcodes. Not using individual line-of-sight product scanning could increase inventory accuracies and decrease transaction times. For example, water marking covers the whole pack, reducing the time needed to find the scannable area.
- **Extended life** Improvements in longer life packaging could open up new export market opportunities.

See Food chain data revolution for more information on how these technologies can be applied.



Current trajectory

Sales packaging will become an information gateway for businesses and consumers.

- **RFID adoption** This will become more ubiquitous, leading to greater traceability and information availability throughout the supply chain. Sales of RFID readers, tags and software to the retail sector are projected to grow from USD \$738 million in 2014 to USD \$5.409 billion by 2020.
- **Packaging demand** The growing shift in consumer retail behaviour and online shopping means that packaging at point of sale is less important: online grocery sales in the UK are expected to more than double by 2019. This gives manufacturers and retailers the ability to optimise packaging and new technologies in different ways without concern about its effect on sales.
- **Communication opportunity** Supply chain partners and consumers are increasingly apt and willing to scan products in-store to learn more about them. For example, 80% of smartphone owners want more mobile-optimised product information while they are shopping. This presents more opportunities for retailers to engage and promote goods.

“Partnerships will be essential for the future success of all kinds of active and intelligent packaging.”

*Dr. Kay Cooksey,
Clemson University*



Risks

Rapid adoption of new packaging technologies may lead to unintended environmental or policy consequences.

- **Certification delays** Food safety bodies react too slowly or do not know how to adequately determine the risks of new technologies (e.g. dye-based freshness indicators); adoption could therefore be delayed.
- **Household backlash** If the benefits of intelligent packaging are not communicated well; consumers might misunderstand and not welcome them.
- **Recoverability** If packaging continues to use scarce resources, such as data chips, that aren't recovered after household use, it could lead to greater material and commercial loss as they end up in landfills. There may, however, be the opportunity for simple removal of electronic components upon check-out or during recycling.
- **Unproven technologies** Intelligent packaging technologies could be commercialised without adequate testing resulting in failures and malfunctions which reduce household confidence and create reactionary market controls, eg. freshness indicators may not reduce waste.

What active & intelligent packaging means for...

The Producer

Managing input inventory and communicating with customers could become more resource, time and cost efficient.

Opportunities

- Less time spent responding to customer requests for information and data.
- Input inventory sourcing and quality management.
- Higher degrees of traceability showing where their crops and products are going.

Challenges

- Inconsistent technologies used by customers resulting in multiple systems.
- Greater visibility and prominence of second and third tier customers resulting in greater standards or demands.

The Manufacturer

Developing technology will lead to a reduction in energy use and waste while promoting more efficient transport and traceability along the supply chain.

Opportunities

- New and reusable packaging systems for transportation can reduce solid waste, material consumption, energy use, and greenhouse gas emissions.
- Transit packaging can be fitted with radio-frequency identification (RFID), or other scannable technology, to allow data capture throughout the supply chain journey.

Challenges

- Inconsistent infrastructure may limit use of new and reusable packaging at various stages of supply chain.
- Capital costs and differing regulations between countries and regions may be a barrier to introducing new technologies.
- Regulations may not be advanced enough to permit the use of new technologies in food packaging.

The Retailer

Greater understanding and control over food freshness and safety promises to minimise waste and cost.

Opportunities

- Ability to respond more quickly to food safety concerns.
- Better inventory management could lead to reduction in food waste.
- Replace use-by dates with potentially more accurate quality indicators.
- Ability to keep certain foods fresher longer.

Challenges

- Staff and customer training may be needed to take full advantage of new packaging technology.
- As new technology begins to appear on shelves, customers may demand faster rollouts.
- Food safety legislation changes may be needed to support alternative safety and quality indicators.

The Household

Increased information availability may aid decision making and help reduce food waste, thus saving money.

Opportunities

- Greater understanding of the product and its origin.
- Reduction in food waste may save money.
- Better brand and product engagement.
- Greater recyclability likely to be popular.

Challenges

- Without public engagement or education, consumers may not understand or trust new packaging technologies, thereby reducing their effect.
- New materials may confuse consumers, deterring them from recycling their end products.
- Household recycling schemes may lag behind developments in packaging innovations.

Case Study: Ethical Bean Coffee

What is it A Canada-based coffee supplier that sources fairtrade, organic coffee from countries around the world. They currently sell in North America, the Caribbean, and Japan.

Technology Quick Response (QR) codes can be read by smartphones or online through the Lot number, allowing consumers to track their coffee from the exact field it was grown in, see documentation for their organic and fairtrade certifications, and read farmer profiles. Additionally when a code is scanned, Ethical Bean Coffee receives location information, helping them target retailers and distribution.

Future Ethical Bean Coffee plans extensions of its traceability technology, allowing consumers to connect directly to the producers. The company is also working on a companion app for the producers, enabling them to link to those consuming their product.

The packaging is currently not recyclable and so is lacking a core aspect of sustainability, despite the technology not having a direct relationship to the materials. The company is working to address this issue; in the meantime, their coffee bag return programme accepts consumers' used foil-lined coffee bags and stores them until they have come up with a solution for recycling. The company offers an incentive for participation in the programme.

"[Our technology] comes with increased sales, we're still growing at 30% a year. You can buy through the app, and that has gone up. It's also what we think is the right thing to do, as ... a fair trade organic coffee company."

- Lloyd Bernhard, co-founder and chief executive



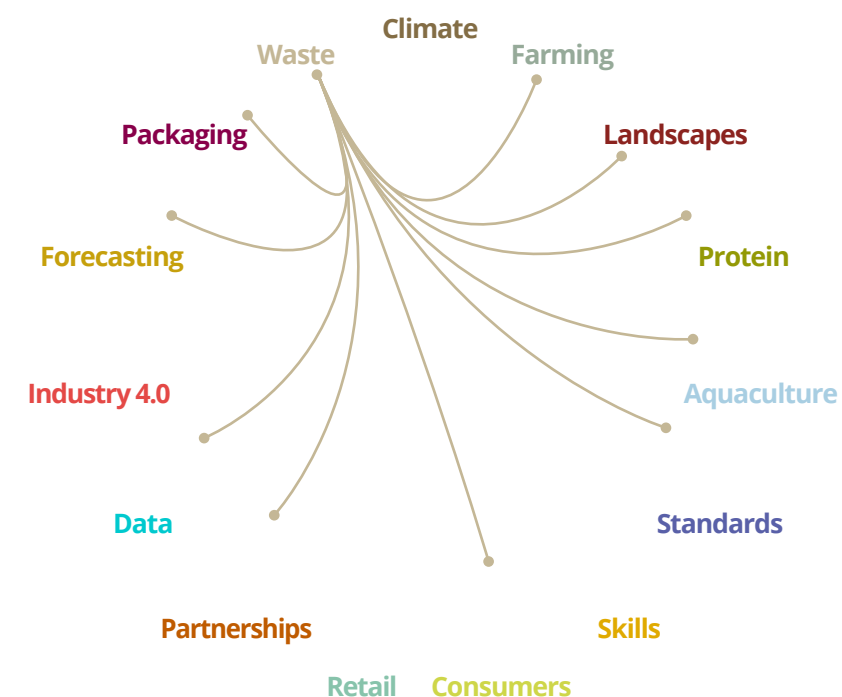


Unlocking new value from waste

In recent years many UK companies have made significant reductions in the volumes of waste that has been sent to landfill. Unavoidable waste is now commonly sent to anaerobic digestion, energy-from-waste solutions, or is used as animal feed. However there is significant potential to make better use of under utilised resources and create new products and value using biological and chemical biorefining techniques. So-called advanced 'valorisation' of waste will be critical to delivering a circular food and drink system in the next decade and will require the restructuring of current models of food and drink manufacturing processes.

"Food waste sources comprise a remarkable complexity as a consequence of their inherent diversity and variability but can provide an infinite number of possibilities and resources through designed and well thought out green technological valorisation strategies."

Rafael Luque and James H Clark,
leading green chemistry researchers



Unlocking the circular food economy

Waste valorisation opportunities exist across multiple sectors

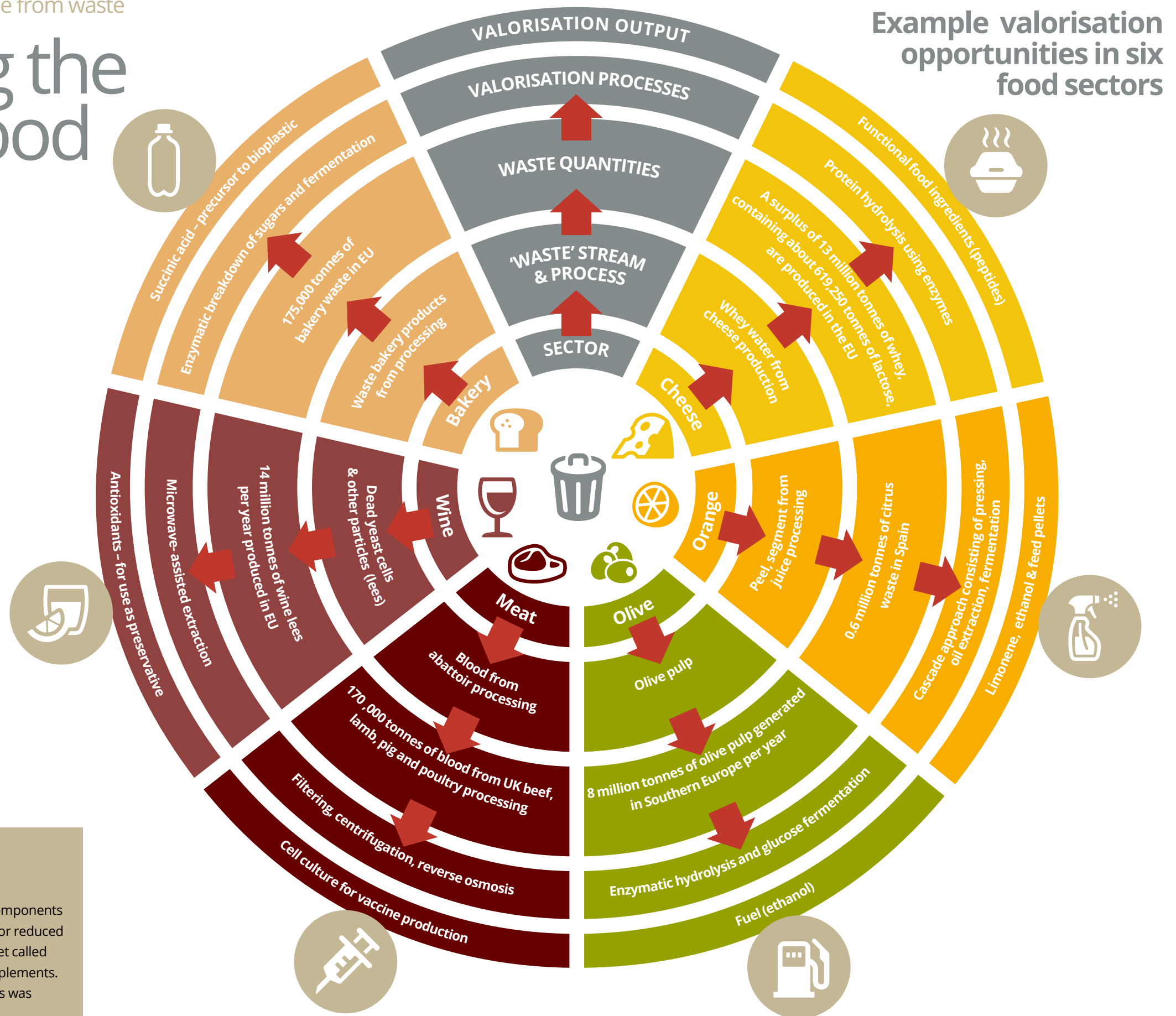
Waste valorisation is the process of converting waste materials into more useful products including chemicals, materials, and fuels. Advanced techniques enable the recovery of existing high-added value compounds within waste or the transformation of waste components to new products, such as proteins, sugars, vitamins, alcohols, fatty acids, etc. These can be used in food products, such as 'functional foods,' (see box below), or as the basis for pharmaceutical and biomaterial products, including packaging. The diagram, right, shows potential routes to new products from six key food groups ('food sectors') and represents a snapshot of what innovation in valorisation could achieve.

Benefits of valorisation

Beyond the creation of new products, waste valorisation has the potential to provide additional benefits to business and society including: reduced environmental impacts; reduced waste disposal costs; reduced dependence on non-renewable raw materials; and increased food security.

Functional foods and nutraceuticals

Functional foods contain biologically active components which offer the potential of enhanced health or reduced risk of disease. They are part of a larger market called 'nutraceuticals', that also includes dietary supplements. In 2013, the global market for functional foods was worth an estimated USD \$43bn.



Realising the wasted potential

The trajectory for unlocking new value from waste: Risks and opportunities on the pathway to 2025



Opportunities

New approaches to the commercialisation of waste valorisation underpin the delivery of a circular food economy in the UK.

- **Decision support tools** A suite of powerful and user-friendly analytical tools and processes could help businesses to identify opportunities for waste valorisation.
- **Data sharing** Increased uptake of valorisation would also be supported by real-time, spatially explicit, waste data sharing across new networks and between partners across multiple sectors and sites.
- **Industrial symbiosis** The use of more integrated approaches to whole supply chain resource management supports advanced valorisation strategies. These might see collaborations between two or more industrial facilities or companies in which the wastes or by-products of one would become the raw materials for another.
- **Transdisciplinary approaches** Maximum exploitation of the potential of food waste could be achieved through transdisciplinary approaches drawing upon disciplines as diverse as engineering and socio-economics.



Current trajectory

There remains limited commercialisation of advanced waste valorisation approaches due to unresolved challenges.

- **Limited market application** Without unlocking the 'Technology Readiness Level' pathway from basic academic research to market application, waste valorisation has the potential to remain a relatively niche activity.
- **Variability & traceability** Variable consistency, composition, and poor traceability of waste hinders valorisation opportunities.
- **Legal definitions** Legal definitions of waste, by-products and residues impact the potential for different waste management options.
- **Compliance costs** Regulatory compliance costs are too large for small businesses to innovate.

"The conversion of biomass waste to bulk chemicals was found to be nearly 7.5 and 3.5 times more profitable than the conversion to animal feed and transportation fuel, respectively."

Carol Lin, The City University of Hong Kong



Risks

UK food and drink sector does not fully exploit the potential of waste valorisation to create circular food economy.

- **Resource competition** If competition for renewable materials intensifies, it would raise challenging questions over the prioritisation of destinations (e.g. between energy generation, animal feed, industries, growth medium, or fertiliser).
- **Contamination** Health scares associated with by-product contamination would reduce consumer acceptability of techniques and further slow adoption.

Cross-sector valorisation partnerships

From prawns to PCBs

Shellfish waste derivatives have the potential to recover valuable metal resources from electronic industry effluents.

The UK seafood industry produces large amounts of crab and prawn shells, which can be expensive to dispose of. Chitin from these shells can be used as a bioabsorbent for recovering metals from effluent created during the manufacture of printed circuit boards (PCBs). The technique, which has been piloted by a cross-sector consortium, has the potential to also recover rare and endangered metals such as platinum, palladium and rhodium.



From stalks to skin serum

Chemical compounds extracted from red grape skins used to create exclusive cosmetics range.

Grapes are the world's largest fruit crop - more than 65 million metric tonnes of the fruit are produced a year, and this yields a significant quantity of waste skins, seeds, and stems. Marks & Spencer collaborated with a University of Leeds spin-off company called Keracol to develop a novel process for extracting resveratrol from these waste by-products. The molecule, which is found in the outer skins of red grapes, has been used in a range of cosmetic products because of its antioxidant and anti-aging properties.



From ketchup to cars

Rice husks and tomato plant by-products used to create bioplastics for use in production vehicles.

Researchers at Heinz are looking for innovative ways to create new commercial value from the peels, stems, and seeds of the two million tonnes of tomatoes they use annually. The company is exploring converting the waste to bioplastics for use in Ford Motor Company vehicles. Dried tomato skins could become the wiring brackets in a Ford vehicle or the storage bin a Ford customer uses to hold coins and other small objects. Ford are already using food sector by-products, such as rice hulls, as a replacement for talc-based reinforcement in a polypropylene composite.



Valorisation networks

UK and international networks bring together industry and researchers to identify valorisation opportunities.

Collaboration is critical for unlocking new value from food waste. FoodWasteNet (www.foodwastenet.org) aims to realise the potential of using food waste and by-products to produce renewable chemicals and biomaterials with added value and market potential. The network organises events and provides funding via Business Interaction Vouchers and Proof of Concept Funding. On the international stage, EUBis (www.costeubis.org) is a network of academics and industrial partners examining novel strategies for the valorisation of food waste. A key objective is to demonstrate the most promising valorisation processes at a larger scale.



Unlocking value from dairy sector wastes

Cheese whey wastewater (CWW) is a by-product that occurs during the precipitation and removal of milk casein during cheese manufacturing.

"The dairy industry is a great example of how a sector can produce multiple products from a waste stream that had represented a disposal cost."

Nina Sweet, WRAP



2.3 litres waste water are created per kg cheese produced.



It is estimated that a surplus of 13 million tonnes of whey are produced in the EU each year. Different valorisation options exist (see below), each with pros and cons. An opportunity exists to extend more advanced techniques to smaller producers.

Direct utilisation (Basic valorisation)

Fertiliser & animal feed

High salinity levels of CWW can affect soil structure when applied to land and costs of transport make economics challenging. Lactose levels must also be within a certain range for use as animal feed.

Transformation into energy

Hydrogen and biogas

Low alkalinity and low hydrogen yields makes energy production using fermentation and anaerobic digestion challenging at the moment.

Recovery

Whey proteins & lactose

There are a variety of applications for whey contents, from additives that extend shelf life of products to 'filler' for pharmaceutical products and biomaterials e.g. edible film.

Transformation into products (Advanced valorisation)

Peptides & glucose

The fermentation of lactose can produce high value products (e.g. volatile fatty acids) that could serve as a 'chemical platform' for other food and pharmaceutical products.

Responding to the key food system challenges and opportunities of the next decade

Creating supply chains FIT for the future while investing in data and health innovation

This report has identified and described 15 topics and three key trends that will influence the way that we produce, process and consume food and drink over the next decade. These topics, selected in collaboration with the project's Thought Leadership Group, cover a diversity of issues ranging from rapidly evolving production methods to external threats to production and potential levers for change. They also highlight some of the key risks and opportunities on the pathway to a more resilient, sustainable food system in 2025. The breadth of topics covered is an indication of just how much our understanding of the food system has progressed since the *Grocery Futures* report was published in 2006.¹ If the past decade has been one of discovering the nature and scale of the issues we face and beginning to respond to them, then the success of the next ten years will be judged on the choices we make in finding solutions to achieve sector transformation.

In undertaking the research three key cross-cutting trends emerged: increasing challenges to food system resilience; the explosion of data-enabled technology; and the alignment of the health and environmental sustainability agendas. These are explored in more detail in this section and have been used by WRAP and the research team to develop high-level recommendations.

Key trends



Increasing challenges to food system resilience



Explosion in data-enabled technology



Alignment of health & sustainability agendas

High-level recommendations

Create supply chains FIT for the future

Invest in food chain data capabilities

Promote innovation and consumer engagement on health & sustainability

Increasing challenges to food system resilience

External pressures and the nature of globalised supply chains means food system models and practices need to change



The food system continues to become an increasingly volatile, uncertain, complex, ambiguous ('VUCA') domainⁱ. Recent events, such as the 2007/8 World Food Price Crisis and 'Horsegate', have highlighted the

fragility of the food system to stressors, such as climate change, environmental degradation, criminal activity, civil unrest and political decision-making in exporting countries.² While the OECD/FAO's forecast to 2024 is for the prices of agricultural commodities to decrease in real terms, it warns that "there is a high probability of at least one severe shock to international markets within the next ten years".³ Looking further ahead, a preliminary analysis undertaken by a joint UK-US Taskforce has suggested that the risk of a 1-in-100 year production shock is likely to increase in frequency to 1-in-30 or more, by 2040.

Financial risks

Investors and financial institutions, perhaps sensitised by the recent global financial crisis, are becoming increasingly conscious of wider systemic risks to the economy and food system. For example, Mark Carney, the Governor of the Bank of England, identified that "the challenges currently posed by climate change pale in significance compared with what might come".⁴ Work by the University of Oxford has also highlighted the significant value of agricultural assets (such as land) that

have the potential to be strandedⁱⁱ due to environmentally-related risk factors.⁵

Production shocks

As concerns about external pressures, such as water scarcity, have been the focus of debate on supply chain risk,

"There is now a growing appreciation of the risks that stem from the form that modern supply chains and economies take."

there is now a growing appreciation of the risks that stem from the form that modern supply chains and economies take: large systems that are increasingly interconnected, specialised and consolidated.^{2,6,7} For example, researchers and businesses have come to better understand the risk inherent in monocultures of nutritionally important

crops: Bananas and oranges provide significant sources of nutrition in both developed and developing world diets but are progressively threatened by Panama Disease and 'citrus greening'.^{8,9,10} Today only 30 plant species are cultivated to provide 95% of food and feed.¹¹ These issues – and others – point to an urgent need to re-examine the potential dangers of 'efficiency' driving the wrong policy and business responses to the complex food system challenges we face.¹² As Ian Goldin, a former Vice President of the World Bank, warns: "Through the transformation of supply chains, globalisation has made production more efficient but simultaneously left the world trade network susceptible to systemic failures".⁷

"Failure to respond to these challenges will leave businesses exposed to supply chain disruption."

Moving beyond business as usual

These new challenges will also mean that the past business models, policy incentives and value chain relationships will need to be reframed and redesigned to improve resilience and reduce waste. Failure to respond to these challenges will leave businesses exposed to volatility and supply chain disruption; or left with business models that are unable to respond to changing consumer and regulatory demands. This report highlights that supply chain relationships and business governance will need to evolve to deal with new external pressures and power dynamics: food and drink sector employees will need to develop new skills to deal with complexity and wisely realise the potential gains to be had from adopting new technologies on our farms and in our factories, restaurants, and stores. Accessing the full potential of different forms of partnership and collaboration will help deal

with systemic challenges that span multiple disciplines. The diversity and location-specific nature of the challenges we face means that much innovation will have to emerge from the fields and factories – and these will need to be nurtured.¹³

Finally, it is worth noting that changes in response to food system complexity are not just

relevant to business stakeholders: they will have implications for consumers as well. Creating a more resilient food system is likely to require a greater diversity of raw material inputs and products. The need to engage consumers on these new foods and ingredients, and related issues, such as health and sustainability, will only increase as we head towards 2025.

i. The acronym VUCA (Volatile, Uncertain, Complex and Ambiguous) was coined by the US military but has since been adopted by business strategists.

ii. Stranded assets: "environmentally unsustainable assets suffer from unanticipated or premature writeoffs, downward revaluations or are converted to liabilities, can be caused by a range of environment-related risks". Caldecott et al (2013)

Create supply chains FIT for the future



To respond to the challenges outlined above, future supply chains will need to be FIT for the future: flexible (F), intelligent (I) and transparent (T).

- *Flexibility* will come from a range of attributes that

encourage resilience such as diversity and redundancy.ⁱⁱⁱ

- *Intelligence* will come from businesses and policymakers investing more in understanding and managing risks. This will also require interdisciplinary approaches, partnerships, better use of data and a reassessment of the skills and training needs of the UK food workforce.

- *Transparency* is needed to help uncover hidden risks that come from complexity and create incentives that drive the right changes in supply chains.

Opportunities & recommendations...

...for businesses

- **Show leadership on climate change.** Climate change is a threat multiplier that challenges the food system's ability to deliver safe and nutritious foods. One of the most effective ways to increase the long term resilience of the food system is for business to take a leadership position on climate change and act to limit temperature increases to 2°C.

- **Drive product innovation through harnessing diversity.** An effective method of increasing resilience is to diversify the ingredient-base of your portfolio. With this comes opportunities for innovation, new business models, collaborations and product lines. For example, there is the potential to develop novel offshore and land-based aquaculture; explore alternative protein sources for food and feed; provide consumers with new product experiences by harnessing crop variety diversity – and at the same time mitigate water or disease risks; or help to unlock new commercial value by creating nutritionally beneficial products from food supply chain by-products.

- **Drive down farm-to-fork food waste.** One third of all food grown globally goes to waste. Apply FIT principles by tackling food waste along the value chain to improve productivity, food security, and help shoppers to act; whilst simultaneously reducing costs, sourcing risks and additional damage to the natural environment.

- **Unlock the value of landscape partnerships.** Sustainable food production is closely connected to a system of soil, landscape and resource management (such as within a water catchment) that improves fertility and natural capital, reduces waste, and builds resilience to climate shocks. By creating partnerships in specific landscapes business can unlock new potential for delivering tangible sustainability improvements and business opportunities.

...for policymakers

- **Support the creation of business tools for food system resilience.** Policymakers, through the funding of innovative research, can help to provide evidence to industry on the business principles, practices and supply chain structures that are best equipped to deal with an increasingly volatile, uncertain, complex and ambiguous operating environment. It is critical to provide the right tools and frameworks to help business create FIT supply chains.

- **Create a regulatory environment that fosters partnerships and diversity.** Greater resilience could be enabled by updates to guidance and, where necessary, the legal framework. For example, by supporting more beneficial collaborations within the framework of competition law; and accelerating the processes for the safe adoption of new innovations (such as alternative protein sources).

- **Develop an open spatial data infrastructure.** Given the location-dependent nature of food system challenges and solutions the UK government could develop a UK food system spatial data infrastructure (SDI). An SDI is a framework of geographically-relevant data, policies, users and tools that are linked in such a way that the data can be used widely and effectively. The UK has a rich mapping history, and could now follow the lead of other countries, such as South Africa, by launching open resources to help plot supply, demand; and improve the management of natural resources. Governments could work with food businesses and others to create a common platform for the collection and sharing of this information, as a foundation for businesses to use, analyse and apply or tailor to their own supply chains.

iii. Resilient systems have five characteristics: robustness, redundancy, resourcefulness, response and recovery. Redundancy involves “having excess capacity and back-up systems, which enable the maintenance of core functionality in the event of disturbances”.¹⁴

Explosion of data-enabled technology

Opportunities across the value chain to harness power of the Green Data Revolution



This research highlights that data and technology are core to a number of developments transforming our food system. The effective use of data-enabled technology presents one of the greatest opportunities for increasing the productivity

and resilience of the food system since the Green Revolution. Whereas the Green Revolution was about increased agricultural production through techniques such as plant breeding and the use of synthetic fertilisers, the “Green Data Revolution” is about maximising the efficacy of whole value chains using newly available technologies and data resources.¹⁵ The characteristics of the food system, such as complexity, huge geographical range, and diversity of operators, make it particularly ripe for exploiting data-enabled technology. Different ways of communicating, monitoring and collaborating will open up new innovation pathways that connect people and organisations across value chains and landscapes in ways that have not been possible before.

Many of the topics covered in this report introduce the growing importance of these technologies in providing new insights and opportunities in food production, supply chain operations and consumer engagement. However, our research shows that the delivery of the promise of what these technologies may unlock is by no means inevitable: there is a need to actively promote the adoption of these approaches.

New approaches to data sharing

The topics addressing *Intelligent supply and demand* and *Unlocking*

new value from wastes highlight the opportunities - but also the challenges - in transferring data from business-to-business and business-to-consumer. Data-enabled technology has the potential to increase the ability of supply chain partners to more effectively share product information, optimise product life, trace raw materials, track and reduce waste or have access to up-to-date geospatial information on waste streams and managing wider risks. However, within this area of opportunity there is also a need for consistent data ‘interoperability’: the ability to easily share and interpret data between different systems and businesses. The increased reliance on data-enabled technology will also pose new data security and privacy challenges – issues that are not necessarily the traditional domain of food and drink

“The increased reliance on data-enabled technology will also pose new data security and privacy challenges.”

businesses – as well as increase concerns over competition laws that prevent the sharing of what could be considered sensitive information. Data interoperability, security and supply chain data sharing are national and international issues requiring governmental guidance.

It is important to remember that data and technology-related initiatives must sit within existing business culture and ways-of-working. Potential improvements to food system sustainability and resilience from the adoption of data-enabled technology will require changes to business processes and practices; the agreement of new and revised data standards; and investment in training and development.

Adding value to products

Business needs to be open to different ways in which consumer

behaviours and societal expectations will change. Data and technology can allow consumers to connect directly with producers to purchase goods that have been harvested that day for collection or delivery, with much more clarity about their

“We have reached a tipping point where the volume of data we have in the world is increasing at an exponential rate.”

provenance and pedigree. In conjunction with Industry 4.0, technology could allow for tailored products to be produced for individuals or families depending on their lifestyles, age, nutritional or health requirements. Such a system could be significantly more productive, with less waste and greater added value.

In other sectors, recognising and exploiting these same types of changes has led to the creation of new business models that add value by changing the idea of buying a product to paying for a service. Despite the linear nature of food consumption (i.e. what is produced must be consumed or wasted), the business models used by companies in the sector can realise new value by reassessing how technology can be used to provide a better service to their customers.

In 2006, smartphones were niche products and the ‘Internet of Things’ was still a theoretical topic at trade conventions. Over the next ten years, technology, and its precise application in the food system, will undoubtedly advance in new and difficult to predict ways.

Beyond the tipping point

What is clear, however, is that we have reached a tipping point where the volume of data we have in the world is increasing at an exponential rate, whilst our ability to harness and understand this data will provide significant opportunities to boost food system resilience and build consumer confidence.

Invest in food chain data capabilities



In order to develop a more resilient food and drink system, businesses will need to invest in and exploit the use of data and technology to better connect their value chains, including their

customers. But the explosion in data-enabled technology offers far more potential than this. The Green Data Revolution can support the delivery of a smarter, more flexible, food system which can optimise the way land is used and food is grown, harvested, processed and eaten. It also offers consumers new ways to access food, and engage with food in a way that will challenge the established systems and promote the adoption of Industry 4.0 technologies and new business models.

Opportunities & recommendations...

...for businesses

- **Drive product innovation and supply chain resilience through clear data strategy.** By developing a food chain data strategy business can leverage the most promising data-enabled technologies and drive innovation to deliver new consumer and business value. This will need to build on existing systems and stretch down the supply chain to primary producers to maximise the benefits. This will also involve reviewing data privacy policies with suppliers and customers to promote a greater understanding of what information can be shared and the mechanisms that should be put in place to do so to protect privacy, comply with data protection requirements, competition laws and principles.
- **Create business culture and capacity that can harness potential of food chain data.** Invest in training and expertise, in particular for data analysts and computer scientists, who will be critical to building new business value from ever-increasing volumes of available data. This will also include training those who communicate data and information with those outside of the business (e.g. suppliers, customers and households). Part of this should include developing a responsive culture that is able to act on new information as soon as it becomes available. There will be uncertainty in the data and organisations must be capable and comfortable with making decisions on both precise and imprecise information quickly and effectively.
- **Support data interoperability initiatives.** Adopt interoperable data management standards and requirements to support the use of supply chain knowledge within the business and enable data sharing between different supply chain partners, who may be using different information systems. This will involve collaboration across industry and with technology providers.

...for policymakers

- **Create a food and drink sector data strategy.** Pursue the development of a sector-wide strategy to promote food system innovation through the use of data-enabled technology. This should include continuing to open up government data resources to the public and businesses and promoting the ready exchange of data, for example through extension of the Centre of Agriculture Informatics and Metrics of Sustainability to look beyond the farm gate to extend to the rest of the supply chain.
- **Fund training and skills development in food chain data.** Actively fund and support new skills and training in the food chain, particularly in technology and informatics. A focus on skills to support the application of agricultural technology and food chain data science to develop the workforce will help enhance the competitiveness of businesses whilst putting the UK at the forefront of the Green Data Revolution.
- **Provide guidance on the competition implications of greater data sharing.** Provide guidance to businesses on how data exchange can take place without infringing competition laws. This will help businesses take advantage of the opportunity within the existing legal and regulatory framework. This will also require working with international partners to harmonise this framework, so that companies can operate within a single set of rules whereby legal systems around the world have a shared understanding of what is considered shareable data.

Alignment of health & sustainability agendas

A systems approach to health and sustainability is critical for meeting future food security goals



Since the publication of the WRAP *Grocery Futures* report in 2006, the links between food sustainability and public health have become of increasing interest to business leaders, policymakers and civil society. The

concept of 'healthy sustainable diets' has come to dominate discussions - in particular the synergies and trade-offs between dietary preferences and the environmental impacts of food supply chains.^{16,17} As noted in the topic on *Conscious food choices*, national governments and civil society organisations are starting to add weight to this debate by exploring dietary recommendations that address both environment and nutrition challenges.^{18,19,20,21}

Understanding the direct relationship

Food Futures has also underlined the wider set of interdependencies between public health, the food system and the integrity of the natural environment. For example, in the topic on *Climate risks to food chain resilience* it can be seen how environmental change has the potential to impact public health by increasing food safety risks and reducing the nutritional quality of crops. In the *Aquaculture expansion* and *Alternate feeds and proteins* topics the point is made that personal choices on the future sources of dietary protein will influence public health and environmental outcomes.

Promoting balance

Bridging the gaps between health and sustainability policies does not necessarily mean that any single product or ingredient need to be avoided at all costs and the food chain will need to recognise that careful thought is required in the use of ingredients and foods that have acknowledged health and sustainability issues

associated with them. The challenges for businesses in the next ten years will be innovating to find new ways of delivering the nutritional content needed by society while reducing the impact on the planet. The challenge for policymakers will be to ensure that any new guidance considers this.

"Food Futures has also underlined the wider set of interdependencies between public health, the food system and the integrity of the natural environment."

Embracing joined up approaches

Ensuring the UK has a diversified, sustainable supply of protein is one of the defining challenges of the 21st century. One potential solution presented in the report - new commercial models of sustainable aquaculture - has many potential advantages: the public health benefits associated with increased fish consumption; reduced dependence on more resource intensive forms of protein production; reduced pressure on wild fish stocks; and a more circular food economy through the use of recirculating, multi-trophic aquaculture systems.²² However, to achieve this goal a careful route needs to be

plotted to avoid increased antibiotic resistance, livestock disease transmission and water pollution - all of which have human and environmental health implications. A systems approach to dealing with health and sustainability outcomes in the food system is therefore critical when it comes to considering our future protein sources.

"A systems approach to dealing with health and sustainability outcomes in the food system is critical when it comes to considering our future"

Promote innovation and consumer engagement on health & sustainability



By bringing together the health and sustainability agendas society can make the most of recognised synergies between the two and ensure that any trade-offs or tensions can be addressed holistically.

The looming 'protein challenge' should be the initial focus of this work: animal protein places significant resource pressures on the world and over-consumption is associated with negative health outcomes. The need to increase public engagement will also be crucial to determining the future health of the nation and sustainability of the food system. Consumer interest in health and nutrition is increasing and this trend should be capitalised on to also deliver broader sustainability outcomes, where there is a link between dietary choices and the integrity of the natural environment.

Opportunities & recommendations

...for businesses

- **Review governance of health and sustainability.** Undertake a strategic review of overlaps between sustainability and health-related policies to ensure alignment and trade-offs can be managed. For example, explore potential benefits of bringing nutrition and sustainability requirements together in agricultural production standards to promote an integrated approach to food product nutrition and sustainability.
- **Use health and sustainability agenda to fuel product innovation and novel partnerships.** Opportunities here include developing nutraceuticals and other health-related products from food supply chain by-products, or creating new plant and livestock-derived sources of dietary protein. The interconnected nature of the health and sustainability challenge will call for novel partnerships - for example between product development, marketing, crop breeding and nutrition specialists.
- **Increase consumer engagement on health and sustainability.** The need to engage consumers on health and sustainability will only increase as we head towards 2025. Opportunities here include product personalisation (e.g. developing portions and nutritional profile that reflect a person's age and activity levels).
- **Support enterprises and initiatives that deliver health & environment outcomes.** For example, through linking agricultural production to outdoor access and physical activity in areas near to growing urban populations.

...for policymakers

- **Pursue joined up policies on health and sustainability.** Create a joint taskforce to undertake a review of policy areas to identify where there are opportunities for better, more cost-effective outcomes, reduce regulation where appropriate and drive more efficiency and consistency in policy delivery and outcomes. Consider the role of sustainability within the remit of government agencies concerned with health and dietary advice (e.g. the Scientific Advisory Committee on Nutrition, the Food Standards Agency, Public Health England).
- **Extend Food Enterprise Zones to support health outcomes.** Explore the potential to create a network of UK landscapes that deliver health, economic, environmental and food production objectives. This could use the 'Food Enterprise Zones' model as a basis for action and bring a broad range of business and civil society partners.
- **Champion international agreement on dietary advice.** Pursue international agreement on the integration of sustainability considerations into dietary advice, drawing upon experiences of work in the UK, US and other countries – e.g. through the World Health Organisation (WHO).
- **Use public procurement to drive health and sustainability agenda.** Review the criteria used in the procurement of food and drink by the public sector to ensure that health and sustainability criteria are effectively delivered.

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Below are the references used in the Conclusions section. The sources used to develop the whole report are available to download from www.wrap.org.uk/foodfuturesreferences

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