Institute of Food Science + Technology

FOOD SYSTEM FRAMEWORK

a focus on food sustainability




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A word from the president

The sustainability of the food system is critical, not just to those of us working in the sector, but to every citizen on the planet – we are all consumers and we will all be affected by resource pressures, climate change and subsequent social and economic changes. Much good work is underway, and exciting new technologies are being developed to address the many challenges. IFST is committed to working with interested partners to help speed progress in key areas, or to bring focus to needs that may be currently overlooked. This report is the first step in that process, a framework to identify where IFST can and should get involved, to maximise our impact in this broad endeavour. We will be speaking out more as we develop our activities; we welcome your comments and offers of involvement."

David Gregory, IFST President

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EXECUTIVE SUMMARY

There is a clear and urgent need for science and applied technologies to help deliver sustainable food systems, which provide 'food security and nutrition for all in such a way that the economic, social and environmental bases to generate food security and nutrition for future generations are not compromised' (FAO, High Level Panel of Experts on food security and nutrition). IFST as the 'Voice of the Food Profession' is well placed to bring focus to important aspects of developing sustainable food systems.

To direct our efforts in what is a wide topic area, we have commissioned this report by 3Keel to focus activity on practical elements where we can have an impact that is most relevant to our members, and also benefit wider society.

The report outlines 6 key themes that provide a framework for IFST to develop guidance, new knowledge, policy, and other initiatives to support the vision of sustainable food systems, while keeping a focus on food, technology and evidence. Recommendations for broad activity areas are made under each of these themes:

1. **Resource risks and pressures** – the food system is dependent on the natural environment and at the same time is causing significant environmental impacts. IFST can contribute to UK and global efforts to increase food system resilience through:
    - Developing guidance for food industry on mitigating the impact of emerging global environmental risks
    - Supporting research to identify how food science and technology could help the industry adapt to the impacts of climate change
    - Identifying how a broader set of environmental and social risks can be integrated into food business and supply chain risk management.
    - Being a vocal supporter of efforts to address climate change mitigation and adaptation in the food sector.
2. **Healthy sustainable diets** – there is a need to deliver good human and environmental health outcomes from the food system at the same time. Partnering with appropriate technical colleagues, IFST can:
    - Help develop and disseminate best practice guidance on how to incorporate sustainability into the assessment of new processes and products, i.e. 'Designing in sustainability' to NPD or R&D processes
    - Contribute to the development of solutions to the global challenge of food and nutritional waste through the application of science and technology
3. **Circular economy and sustainable manufacturing** – the current economic model of 'take-produce-consume-discard' is unsustainable. IFST can:
    - Address food safety and regulatory perspective challenges to support the increased use of wastes and by-products as inputs to other processes and sectors
    - Support and promote industry efforts to increase resource efficiency through reducing energy, waste and water in the food industry
    - Facilitate the creation of new practical energy standards, for SMEs
    - Support optimisation of the usability of foods through the improvement of product date/storage/usage labelling information

4. **Novel production systems and ingredients** – there are opportunities for developing new farming and manufacturing technologies to deliver sustainable nutrition. IFST can:
   - Contribute to the technical, legal, and consumer-acceptability challenges of future protein technologies
   - Promote or support research into automation and increased use of data-enabled technology and 'artificial intelligence' in the food system
5. **Decent work and equitable trade** – the livelihoods and working conditions of the 1+ billion people who work in the food system need to be improved. IFST can:
   - Explore the advantages and disadvantages of a move towards more automation in the agri-food supply chain
6. **Transparency, traceability and trust** – new software and data can help drive improvements in food system sustainability and strengthen consumer trust. IFST can:
   - Increase industry knowledge of emerging traceability and transparency technologies in supply chains
   - Support development and uptake of innovative approaches to assuring the sustainability of supply chain actors

IFST and its member working group will now use this framework and the recommendations to develop more specific activities, which will need to be addressed in conjunction with the many organisations and individuals who are affected by, or are already working in, these areas. The report identifies some of those key stakeholders as potential partners, and IFST is open to discussion and collaboration with these and other interested parties. For more information or to initiate that discussion please contact John Bassett, Policy and Scientific Development Director, IFST at j.bassett@ifst.org.

INTRODUCTION

What is the food system?

According to the United Nations Environment Programme (UNEP) the food system can be defined as "the complete set of people, institutions, activities, processes, and infrastructure involved in producing and consuming food for a given population".[1] This covers all stages of the value chain - from growing and harvesting agricultural products through to processing, packaging, transporting, selling, cooking, consuming, and the disposal of waste food and packaging.

A key characteristic of the food system is the extensive linkages, interdependencies and feedback loops between value chain stages and the wider environment, society and economy. For example, the food system is dependent on natural resources and has a significant impact on the global environment. The food system also has a major influence on human health and is an important global source of employment and economic value. It also has significant cultural significance in many societies.

Growing environmental pressures, including climate change, soil degradation, disruption of water cycles, expanding pathogen ranges and increasing regularity of extreme weather events, coupled with population growth and migration impact on and will continue to affect the food system.

The complexity of the food system means that a 'systems' (or 'joined up') approach is necessary if effective policy responses are to be developed by business and government. For example, a systems approach would avoid the situation where countries subsidise the production of nutritionally poor and environmentally damaging foods while at the same pay the increasing costs of diet-related diseases and pollution.

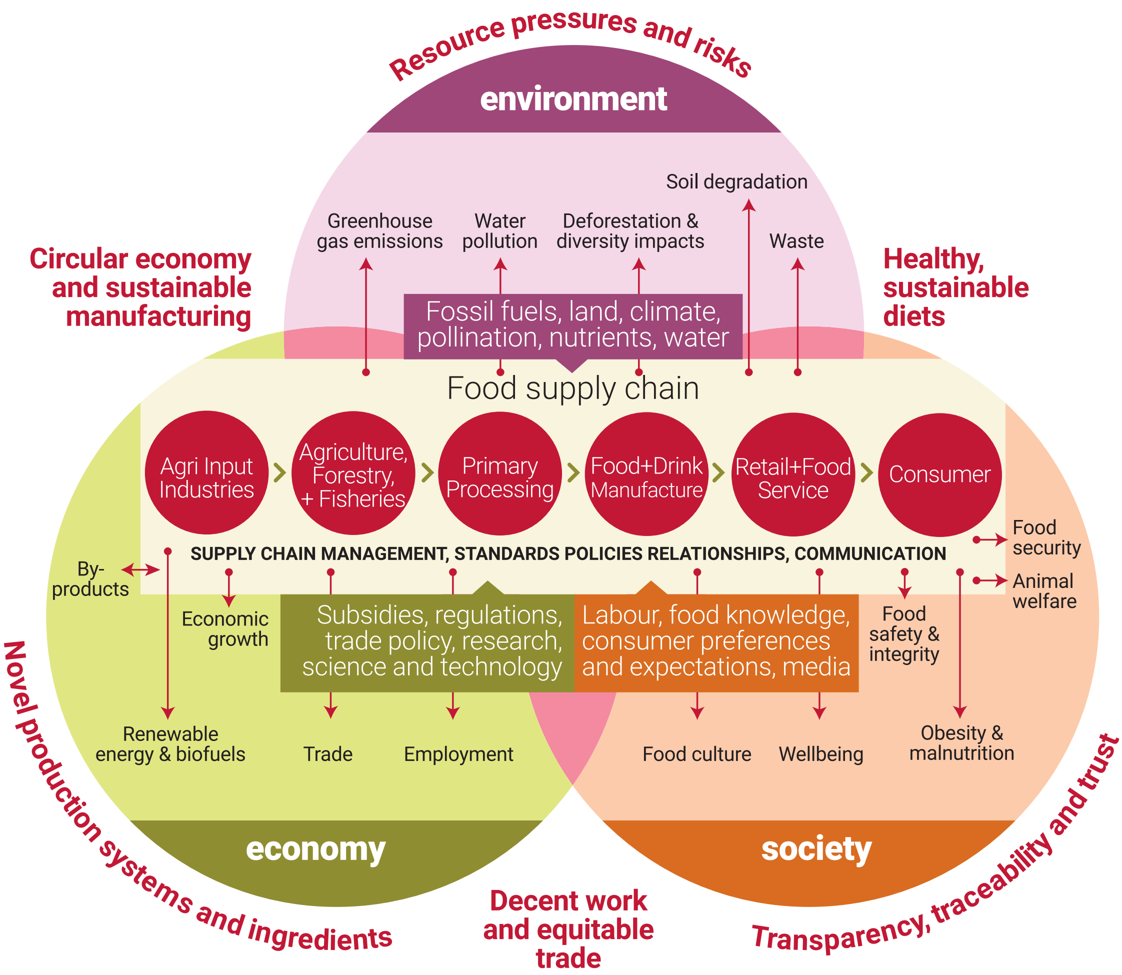
This document explores the key components of the global food system via the lens of six themes identified of being of particular relevance to IFST ***(see Figure 1 below)***:

- **Resource risks and pressures**
  The food system is dependent on the natural environment and at the same time is causing significant environmental impacts
- **Healthy sustainable diets**
  There is a need to deliver good human and environmental health outcomes from the food system at the same time
- **Circular economy and sustainable manufacturing**
  The current economic model of "take-produce-consume-discard" is unsustainable
- **Novel production systems and ingredients**
  There are opportunities for developing new farming and manufacturing technologies to deliver sustainable nutrition
- **Decent work and equitable trade**
  The livelihoods and working conditions of the 1+ billion people who work in the food system need to be improved

1 UNEP (2016) Food Systems and Natural Resources. A Report of the Working Group on Food Systems of the International Resource Panel.

- **Transparency, traceability and trust**
  New software and data can help drive improvements in food system sustainability and strengthen consumer trust

Figure 1: The food system - and key IFST food system themes



RESOURCE PRESSURES AND RISKS

The food system is on the front line of environmental change and anticipated resource constraints. Agriculture, in particular, is a major user of key natural resources, occupying nearly 40% of total land area[2] and accounting for over 70% of global water withdrawals[3]. The food sector is also severely exposed to climate change, which will impact on crop productivity, animal health and trade patterns both directly and indirectly through its effects on water, land, and populations[4]. The nature of modern food production - which has become increasingly homogenous, inter-connected, concentrated and input dependent[5,6] - also has the potential to increase exposure to some emerging risks, such as plant and animal diseases, especially those that have become resistant to current control mechanisms.

Agri-food intensification and consolidation

The current food system - especially in developed countries - is characterised as being specialised, consolidated, globalised, intensive and increasingly homogenous.[7] These characteristics have important implications for the long-term sustainability and resilience of food supplies - especially in the context of external pressures such as climate change[5].

Agricultural intensification is the use of inputs, technologies and practices to increase production output per input of unit.[7] This increase in efficiency may help to meet the 90% increase in global crop production needed to feed the future population.[8] Intensification can also offer environmental benefits - most notably sparing non-agricultural land from conversion. However, if not properly regulated, it can have significant environmental downsides such as soil degradation, increasing water pollution and contamination from agro-chemical run-off.[9] Many agricultural production systems are now dependent on a range of inputs such as pesticides, inorganic fertilizers, antibiotics and irrigation[10].

2 The World Bank Group (2016) World Bank Indicators: Agricultural land (% of land area)

3 FAO (2016) AQUASTAT website. Food and Agriculture Organization of the United Nations

4 Wheeler, T., von Braun J. (2013) Climate Change Impacts on Global Food Security. Science. Vol 341(6145):508-13

5 Rotz, S. & Fraser, E.D.G. (2015) Resilience and the industrial food system: analyzing the impacts of agricultural industrialization on food system vulnerability. Journal of Environmental Studies and Sciences. Volume 5, Issue 3, pp 459–473

6 Bleischwitz, R., Johnson, C.M. & Dozler, M.G. Eur J Futures Res (2014) Re-Assessing resource dependency and criticality. Linking future food and water stress with global resource supply vulnerabilities for foresight analysis. 2: 34.

7 WWF Netherlands (2016) The global food system: an analysis

8 FAO (2009) How to Feed the World in 2050

9 Troell, M. (2014) Does aquaculture add resilience to the global food system? PNAS, vol. 111, no. 37, pages 13257–13263

10 Tilman et al. (2002) Agricultural sustainability and intensive production practices. Nature 418, 671-677

Intensification has been associated with specialisation and a loss of diversity in production systems and supply chains - this can lead to greater exposure to disease risks and increased dependence on energy and chemical inputs.[7] Regional specialisation of production has encouraged the patterns of trade and commodity use seen today.[7]

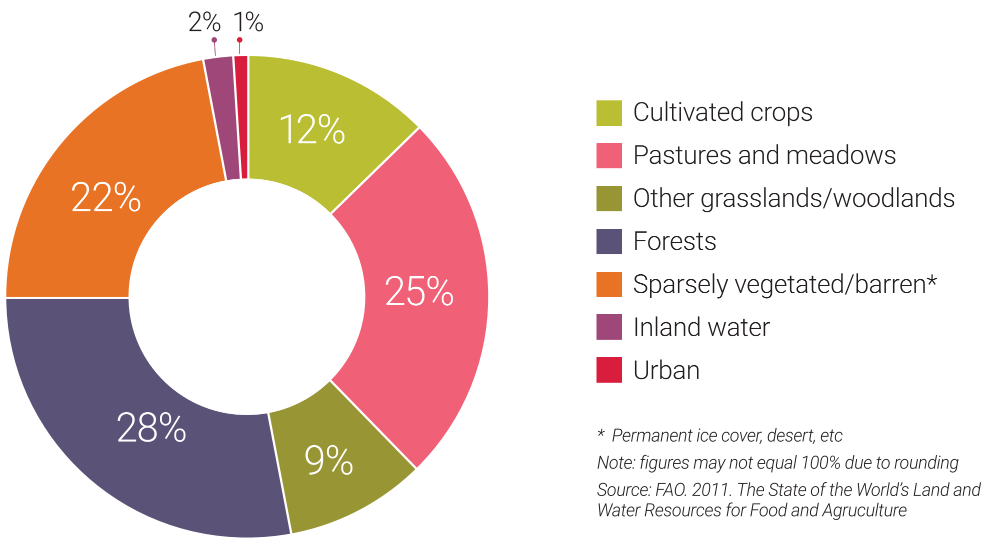
The food system is increasingly consolidated and homogenous - for example four agribusinesses control 90% of the global grain trade[7] and two thirds of human calorie needs requirements are provided by four crops (rice, wheat, maize, and potatoes).[10]

A key emerging concern is the implications of continued and expanding use of antibiotics in animal production. A recent review for the UK government underlined the scale of antibiotic use - especially in the United States and emerging economies - where more than 70% of medically important antibiotics are used in animal production.[11] This has important ramifications for human health, due to the rise of antibiotic resistance, and is facing increasing political and public attention. For example the FDA'a strategy on antimicrobial resistance aims to phase out the use of medically important antimicrobials in livestock for non-therapeutic processes.[12]

Land use

Land availability and quality is a key constraint on agricultural production. Globally, land is used not only to produce human-edible food - but also biofuels, fibre and livestock feed. Overall, c. 12% of the world's land is cultivated and 25% is used as pasture (see Figure 2 below). The expansion of cropland and pastures is the leading cause of ecosystem degradation and biodiversity loss and contributes 11% of greenhouse gas emissions.[13] Balancing these competing demands for land in a sustainable way is a fundamental challenge facing the food system in the 21st century.

Figure 2: Global land use[14]



** Permanent ice cover, desert, etc*

Note: figures may not equal 100% due to rounding

Source: FAO. 2011. The State of the World's Land and Water Resources for Food and Agruculture

11 O'Neill (2015) Antimicrobials in agriculture and the environment: reducing unnecessary use and waste. The Review on Antimicrobial Resistance

12 US Food & Drug Administration (2015) FDA's Strategy on Antimicrobial Resistance - Questions and Answers

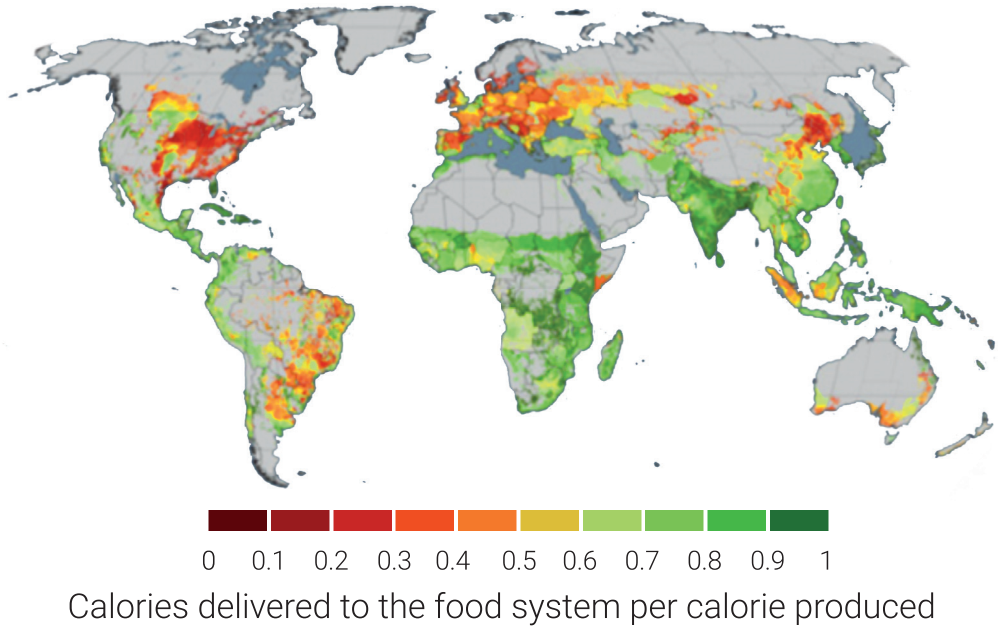
13 WRI (2014) Creating a Sustainable Food Future: Interim Findings

14 WRI (2013) The great balancing act. Installment 1 of "Creating a Sustainable Food Future"

Land quality, in particular soil health, is vital for agricultural production. The first global soil assessment took place in 2015, revealing that a third of land is moderately to highly degraded as a result of soil erosion, compaction, salinisation acidification and pollution.[15] Moreover, it is estimated that 12 million hectares of topsoil are lost every year to soil degradation.[16] Soil management strategies will be key to ensure the future health of this resource.

There is a significant variation in the proportion of land used to feed humans directly versus being used for feed or other uses. Overall, 59% of the total produced calories are delivered to the world's food system (see Figure 3 below), with the rest lost in the transition from animal feed to human consumption, or used industrially or as biofuels[17]. 89% of the calories used in animal feed are lost to the food system through inefficiencies of the feed-to-edible food conversion. The majority of calories produced in the major croplands of Europe, US and China are not used for human consumption but other uses - particularly feed and biofuels to meet growing meat, dairy and energy demands. Crop requirements needed for livestock have caused major livestock-producing countries to become net importers of grain.[18]

Figure 3: Calorie delivery fraction per hectare[18]



15 FAO and ITPS (2015) Status of the World's Soil Resources (SWSR) – Main Report. Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils, Rome, Italy

16 Rickson, R. J., et al (2015). Input constraints to food production: the impact of soil degradation. *Food security*, *7*(2), 351-364.

17 Cassidy, E. (2013) Redefining agricultural yields: from tonnes to people nourished per hectare. Environ. Res. Lett. 8

18 Chatham House (2016) Agricultural Commodity Supply Chains Trade, Consumption and Deforestation

Local and global environmental limits

The food system is the biggest user of key natural resources, such as terrestrial and marine biodiversity, soils, freshwater, minerals and fossil fuels.[1] For example, the United Nations Environment Programme (UNEP) estimates 60% of global terrestrial biodiversity loss is related to food production (see Box 1 below for other statistics from UNEP). As such, the food system has significant influence over critical global and local biophysical processes such as the water cycle, climate, nitrogen cycle[19]. The status of many of these sub-systems are declining and have the potential to impact upon the future production capacity.

Water, in particular, has been identified as a critical food system resource that is under threat and has the potential to impact upon yields, quality and safety of food. Agriculture uses 70% of all freshwater withdrawn from rivers, lakes, and aquifers, which can lead to depletion of water resources when more water is extracted than can be replenished.[17] Loss of wider ecosystem services such as pollination, also threatens future production.

Box 1:

The status of key natural resources underpinning the food system[1]

According to the UNEP:

33% of soils is moderately to highly degraded due to erosion, nutrient depletion, acidification, salinization, compaction and chemical pollution

61% of 'commercial' fish populations are fully fished and 29% are fished at a biologically unsustainable level.

At least 20% of the world's aquifers are overexploited, including in important production areas such as the Upper Ganges (India) and California (US);

60% of global terrestrial biodiversity loss is related to food production, while ecosystem services supporting food production are often under pressure;

Of the total input in the form of nitrogen- and phosphorus fertilizers, only 15-20% is actually embedded in the food that reaches the consumers' plates, implying very large nutrient losses to the environment.

Globally, food systems account for around 24% (21-28%) of the global greenhouse gas emissions"

19 Steffen, W. et al (2015) Planetary boundaries: Guiding human development on a changing planet

DECENT WORK AND EQUITABLE TRADE

The global food system is highly dependent on labour: approximately 1.2 billion people work in agriculture - about 31% of the global workforce[20]. Many of these workers are in developing countries - such as sub-Saharan Africa.

In the United Kingdom, approximately 0.5 million people are employed in agriculture and fisheries sectors (only 2% of total UK employment). Some 3.9 million people are employed in the UK in the agri-food sector (i.e. from farm to retail[21]). This represents 14% of national employment. More than 70% of employees in the UK agri-food sector are in retail and foodservice jobs.

Improving the working conditions and economic status of these workers is a key food system challenge. Looking to the future, it is also anticipated that mechanisation and automation will impact upon employment at all stages of the food value chain.

Human rights and a living wage

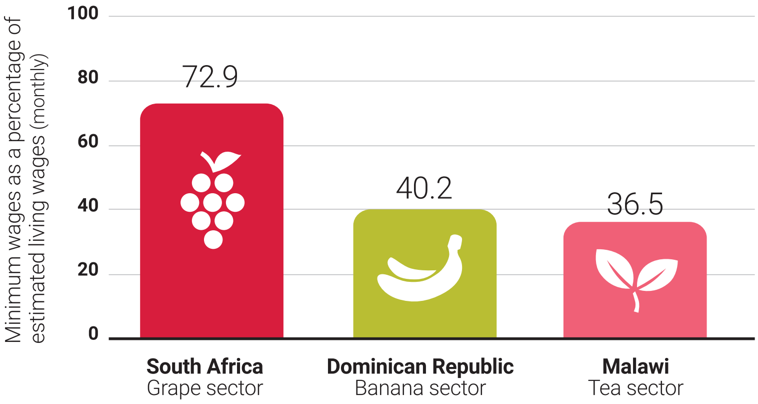
In the UK, the Modern Slavery Act 2015 has been credited as being a 'game changer' in raising the awareness of human rights in global supply chains - and making action on human rights issues 'business critical'[22].

Work within the food system are often '3D' jobs: dirty, dangerous, and difficult.[23] For example, according to the International Labor Organisation (ILO), agriculture accounts for approximately half of all fatal workplace accidents globally. The nature of the agri-food labour market - which relies heavily on migrant, subcontracted labour in unregulated regions of the world - increases the risk of labour rights abuses. Business focuses on addressing fundamental labour issues, as set out by the ILO: forced labour (modern slavery); freedom of association and rights to organise; equal remuneration; and child labour.

Beyond the 'dirty, dangerous and difficult jobs in the food system, there are millions of legal 'low road' jobs where workers are trapped in poverty and have no job security[24]. Tackling low wages and providing a living wage in the food system will be critical to achieving ethical trade[25]. For example, a study by development NGOs found that the minimum wage key agricultural crops were well below that needed to provide decent food, clothing, housing and some discretionary spending ***(see Figure 4 below)***[26].

20 UNFAO (2015) Statistics Pocketbook
21 Defra (2016) Food Statistics Pocketbook
22 Ethical Trade Initiative (2016) Corporate Leadership on Modern Slavery
23 Verite (2015) Strengthening Protections Against Trafficking in Persons in Federal and Corporate Supply Chains
24 Oxfam (2014) Steps towards a living wage in global supply chains
25 Joint Ethical Trades Initiative (2015) Living wages in global supply chains - A new agenda for business
26 Referenced in: Oxfam (2014) Even It Up - Time to end extreme inequality

Figure 4: Minimum wages as a % of estimated living wages (monthly)[27]



Smallholder agriculture

Smallholders are a key part of the global food system - managing more than 80% of the world's 500 million small farms.[28] Smallholders produce many of the major globally traded crops such as cocoa, coffee, tea and cotton, as well as vegetables, fruits and flowers.[29] Smallholders in developing and emerging economies face many challenges such as climate change, poor infrastructure, rising input prices and lack of agricultural extension services, which can result in smallholders being subject to unfair trading.[28] Cooperative groups and growers associations aim to ensure fairer conditions for smallholders.

The role of women and children in global food production are of particular note. Women small holders and subsistence farmers produce half of the world's food, with women accounting for around 43% of the global agricultural labour force[30], but are often unpaid and offered less support than men.[23] Various initiatives aim to empower women farmers including the Fairtrade Foundation and the Ethical Trading Initiative. It is also estimated that 60% of all children engaged in labour work in agriculture.

Increasing automation and mechanisation

Robotics companies are exploring the potential for agricultural processes, such as spraying, harvesting and grading, to be automated further. Automated technologies of this kind may bring many benefits to the food system - such as reduced costs, increased safety, greater yields, increased operational flexibility and reduced waste.[31]

As a result of increased automation and sustained cost pressures, the UK Commission for Employment and Skills expects employment in agriculture to fall.[32] Jobs in all parts of the food supply chain are at risk from automation and computerisation. An analysis by Oxford University rated jobs including food science technicians, farm labourers, food service staff, meat cutters and food manufacturing operatives as more than 80% likely to be automated in the future – although no timeframe was provided in the analysis[33].

27 Oxfam (2014) Even It Up - Time to end extreme inequality

28 IFAD (2013) Smallholders, food security, and the environment

29 UNCTAD (2015) The role of smallholder farmers in sustainable commodities production and trade

30 FAO (2011) The State of Food and Agriculture 2010–11. Women in agriculture: closing the gender gap for development. Rome.

31 *Robotics-VO (2013) A Roadmap for U.S. Robotics—From Internet to Robotics* and International Federation of Robotics. Fanuc Robotics Europe S.A case study

32 UKCES (2014) Working Futures 2012-2022, Evidence Report no 83

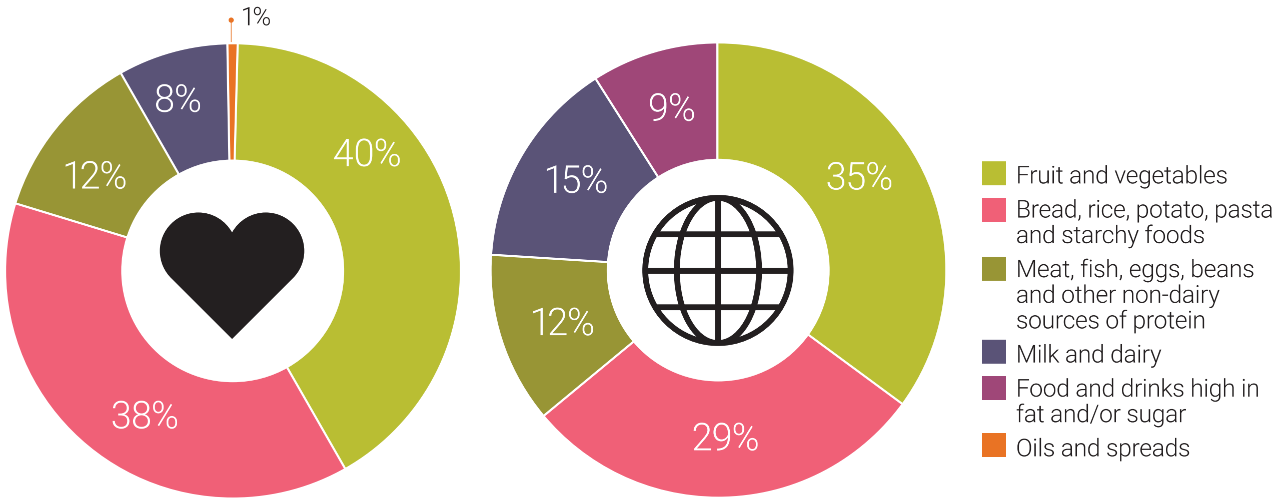
33 Frey, C.B. and Osborne, M. A. (2014) The Future Of Employment: How Susceptible Are Jobs To Computerisation?

SUSTAINABLE DIETS

In the past few decades, the idea of a "sustainable diet" - a diet healthy for both people and planet - has gained traction. The UN FAO defines sustainable diets as *"those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources".*[34]

The foundational aspects of the concept of a sustainable diet are the linkages between human health, nutrition, and dietary requirements and environmental impacts. Currently, policy does not consider them as a whole - for example, consider US governmental subsidies for corn production and national efforts to combat and reduce obesity. The emerging message is that healthier foods also tend to be better for the environment. For example, the Eatwell Guide released by Public Health England to provide dietary advice, ***(Figure 5a)***, and the Livewell Plate released by WWF to provide information on sustainable diets, ***(Figure 5b)***, both recommend reducing meat consumption by cutting non-dairy protein to 12%.

Figure 5: Recommended food intake from (a) Eatwell Guide[35] (b) Livewell Plate[36]



Evidence shows that shifting dietary patterns to more plant-based diets can significantly reduce GHG emissions and land and water use, as well as decreasing the risk of all-cause mortality in humans.[37] The promotion of sustainable diets is increasingly important in a world dealing with shifting dietary preferences and expected global meat consumption increase of 76% by 2050.[38]

34 Burlingame, B., & Dernini, S. (2012). Sustainable Diets and Biodiversity: Directions and Solutions for Policy, Research and Action. International Scientific Symposium, Biodiversity and Sustainable Diets United Against Hunger, FAO Headquarters, Rome, Italy, 3-5 November 2010.

35 Public Health England (2016) Eatwell Guide

36 WWF (2011) Livewell Report

37 Aleksandrowicz L et al. (2016) The Impacts of Dietary Change on Greenhouse Gas Emissions, Land Use, Water Use, and Health: A Systematic Review. PLoS ONE 11(11): e0165797

38 Alexandratos, N. and J. Bruinsma (2012) World agriculture towards 2030/2050: the 2012 revision. ESA Working paper No. 12-03.

Impacts of consumer diets and lifestyles

As global diets transition and meat intake increases, the prevalence of non-communicable diseases is expected to rise. Currently more people are now obese than underweight globally[39] and obesity is projected to affect over one third of men and women in the UK by 2030, compared with current rates of around 25%.[40]

In addition to their effect on public health, these non-communicable diseases represent a serious financial burden for governments and taxpayers. Obesity alone has a USD $2.0 trillion impact on global GDP.[41] Many countries are looking at regulations as a way to combat these emerging diet-related threats to health, such as taxes on specific foods or ingredients to reduce consumption. These approaches are controversial and still relatively new, and so it is uncertain whether they will encourage the development and consumption of healthy foods.[42]

Sustainable diets research has tended to focus on consumption-side measures – particularly moderating the consumption of livestock products and products high in fat, sugar and salt[43] ***(see section on 'alternative proteins' below)***. Alternate approaches to improving nutrition and reducing resource use include the use of genetic modification to insert genes from algae into Camelina plants so that they produce omega-3, an essential amino acid normally found in foods such as fish oils[44,45].

Researchers are also examining the potential to use a person's genetic information – as well as other information – to personalise diets. The hypothesis is that by providing personalised nutrition advice a larger, more appropriate, and sustained change in dietary behaviour could be achieved. There is evidence that personalised nutrition is effective, however no benefits from including genetic or phenotypic information has been found so far[46]. Personalised nutrition opens opportunities for the food industry to develop new products and services – for example the use of consumer software and 'wearable' technology to help support more sustainable diets[47].

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39 Global BMI Mortality Collaboration (2016) Body-mass index and all-cause mortality: individual-participant-data meta-analysis of 239 prospective studies in four continents. The Lancet, 388(10046), 776-786.

40 WHO (2015) Proportion of overweight and obese males and females to increase in most European countries *by 2030, say latest projections by WHO.* Press release.

41 McKinsey Global Institute (2014) How the world could better fight obesity

42 University of North Carolina (2015) Purchases of taxed beverages decline in Mexico after excise tax takes effect.

43 Global Food Security (2014) The principles of healthy and sustainable eating patterns

44 Rothamsted Research (nd) GM Camelina field Trial: Information. Available at: http://www.rothamsted.ac.uk/camelina

45 Tejera, N. et al (2016) A Transgenic Camelina sativa Seed Oil Effectively Replaces Fish Oil as a Dietary Source of Eicosapentaenoic Acid in Mice. Journal of Nutrition vol. 146 issue 2 pp: 227-235

46 Celis-Morales, C. (2016) Effect of personalized nutrition on health-related behaviour change: evidence from the Food4me European randomized controlled trial

47 Rick Pendrous (2015) Wearable devices to track personal nutrition by 2020. Food Manufacture.

Alternative proteins

Intensive livestock production is acknowledged to be a major driver of global resource use and contributes significantly to GHG emissions.[48] The coming years will see innovation to reduce the land, water and carbon footprint of proteins that are edible for human consumption, including the development of alternative protein, such as insects, algae and 'lab meat'.

Benefits of alternative proteins include much smaller land requirements and fewer GHG emissions than "traditional" protein such as beef, pork, and chicken.[49] Other benefits include the ability to be grown on substrates that are either currently have little economical use (such as organic waste) or are available in abundance (such as seawater for seaweed).[50,51] Consumer acceptance may be a barrier to initial adoption of alternative proteins.[52,53]

48 Gerber PJ et al. (2013) Tackling climate change through livestock – A global assessment of emissions and mitigation opportunities. Rome, Italy: UNFAO

49 Oonincx, D., et al. (2010) An Exploration on Greenhouse Gas and Ammonia Production by Insect Species Suitable for Animal or Human Consumption. *PLoS ONE, 5*(12), e14445

50 UNFAO. (n.d.). Growing Seaweed. In Handbook on Eucheuma seaweed cultivation in Fiji

51 Makkar, H., et al. (2014) State-of-the-art on use of insects as animal feed. *Animal Feed and Science Technology, 197*, 1-33.

52 UNFAO (2013) Edible insects: future prospects for food and feed security. Rome.

53 Verbeke, W., et al. (2014) 'Would you eat cultured meat?': Consumers' reactions and attitude formation in Belgium, Portugal, and the United Kingdom. *Meat Science, 102*, 49-58.

NOVEL PRODUCTION SYSTEMS AND INGREDIENTS

Conventional agricultural systems have remained largely the same for many decades, especially since the "green revolution" of the early-mid 1900s. However the continually increasing need to produce more food for a growing population is ramping up pressure on finite environmental resources.[54]

At the same time, the agricultural labour force is seeing a skills shortage and overall decline in number of workers, leading many farmers to predict a labour shortage over the next 15 years.[55,56] This shortage is in part due to an aging workforce and unpopular image among young people; other barriers include land ownership or access to land.[57]

These increased environmental and labour pressures may result in new agricultural systems emerging or becoming more popular. These changes may include the use of new technologies as well as alternative and novel feed and food ingredients, within a supporting regulatory framework.

Farming system innovation

The FAO estimates that a 90% increase in global crop production will be needed to feed the future population.[9] One way to balance the need for increased food production with finite land and resources with which to grow food is to improve productivity and efficiency. Technology and innovations in farming systems (as discussed in the section 'Agri-food intensification and consolidation' in 'Resource pressures and risks') are likely to play a key role in this area.

Examples of farming system innovations include vertical farming and urban agriculture to capitalise on limited land in urban areas, though these may not be economically viable due to high energy demands.[58] Another innovation might be the use of water-based systems that grow indoors and without soil, such as hydroponics and aquaponics. Aquaponics combines hydroponics with an aquaculture system, raising fish - often tilapia - in the water that serves as the media for growing the crop. Increased adoption of bio-controls in agriculture - for example, using insects to manage pests as a way to reduce dependency on chemical inputs – is also likely to continue.

A rising use of technology in novel farming systems is through a management practice known as precision agriculture, a methodology which encompasses a number of different techniques, some or all of which may be used by a farmer. Precision agriculture techniques include variable rate technology, which uses specific maps of soil and plant data to calibrate precise spraying and seeding applications, and controlled traffic farming, which uses GPS and machine guidance to drive tractors and major farm appliances. Both techniques increase efficiency and can lead to reductions in chemical use and minimise soil compaction.[59,60] Precision agriculture techniques can also be used in livestock production to ensure efficient use of inputs.

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54 Bringezu S., et al. (2014) *Assessing Global Land Use: Balancing Consumption with Sustainable Supply.* A Report of the Working Group on Land and Soils of the International Resource Panel. UNEP.

55 Walport, M. (2014) *The Role of Science in Agriculture.* PowerPoint slides, presented to the Country Land and Business Association, on 12 November 2014.

56 Boston Consulting Group (2015) Crop Farming 2030: The Reinvention of the Sector.

57 J Sainsbury plc. (2015). Sainsbury's farming apprenticeship scheme to help support shortage of young farmers.

58 The Economist (2010) Vertical farming – Does it really stack up?

59 Joint Research Centre of the European Commission (2014) Precision agriculture – An opportunity for EU farmers - Potential support with the CAP 2014-2020.

60 http://cema-agri.org/page/precision-farming-key-technologies-concepts

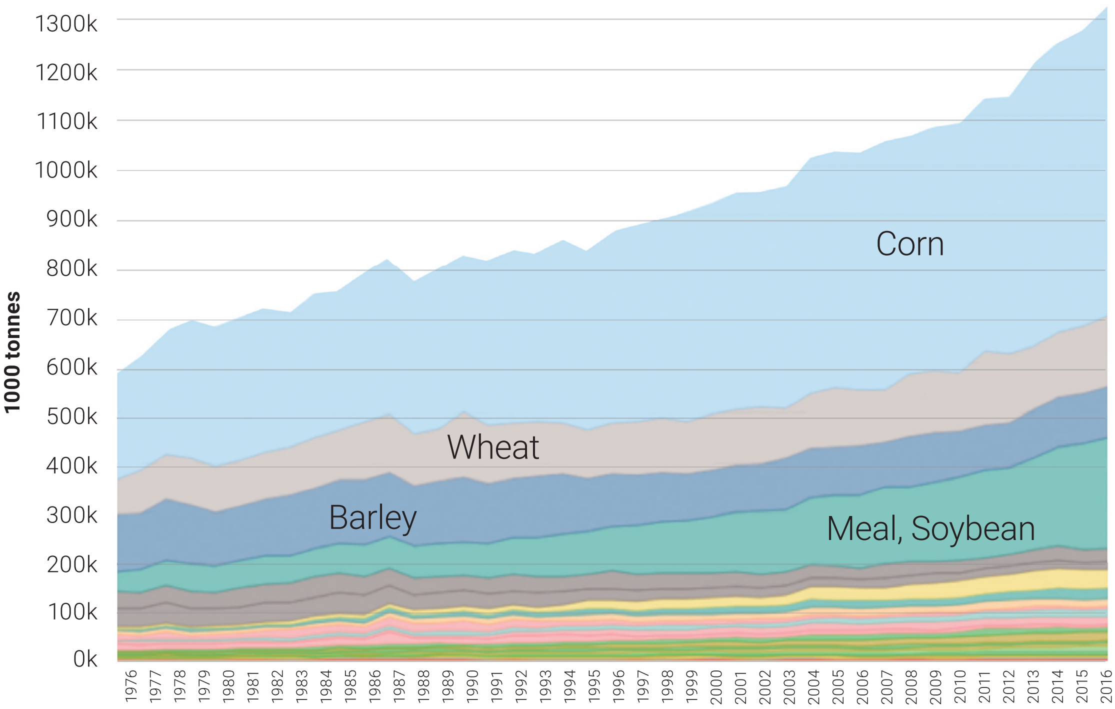
Across the value chain there is likely to be a move towards increased mechanisation and automation of processes, driven by factors such as the cost and availability of labour mentioned above. New systems taking advantage of automation include automatic milking systems on dairy farms, and the use of drones in crop production for weather predictions, data collection on crop damage and yield potential, and, in the future, precision application of pesticides, herbicides, and fertilisers.[61,62,63]

Another way in which technology is likely to contribute to production efficiency is through genetic improvements to crop and livestock species. This involves improvements to crop and livestock traits through the use of both conventional breeding and genetic engineering technologies, with the latter being a major focus of research and development. Improvements in genetic sequencing technologies will aid these innovations[64,65] but considerable public opposition may prove a barrier to the uptake of the genetically engineered crops and animals.

Livestock feed alternatives

Livestock agriculture - especially monogastric species such as pigs and poultry - is highly reliant on human edible crops such as maize, soy and wheat ***(see Figure 6 below)***. As land and resource pressures mount, producers are seeking alternative animal feeds.

Figure 6: Global crop used in animal feed, 1976-2016[66]



61 Butler, D., et al (2012). The impact of technological change in dairy farming: robotic milking systems and the changing role of the stockperson. *Journal of Royal Agricultural Society of England, 173*, 1-6.

62 CROPS Seventh Framework Programme. (2014). Intelligent sensing and manipulation for sustainable production and harvesting of high value crops.

63 Farming Futures. (2015). Pilotless aircraft will play critical roles in precisions agriculture.

64 Varshney, R.K., Terauchi, R., McCouch, S.R. (2014). Harvesting the Promising Fruits of Genomics: Applying Genome Sequencing Technologies to Crop Breeding. *PLOS Biol, 12*(6), e1001883.

65 Ray, S., Satya. P. (2014, 30 July). Next generation sequencing technologies for next generation plant breeding. Frontiers in Plant Science.

66 Analysis based on US Department for Agriculture PSD database by 3Keel

Livestock feed must meet two primary nutritional needs (in addition to vitamins, micronutrients, etc.): energy and protein.[67] Typically, corn (maize), wheat and barley are commonly used for energy, and while soy and alfalfa are used to meet protein needs. Livestock feed alternatives will then generally need to replace either the energy crop or the protein crop.

Alternative proteins therefore come into play again here. In addition to those listed in the theme above, bacteria are a source of alternative protein that is being developed specifically for animal feed (not human consumption). Bacteria assimilate high levels of protein and can be grown on wastewater or methane, without other feed inputs or sunlight, resulting in significant implications for land and resource use in production.[68,69] Using alternative proteins such as insects in animal feed (rather than for human consumption) may also be more palatable to consumers (and therefore potentially easier to scale up).[70]

Alternatives for energy crops such as maize and wheat are less advanced and popular than protein substitutes, and primarily revolve around other crops that may be more efficient at producing biomass per unit of input, such as sorghum, or crop by-products such as maize gluten feed.[71]

As alternative livestock feeds gain traction, legislation and regulation can be stumbling blocks. Sometimes this is a result of oversight, or legislation prepared before such feeds were possibilities. However, policymakers are working to change this[53] and in December 2016, the EU commission approved the use of insects in the aquaculture industry, though it is still not allowed in monogastric or ruminant feed.[72]

Novel ingredients

In addition to alternative proteins, there is potential for new ingredients and foods to be experimented with for human consumption. As with alternative proteins, some of these new and novel ingredients are aimed at substituting for foods that have a complicated relationship with sustainable food systems and sustainable diets (e.g. for environmental resource limitations, labour, or diet reasons), such as cocoa and dairy. New cocoa butter alternatives are being explored; e.g. in addition to exploring more uses for shea butter, wild mango has been identified as a potential substitute.[73]

Some of these new ingredients are focused on giving consumers healthier alternatives for popular food ingredients, to aid the adoption of a more sustainable diet and to meet rising trends in "flexitarian" diets, an example of which might be choosing to purposefully reduce meat and dairy consumption without going fully vegetarian or vegan (see 'Sustainable Diets'). For example, new technology is allowing manufacturers to produce cultured milk products based on coconut, such as yogurt, sour cream and cooking cream.[74]

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67 Queensland Department of Agriculture (2010) Pig production nutrient needs. Accessible at: https://www.daf.qld.gov.au/animal-industries/pigs/feed-nutrition/nutrients-diets/nutrient-needs

68 Nutrinsic. (n.d.). *Environmental and Sustainability.* Retrieved from: http://nutrinsic.com/environment-sustainability/

69 Overland, M., et al (2010). Evaluation of methane-utilising bacteria products as feed ingredients for monogastric animals. *Arch Anim Nutr., 64*(3), 171-89.

70 Verbeke, W., et al. (2015). Insects in animal feed: Acceptance and its determinants among farmers, agriculture sector stakeholders and citizens. *Animal Feed Science and Technology, 204,* 72-87.

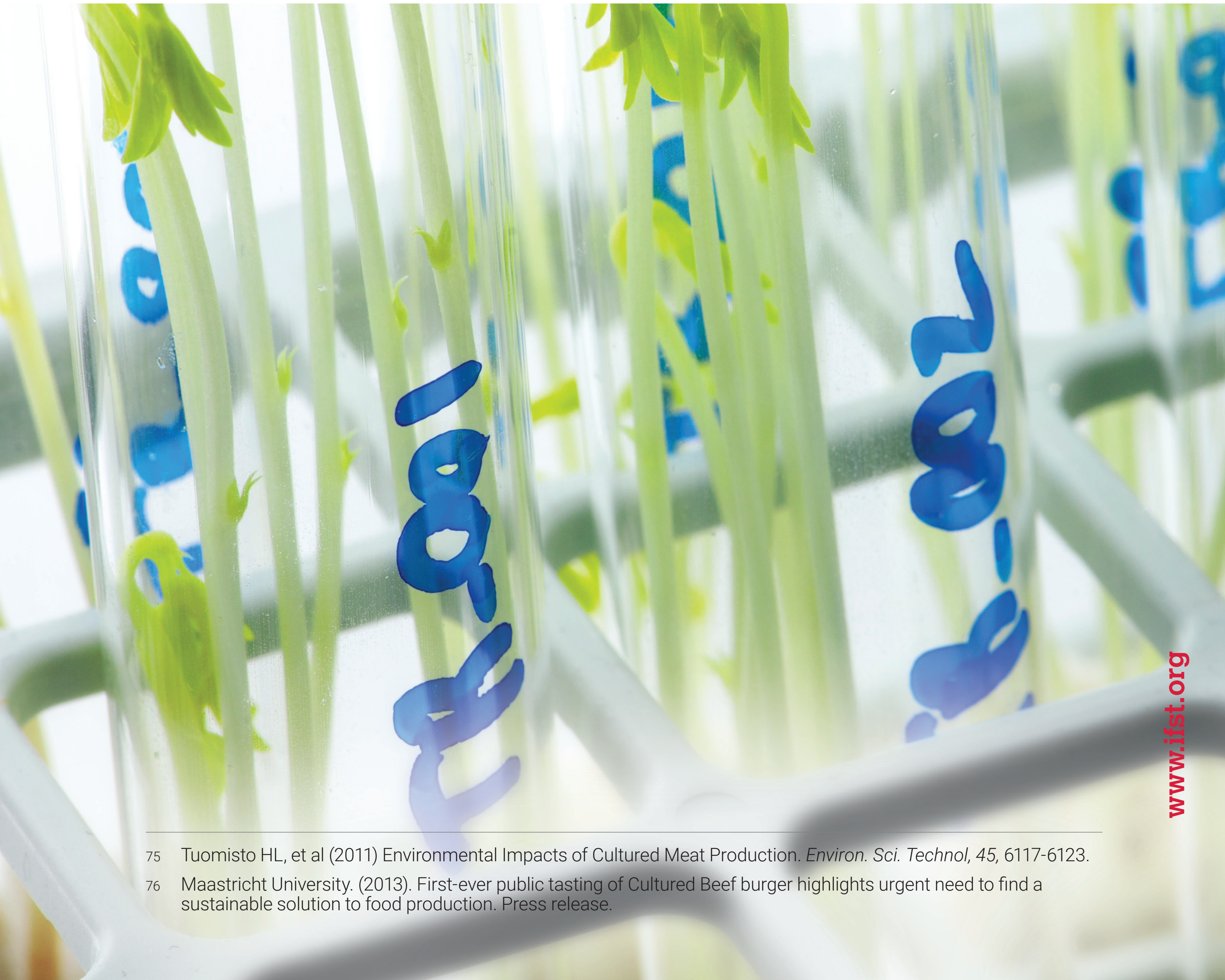
71 KW Alternative Feeds (nd) Maize gluten feed product specification. Retrieved from: http://www.kwalternativefeeds.co.uk/products/view-products/maize-gluten-feed-/

72 FeedNavigator (2016) Green light for insect protein in fish feed in EU

73 Akhter, S., et al (2016). Mangifera sylvatica (Wild Mango): A new cocoa butter alternative. Scientific reports, 6.

74 Foodingredientsfirst.com (2016) Hydrosol Develop Vegan Alternatives Based on Coconut

Genetic engineering is also giving rise to novel ingredients. "Lab-grown meat" is cultured meat grown from cells in a laboratory environment. In addition to ethical benefits, since the raising and slaughter of livestock is removed from production, lab-grown meat takes less energy and 99% less land to produce than conventional meat, and reduces GHG emissions by up to 96%.[75] While the technology is still new and prohibitively expensive, proponents say that commercially available ground beef, pork, and sausage is feasible in the next 5-10 years.[76] As with some of the alternative proteins and genetically modified crops, lab-grown meat may have some hurdles to overcome when it comes to consumer acceptance. Consumer safety also needs to be considered, within a supportive regulatory framework.



75 Tuomisto HL, et al (2011) Environmental Impacts of Cultured Meat Production. *Environ. Sci. Technol, 45,* 6117-6123.

76 Maastricht University. (2013). First-ever public tasting of Cultured Beef burger highlights urgent need to find a sustainable solution to food production. Press release.

CIRCULAR ECONOMY & SUSTAINABLE MANUFACTURING

The food manufacturing and processing sector has a critical role to play in a sustainable food system. As a central node of the value chain it has influence over the design of food products and packaging and the sourcing of ingredients - two key points for influencing the sustainability of food production and consumption. Food manufacturing will also play a pivotal role in creating a more circular food economy through reducing supply chain food waste and re-using by-products. Food manufacturing is itself a notable user of energy, water and raw materials in the UK – for example it is the 4th largest emitter of greenhouse gases after energy-intensive sectors steel, cement and chemicals.[77] Meat, baking and brewing sub-sectors are the top three users of primary energy in the food sector (see Figure 7). Energy and water use are typically 1.5%-3.5% of site costs ***(see Figure 8)***

Figure 7: Primary energy demand for subsectors of food and drink [77]

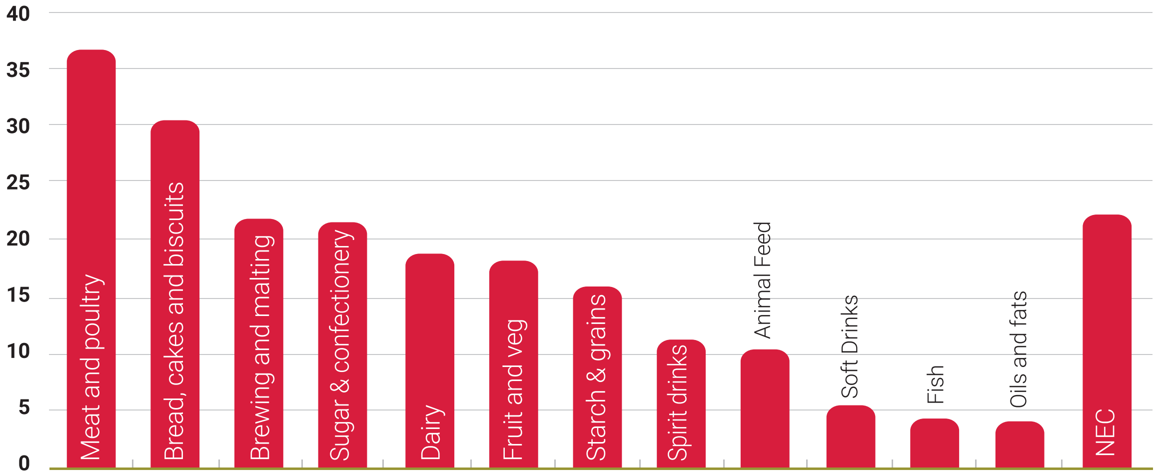
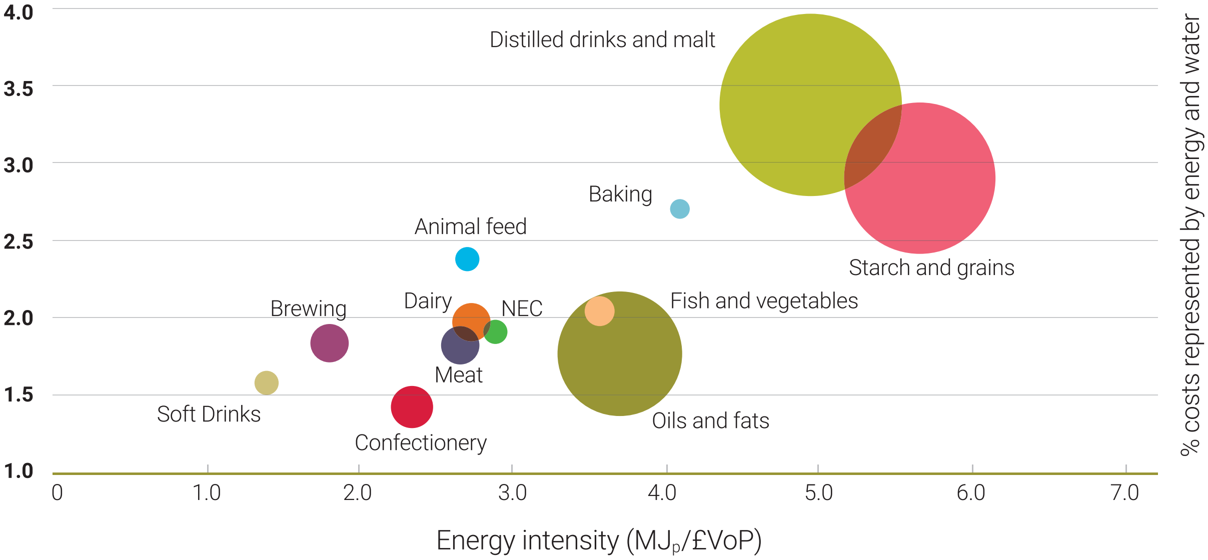


Figure 8: Primary energy intensity, percentage of costs represented by energy and water, and energy use per site (represented by the area of the data points) [77]



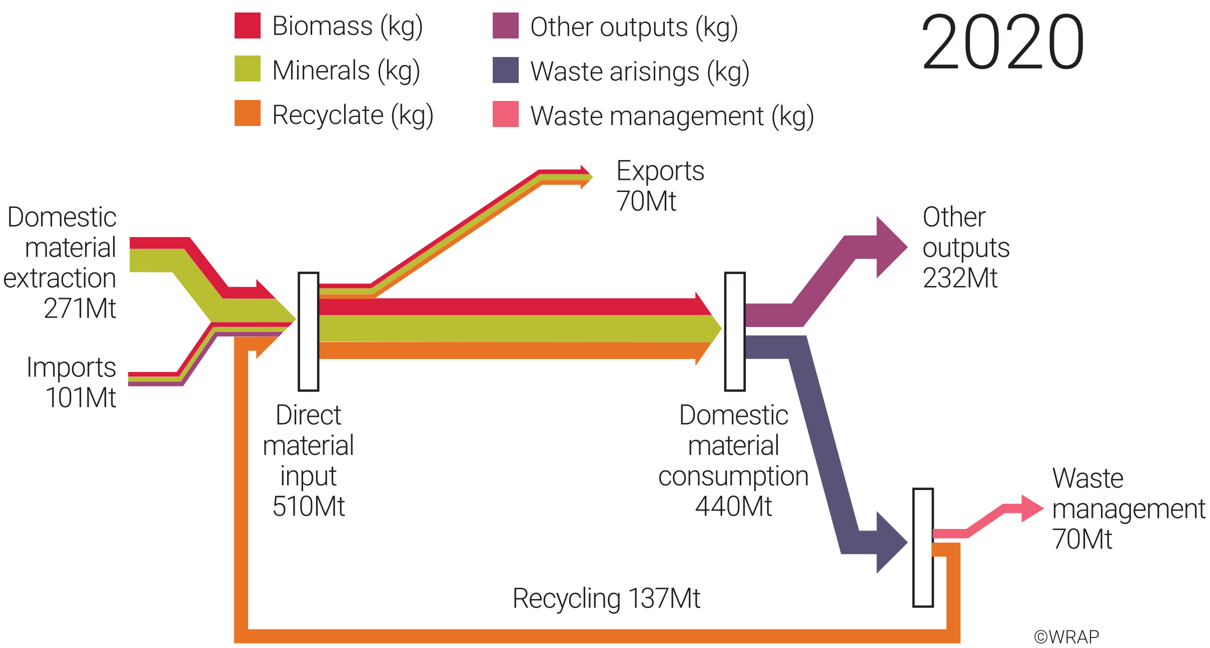
77 Griffin, P. Hammond, G. and Norman, J. (2016) Industrial energy use and carbon emissions reduction: a UK perspective. WIREs Energy and Environment

Circular food economy

The concept of the 'circular economy' has gained significant popularity in recent years and builds upon the principles of 'industrial ecology'. The aim of the circular economy is to move away from the current business model of "take-produce-consume-discard" and instead to "close the loop" of materials in order to reduce resource consumption and pollution. A circular food economy is one in which nutrients are recycled, by-products are fully utilised, waste is reduced, water use managed, and consumer diets move toward more diverse and more efficient food pattern.[78] Achieving a circular economy would contribute significantly to addressing resource constraints and reducing the impact of production and consumption. As a result it has become a key aim for policymakers and business, for example, the EU action plan for the Circular Economy [79].

Defra has estimated that low/no cost options for improving energy, water and waste resource efficiency could be worth up to £23 billion per year for business - of which a at least £500m is in agriculture, food manufacturing and retail sectors.[80] WRAP's vision is that by using circular economy measures the UK economy could save 20 million tonnes of materials and achieve a 20% reduction in waste by 2020 ***(see Figure 9 below)*** [81].

Figure 9: WRAP's vision of a more circular economy by 2020[71]



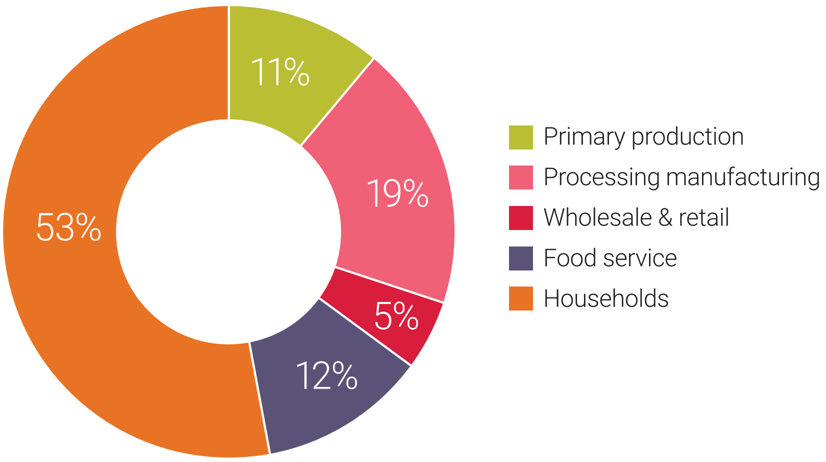
As part of the circular economy agenda, waste 'valorisation' is gaining popularity. Waste valorisation techniques aim to convert previously low value waste materials (e.g. fruit stalks, skins and leaves) into products such as pharmaceuticals, bioplastic materials and fuels. The food system currently produces a significant amount of by-products and waste that have the potential to be 'valorised' into new products. For example, a surplus of 13 million tonnes of whey are produced by the dairy sector in the EU each year which could be better utilised[82].

78 Jurgilevich, A. (2016) Transition towards Circular Economy in the Food System. Sustainability 8, 69
79 EU Commission (2017) Report on the implementation of the circular economy action plan
80 Defra (2011) The Further Benefits of Business Resource Efficiency
81 WRAP (2015) WRAP's vision for the UK circular economy to 2020
82 WRAP (2015) Food Futures

Food waste

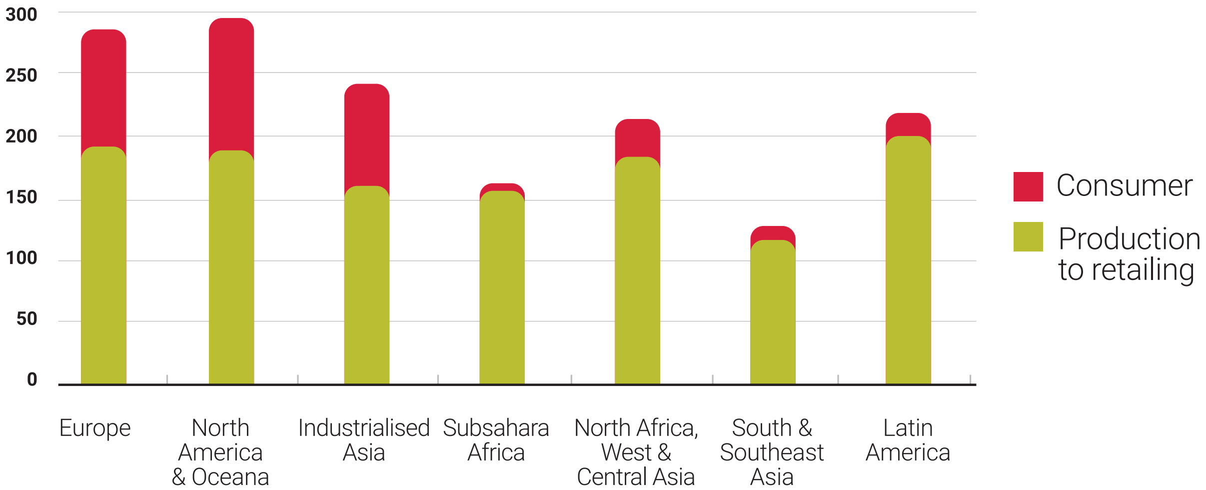
Food waste occurs across the whole food system – with the most significant source in the EU being food thrown away by consumers at home ***(see Figure 10 below)*** The Waste Resources Action Programme (WRAP) estimate that 12 million tonnes of food waste occur in UK households, hospitality and foodservice, food manufacture, retail and wholesale – the scale of food waste is more uncertain and is currently the focus of further research as there is anecdotal evidence of high waste rates in some sectors e.g. fresh produce. The waste has a value of more than £17 billion a year, and is associated with approximately 20 million tonnes of greenhouse gas emissions.[83] WRAP has calculated 60% of this waste could have been avoided.

Figure 10: Summary food waste arisings in the EU-28 [84]



In industrialised countries, more than 40% of food waste occurs at the retail and consumer levels ***(see Figure 11 below)***.[85] In the UK, 7 million tonnes of food is wasted annually in the home; this comprises almost half of the UK's total food waste.[86,87]

Figure 11: Per capita food loss and waste at production and consumption (kg/year) [85, 88]



83 WRAP (2016) Estimates of Food Surplus and Waste Arisings in the UK

84 EU FUSIONS (2016) Estimates of European food waste levels. European Commission

85 UNFAO (n.d.) Key facts on food loss and waste you should know

86 WRAP (2013). Estimates of Food and Packaging Waste in the UK Grocery Retail and Hospitality Supply Chains

87 Love Food Hate Waste (n.d.) Why save food

88 UNFAO (2011), Global Food Losses and Food Waste - extent, causes and prevention.

If the rate of overall food waste were cut in half, WRI estimates that the world would need 1,314 trillion kcal less food per year than it would in the current projected business-as-usual scenario.[89] This would translate into a greatly reduced burden on the environment to produce food for a growing population.

Strategies for reducing consumer food waste include packaging innovation and consumer education. For example, using apps as well as portion and meal planners to aid with shopping and cooking, increasing understanding around date labels (e.g. "use by"), and education on ways to keep food fresh ***(see below)***.[90]

Packaging innovation and education

Packaging plays an important role in reducing food waste by giving portion guidance and extending shelf life.[93] This is a particular area for focus as over 50% of household food waste arises from products 'not used in time' - including products that have spoiled (mouldy, mushy or rotten) as well as those that have passed a date label.[91] There are two key areas at play – keeping food fresh for longer, and increasing understanding around food storage and date labels.

Packaging innovations may help to extend product life. Examples of recent and future areas of innovations include:

- **Re-sealable packs** e.g. for large formats of cheese
- **More diverse pack sizes** to suit different needs e.g. smaller packs of bread
- **Customised modified-atmosphere packaging** for fruit and vegetables and ultra-filtration to keep foods fresher longer. Vacuum packing in meat extends shelf life but has been associated with the growth of virulent, anaerobic bacteria.
- **On-pack freshness sensors and indicators**. Issues surrounding liability and consumer handling may make these innovations hard to implement at retail level but they could help to reduce waste within the supply chain.

Packaging innovations must work in conjunction with clearer and more consistent food labelling to increase customer understanding of the role packaging plays in extending shelf life. Over 60% of consumers believe that keeping fruit and vegetables in their original packaging makes them go off faster, mitigating the benefits of packaging innovations.[92]

Date labelling is also often misunderstood; for example 60% of customers believe they must freeze products on the day of purchase rather than before the expiry date leading to increased wastage.[93] Retailers and regulators have an important role to play to tackle these misconceptions surrounding packaging and food storage. Schools may also contribute to consumer understanding by educating children on food labels and storage.

89 WRI (2013) Reducing Food Loss and Waste - Creating a Sustainable Food Future, Installment Two

90 Examples from lovefoodhatewaste.com

91 WRAP (2012) Household Food and Drink Waste in the United Kingdom

92 WRAP (2013) Consumer Attitudes to Food Waste and Food Packaging

93 WRAP (2012) Helping Consumers Reduce Food Waste – A Retail Survey 2011

TRANSPARENCY, TRACEABILITY AND TRUST

Several trends and high profile events are increasing consumer, policy maker and investor interest in ethical and environmental management of food supply chains. In particular, the rise of social media, the work of campaigning NGOs, and changing consumer expectations mean that there is growing scrutiny on practices from farm to point of sale. Improving practices and building trust will likely mean greater transparency, an evolution of the use of standards and better use of food chain data.

Transparency and disclosure

In this current climate, increasing transparency throughout the food chain is becoming more important, as the risks that arise from untraceable supply chains become more significant. New regulations such as the Modern Slavery Act provide greater impetus to companies to work on transparency within their own supply chains.[94]

Transparency can increase consumer confidence in products and companies and allow them to make more informed decisions. For companies, it can reduce the ethical, financial, and supply risks that can result from a lack of transparency in one's supply chain. Many companies, aware of these benefits, are now beginning to put serious effort towards improving the transparency and traceability of their supply chains. For example, M&S now makes all of their Tier 1 suppliers publicly available through an interactive map on their website.[95]

Retail and environmental standards are being brought up to date with this trend towards increasing transparency. The British Retail Consortium (BRC) has recently updated their standard with new traceability and transparency criteria, including new requirements on labelling and packaging, and an annually required formal risk assessment on food fraud.[96] Similarly, the ISO14001 now encourages a whole supply chain perspective on environmental management.[97] Other organisations are also creating important new initiatives to incentivise transparency and disclosures. For example, the Task Force on Climate-Related Financial Disclosures is currently developing a voluntary climate-related financial risk disclosure for companies to use to provide information to investors and other stakeholders.

94 Ethical Trade Initiative (2016) Corporate Leadership on Modern Slavery
95 Marks & Spencer (2016) Interactive supplier map (https://interactivemap.marksandspencer.com/)
96 GFSI (2015) Key Changes to BRC Food Version 7
97 ISO (2015) ISO 14001 Environmental Management Systems - Revision

Food chain data

The use of 'big data', mapping and web-connected technology such as the Internet of Things has the potential to revolutionise many sectors - including the food supply chain.[98,83] Areas of innovation with the food system include:

- Optimising agricultural and manufacturing systems - including better demand and supply management using real-time data.
- Increasing supply chain traceability and risk management - including the identification of current and future risks to supply risks from disruptions such as climate change.
- Enabling faster product development and innovation.
- Creating smarter logistical chains.

Specific examples of potential future data and tech innovations in food chains include the development of 'food scanners' to enable producers and consumers to analyse food composition, nutrition and potentially harmful ingredients.[99]

It is important to note that there are significant potential data security challenges associated with an increasingly connected food system.

Standards and certification

Standards and certification have become a key tool for implementing sustainability within value chains. These cover private standards developed by retailers and manufacturers (such as the Unilever Sustainable Agriculture Code) as well as standards that are open to all, such as Global GAP, Fairtrade and Rainforest Alliance.

While these approaches to defining and implementing sustainable practices have grown in popularity and coverage – there remains questions of the extent to which they can drive desired environmental and socioeconomic impact[100]. This will remain a key focus of research in the coming years, led by organisations such as ISEAL – the global association of sustainability standards. ISEAL, along with standards setters and users are exploring potential areas for innovation to improve the effectiveness and efficiency of all aspects of standards development and use[101]. One area of particular interest is the use of remote sensing and other technologies to support the verification of standards adherence – for example using satellite imagery to identify deforestation.

In addition to supply chain standards, voluntary agreements such as the Courtauld Commitment or the Deforestation Resolution of the Consumer Goods Forum also play an important role in bringing together businesses to reach a common target[102].

98 McKinsey (2016) How big data will revolutionize the global food chain

99 European Commission (2016) Horizon Prize for Food Scanner

100 Blackman, A. and Rivera, J. (2010) The Evidence Base for Environmental and Socioeconomic Impacts of "Sustainable" Certification

101 Herding, W. & Fischer, S. (2015) Smart Data – An Exploration into Technology Innovations for Sustainability Standards. Report for the ISEAL Alliance, London

102 United Nations Department of Economic and Social Affairs (2013) Voluntary Commitments and Partnerships for Sustainable Development

CONCLUSIONS AND RECOMMENDATIONS

IFST can play an important role in the development of a more sustainable food system. Based on this review we have developed three general recommendations for future IFST activity, as well as 18 specific recommendations under the six food system themes.

The recommendations have been designed to generally support IFST's mission to facilitate the development and sharing of knowledge, support professional development, represent the industry on science matters and encourage new entrants into the sector.

General recommendations

Educate and inform future food professionals

Knowledge of food system sustainability and solutions is still too limited within food and drink businesses and something needs to be done to accelerate its embedding in everyday business practice. As a trusted organisation with competencies that are core to food production, IFST could play an extremely important role in facilitating this. This could be through a variety of approaches, such as:

- Including food system sustainability explicitly in future versions of GMP
- Working with universities and other educational institutions to ensure food systems thinking is reflected in courses that feed the food industry
- Participating and contributing to business, research and policy initiatives that tackle important topics (e.g. sustainable diets, alternative proteins and the circular food economy)
- Developing web materials, tools and information statements on food sustainability topics – some examples are given in the section below, however this could be brought together in a summary report & event exploring the role of science and technology in securing sustainable food security
- Partnering with training providers who can deliver food systems training as part of on-going member CPD
- Holding events that focus on important food system topics

Contributing to the food sustainability evidence base

Delivering food system sustainability is likely to require changes to practice and policy – this comes with risks and uncertainties that need addressing. IFST can help address these concerns and find new solutions by analysing future food sustainability research and evidence needs through engaging a range of stakeholders. This could be used as the basis for commissioning, supporting or promoting new research and industry guidance. This guidance could draw upon existing reviews of research questions – such as those developed by the UK Food Security Programme and other funders.[103] Key topic areas include:

- Food chain data and traceability
- Resource efficiency and food safety/quality conflicts e.g. water re-use, by-products
- Packaging innovation and materials
- Novel proteins and production systems (including automation)

103 Ingram JSI et al. (2013) Priority research questions for the UK food system. Food Security, volume 5, pp 617-636

Partner for food sustainability

The complexity and inter-disciplinary nature of food system sustainability requires partnerships working between the private sector, public sector, NGOs and academia. Indeed, collaboration is a key element of the new UN Development Goals. IFST should develop a partnership strategy that will help deliver the organisation's sustainability ambitions. IFST's credibility and expertise will also be a welcome addition to existing initiatives and collaborations.

It is recommended that the identification and engagement of potential partners is prioritised as this will fast-track IFST's understanding of how they could best contribute their skills, experience and network to the challenge of food system sustainability. Where appropriate, potential partners are identified in the sections that follow.

Recommendations against key themes

In this section, we summarise suggestions on how IFST could contribute to the six themes identified in our report.

Resource pressures and risks

IFST should contribute to UK and global efforts to increase food system resilience. This could be achieved through:

- Developing guidance on **how emerging global environmental risks are/will impact food industry operations** and result in undesirable outcomes e.g. reductions in food safety, quality, availability and increases in cost. Key environmental risks are likely to include climate change and water availability/quality.
- Building on the above, IFST should **support research that aims to identify how food science and technology could help the industry adapt to the impacts of climate change** on raw material quality and quantity. This could be done in partnership with UK research councils and funding bodies active in this area such as Innovate UK, Global Food Security Programme, etc.
- Using knowledge of food safety and other raw material risks to work with industry (e.g. FDF, Chilled Foods Association, WRAP, etc.) to identify how a **broader set of environmental and social risks can be integrated into food business and supply chain risk management.** Currently this is not being adequately addressed by the food industry. This could be achieved through inclusion of information and tools in GMP guidance, CPD and higher education courses.
- As part of its influencing activities, IFST should be a **vocal supporter of efforts to address climate change mitigation and adaptation** in the food sector. This could be achieved through industry campaigns, promotion of research (above), media activity and new partnerships.
- Finally, IFST could **develop partnerships and projects with key academic researchers in this field**, for example the Oxford Martin Programme on the Future of Food.[104] Through this partnership IFST could help researchers understand how to translate science into food industry action.

104 http://www.futureoffood.ox.ac.uk/

Decent work and equitable trade

Considering the social issues within the food supply chain is not a core area of IFST activity, however issues such as child labour and working conditions are of increasing interest to business, policymakers and the public.

- Emerging agri-food technologies could potentially have a positive/negative impact on the working conditions and labour requirements of some agri-food sub-sectors and so **IFST should consider these implications within the scope of future research and communications about new technologies**. For example, IFST could partner with credible social and environmental NGOs to explore the advantages and disadvantages of a move towards more automation in the agri-food supply chain.

Sustainable diets

Sustainable diets – the goal of achieving environmental and social outcomes while at the same time delivering the correct nutrition – is a key theme of interest to researchers and increasingly to businesses too. IFST's experience of working on the nutritional aspects of food makes the organisation a strong potential partner for work in this area.

- Food scientists are increasingly being challenged to deliver against sustainability and nutritional goals. **'Designing in sustainability'** is a critical intervention that is needed, but all too often food technologists do not have the knowledge or tools to be able to integrate sustainability into NPD or R&D processes. IFST should help develop and disseminate best practice guidance on how to incorporate sustainability into the assessment of new processes and products; working with stakeholders such as FDF and WRAP – as well as businesses who have a track record in publicly promoting sustainable diets e.g. Unilever, Nestle, PepsiCo, and Sodexo.
- **Food waste** reduction remains a key priority for businesses and policy-makers – particularly in the home, but also at all stages of the value chain. IFST should actively contribute to the development of solutions to this global challenge through the application of science and technology. WRAP (and its Courtauld 2025 voluntary agreement) is the obvious organisation/initiative to engage with to start with.
- UK NGOs and researchers who are particularly interested in the sustainable diets agenda include WWF-UK, Food Climate Research Network, The Rowett Institute, The Nutrition Group at the London School of Hygiene and Tropical Medicine, and Centre of Food Policy at City University London.

Novel production systems & ingredients

- Central to the sustainable diets agenda **is the future of protein.** There are several new food technologies that are intended to reduce resource dependence and increase nutritional value of animal feeds and human foods – for example, insect-derived proteins, 'lab meat', plant-derived proteins, etc. This topic is of huge interest to business – with many of the major multi-nationals exploring investing in product development. Many of the potential solutions could pose technical, legal, and consumer-acceptability challenges to the food industry and so IFST is well-placed to contribute to this evolving area. An example initiative that has been successful at recruiting members is Forum for the Future's Protein 2040.
- **Automation and increased use of data-enabled technology and 'artificial intelligence'** in the food system is an emerging area of interest for businesses, NGOs and policymakers. IFST could promote or support research into this area and publish findings on the business and societal opportunities and challenges associated with this trend.

Circular economy and sustainable manufacturing

Increased resource efficiency is increasingly being framed by policymakers and businesses around the concept of a 'circular economy'.

- In the food industry, the circular economy will require the increased use of wastes and by-products as inputs to other processes and sectors. This poses challenges from a food safety and regulatory perspective. **IFST needs to be engaged in policy and technical discussions** about the circular food economy so that it can be achieved safely and with the support of the food sector
- Achieving a circular economy will require improved linkages between sectors. **IFST should approach analogous industry bodies in sectors such as chemicals and pharmaceuticals** to explore opportunities for joint projects and initiatives.
- On a more practical note, **IFST could support and promote industry efforts to increase resource efficiency** through reducing energy, waste and water in the food industry. For example, through encouraging the safe recycling and re-use of water with SMEs or working with stakeholders such as WRAP, Campden-BRI, FDF. As there is a lot of focus here by various NGOs and businesses themselves, IFST should speak with these organisations to better understand how it can support these aims.
- IFST could facilitate **the creation of new practical energy standards**, with demonstrable value, for SMEs, working with stakeholders such as government (BEIS, Environment Agency), standards organisations (e.g. BSI), and FDF.
- **Product date/storage/usage labelling information** is acknowledged to have a role in how businesses and consumers use food products – and so affects how much is wasted. IFST should engage with WRAP and other stakeholders such as FDF and CCA to explore how they can maximise the usability of foods.

Transparency, traceability & trust

The final theme concerns the increasing trend within the food industry to understand – and in some instances disclose publicly – the provenance of products and ingredients. This theme has strong relevance to IFST given its role in supporting the safety of food. Given this, it feels like an area that IFST would have credibility and influence.

- IFST could increase industry **knowledge of emerging traceability and transparency technologies in supply chains** – for example there is interest in the application of emerging IT such as 'block chain databases', satellite technology, RFID, etc.
- **IFST could support development and uptake of innovative approaches to assuring the sustainability of supply chain actors.** Currently this is delivered through audit/inspection against standards – although there is potential for this to evolve in the future to new models. ISEAL is the key stakeholder in this regard and is undertaking a lot of research on the future of standards. This would be the first organisation to engage with as they represent all sustainability standards globally, but have a major office in London.

ANNEX RESEARCH APPROACH

To identify the themes and topics to be covered in this report, 3Keel used the approach summarised in ***Figure 12 below***.

Figure 12: Research method process

Topic long listing	Four 3Keel staff all with experience of food systems research and UK/ global agri-food business identified key topics durng a face-to-face meeting
Long list consolidation	Lead author Richard Sheane consolidated topics into a draft long list for comment by the team. A consolidated draft topic long list was created.
Topic ranking	Four 3Keel staff ranked the topic list for "IFST relevance ***(see description below).*** Average rank was calculated Rankings were reviewed by IFST and edits made based on feedback
Theme identification	Ranked topics were used to identify six high level themes Themes reviewed by IFST and edits made based on feedback
Draft report	Literature review (including grey sources) undertaken on identified topics and themes Draft report reviewed by IFST
Final report	Final report created based on IFST comments

Topics were ranked for 'IFST relevance' by 3Keel staff. The purpose of this process was to guide the research focus; help identify themes which are most relevant to IFST members; and ensure no significant topics were missed. It was not intended to give an objectively 'correct' ranking of all food system issues. Given this objective, we think the method was fit-for-purpose and has delivered the desired outputs.

The ranking itself was done as follows: four experienced 3Keel project team members reviewed the 51 topics identified at the 'long list' stage and scored them for relevance against 4 areas that are important 'competency areas' of IFST:

- Good agricultural and manufacturing practice (GAP/GMP)
- Food engineering and technology
- Food safety
- Food regulations

To help with this process scorers were provided with accompanying text descriptions and the chance to seek clarifications during a group meeting.

The scoring approach used a 1-3 scale:

1. Not relevant or marginally relevant to IFST competency areas
2. Moderately relevant: topic is not strategic area of operation for IFST but has clear links to these topics
3. Highly relevant to IFST – topic is core to IFST competencies and interest areas

The scores from each team member were combined to create an average rank – as well as an assessment of the spread of ranking between team members. Where there was a large spread of scores we investigated the reason for this variability and adjusted scores based on the consensus.

An example of the scoring process for 'circular economy' is shown in ***Table 1 below***. This topic was described as follows: "Developing a 'circular economy' has become an important goal for policymakers and businesses wishing to improve resource efficiency and security – as well as reducing the environmental impact of production and consumption. Examples of approaches in the food system include waste valorisation and nutrient recycling".

Circular economy was one of the highest scoring topics as many of the issues are very relevant to IFST.

Table 1: Scoring of 'circular economy' relevance by 4 members of project team (A-D)

Scorer	Good agricultural and manufacturing practice	Food engineering & technology	Food safety	Food regulations	Total score
A	3	2	3	3	11
B	3	3	3	2	11
C	3	3	3	3	12
D	3	2	3	2	10
Average					11

Having ranked the topics we also identified six high-level themes that covered as many of the most important topics as possible. These themes were drafted by project lead Richard Sheane and then reviewed by the team and ultimately by IFST.

Table 2 below summarises the topics identified by the project team and IFST reviewers. These were scored for 'IFST relevance' and allocated to six themes.

Table 2: Food system topics

Topic name	Theme	Score
Animal disease risks	Resource pressures & risks	**11**
Circular food economy	Circular economy & sustainable manufacturing	**11**
Pesticide dependence and regulation	Resource pressures & risks	**11**
Alternative proteins	Sustainable diet	**10.25**
Data and internet-of-things	Transparency, traceability & trust	**10.25**
Food adulteration & fraud	Transparency, traceability & trust	**10.25**
Genetic improvements of crop and livestock	Novel production systems & ingredients	**10.25**
Packaging innovation	Circular economy & sustainable manufacturing	**10.25**
Transparency	Transparency, traceability & trust	**10.25**

Water availability & quality	Resource pressures & risks	**10.25**
Consumer food waste	Sustainable diets	**10.00**
Livestock feed alternatives	Novel production systems & ingredients	**10.00**
Automation	Decent work & equitable trade	**9.75**
Consumer labelling & communications	Transparency, traceability & trust	**9.75**
Novel ingredients	Novel production systems & ingredients	**9.75**
Supply chain risk monitoring	Transparency, traceability & trust	**9.75**
Antibiotic use in agriculture and aquaculture	Resource pressures & risks	**9.25**
Climate impacts on food system	Resource pressures & risks	**9.25**
Agricultural input dependencies	Resource pressures & risks	**9.00**
Risks from specialisation/ intensification of crops and livestock production	Resource pressures & risks	**9.00**
Food waste	Circular economy & sustainable manufacturing	**8.75**
Embedding eco-design in new product development	Circular economy & sustainable manufacturing	**8.50**
Farming system innovation	Novel production systems & ingredients	**8.5o**
Globalisation of supply chains	Resource pressures & risks	**8.50**
Intensification of agriculture	Resource pressures & risks	**8.50**
Food security as a driver of government and corporate food policy	Decent work & equitable trade	**8.25**
Local & global environmental limits	Resource pressures & risks	**8.00**
Re-structuring of supply chains to deal with new risks & opportunities	Circular economy & sustainable manufacturing	**8.00**
Changing consumer food and drink preferences	Sustainable diets	**7.75**
Concerns over animal welfare due to intensification of agriculture	Transparency, traceability & trust	**7.75**
Consumer health	Sustainable diets	**7.75**
Depletion of fossil fuels (energy security)	Resource pressures & risks	**7.75**
Standards & certification	Transparency, traceability & trust	**7.75**
Changes to trade policies	Transparency, traceability & trust	**7.50**
Competition for land resources	Resource pressures & risks	**7.50**
Specialisation of production systems	Resource pressures & risks	**7.50**
Depletion of phosphate reserves	Resource pressures & risks	**7.00**
Ecosystem service degradation - pollinators etc	Resource pressures & risks	**7.00**
Food system input price volatility	Resource pressures & risks	**7.00**
Loss of diversity in crops, varieties	Resource pressures & risks	**6.75**

Wild fish stock depletion	Resource pressures & risks	**6.75**
Transport cost reductions	Circular economy & sustainable manufacturing	**6.5**
Growth in use of renewable energy	Circular economy & sustainable manufacturing	**6.25**
Land degradation, conversion & competition	Resource pressures & risks	**6.25**
Investor activisim	Transparency, traceability & trust	**6**
Smallholder agriculture	Decent work & equitable trade	**6**
Consolidation of power within food system	Resource pressures & risks	**5.75**
New partnerships & collaborations	Circular economy & sustainable manufacturing	**5.75**
Urbanisation of the world's population	Decent work & equitable trade	**5.75**
Human rights	Decent work & equitable trade	**4.5**
Increasing acidification of oceans	Resource pressures & risks	**4.5**

This report was written by **Richard Sheane**, **Catherine McCosker** and **Sam Royston** (3Keel LLP, Oxford) on behalf of IFST.

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