Developing a National Food Strategy

Open call for evidence

Submission from the National Engineering Policy Centre.

October 2019

Cross-Engineering Sector Contribution

This is a cross-engineering sector response, produced by the National Engineering Policy Centre (NEPC), an ambitious partnership led by the Royal Academy of Engineering between 39 different UK engineering organisations representing 450,000 engineers.

The response was developed through contributions from across the engineering profession. In particular, the Academy has worked closely with the Institution of Chemical Engineers (IChemE) and the Institution of Agricultural Engineers (IAgrE), including a workshop held on Friday 11th October, 2019. We would also like to thank the Institution of Mechanical Engineers (IMechE) and the Institute of Physics (IoP) for their contributions and comments.

Structure of the response

As part of this cross-engineering profession response, we have considered the different stages of the food system, as laid out in **Figure 1**. Key messages have been summarised in the main body of the response. Further detail and evidence has been appended and is structured around the different stages in **Figure 1**. This response clearly demonstrates that engineering, the chemical and the physical sciences play a key role in realising opportunities and innovations across the whole food system.

Further information and support

Timeframes for this response have not allowed for a full exploration of the expertise and innovations available, it has concentrated on mapping the areas to which the engineering sector makes a clear contribution.

The NEPC would be very happy to work with Defra and partners in the engineering sector to provide follow up engagement for further exploration of any of the areas outlined in this submission.

Contact: Dr Andrew Chilvers (andrew.chilvers@raeng.org.uk).

Key messages

1. Any vision for the food system must include technological advances based on engineering science, and the use of **systems thinking to build an understanding of the benefits and risks** of new innovations and practices[1]. The food system is inseparable from hydrological and water systems, ecological systems, waste, energy and human health. A whole-system approach is essential to formulating policies that recognise the many interconnections between the food system and human, ecological and economic health; it relies on close collaboration **across professional boundaries** e.g. engineering and the biological sciences.

2. Two important directions of travel are:
   - **A reduction in excessive consumption**, which is linked to negative health outcomes, such as obesity, and generation of waste and related environmental impacts.
   - **A move towards regenerative systems**, that require circular economies across the food system. This will lead to a greater level of recovery, reuse and recycling to reduce raw material inputs throughout the production, processing, packaging, storage, distribution, retail, consumption, waste and disposal stages of the food system. This **move away from a linear 'farm-to-fork' framing**, emphasises the need for by-products and wastes to be utilised as productive inputs, and fed back into production (**Figure 1**). This should be underpinned by maximum use of renewable energy sources. There have been improvements made in these areas but more can and must be achieved.

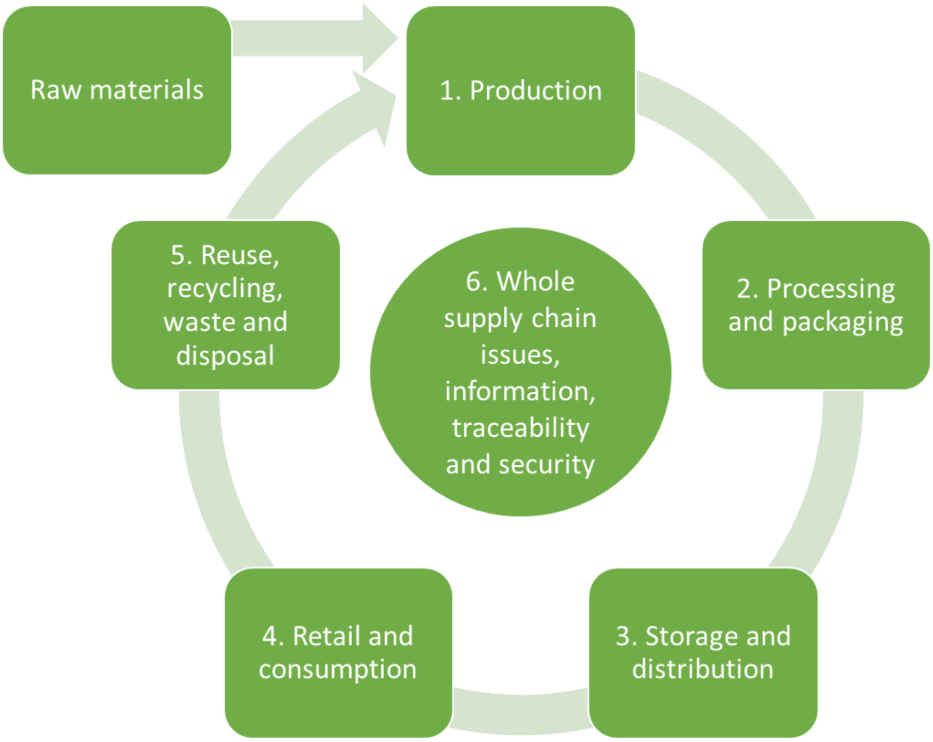
3. The real implications of changes and innovations to the food system must be fully understood. For example, life cycle sustainability assessment studies show that 'circular' does not necessarily mean 'sustainable'. **Full life cycle analyses using tools such as life cycle assessment** (environmental sustainability), life cycle costing (economic sustainability) and social life cycle assessment (social sustainability) must be applied.

4. **A 'sustainable' food strategy should be based on a 'triple bottom line'** encompassing a broad range of issues across economic, environmental and social sustainability, ensuring that trade-offs are properly explored and addressed. Focusing on single policy issues is likely to cause unintended consequences elsewhere. There is a need to ensure that the market captures what are currently externalities; ensuring that the financial costs of food systems better reflect the environmental and social costs.

5. As the UK leaves the European Union, there are opportunities to:
   - shift the existing supply-side subsidy structure from land area and inputs to payments for ecosystem services
   - increase incentives for sustainable farming practices that regenerate soils and promote biodiversity.

[1] Agricultural Engineering: a key discipline for agriculture to deliver global food security, Institution of Agricultural Engineers, 2012

Figure 1: A whole-system approach with life-cycle thinking



6. **Investment and planning decisions that support transition to regenerative circular food systems are needed.** A focus solely on short-term benefits and returns can prevent a shift towards longer term, sustainable food systems. The long-term benefits of soil and ecological regeneration are often omitted from decision-making. SMEs typically lack the resources required to implement changes toward circular economic models.

7. Existing technologies available on the market which demonstrate economic and environmental benefits/savings have suffered from limited uptake[2]. **Greater policy focus on support for uptake and deployment would be beneficial**.

8. Standard cost-benefit analysis can often treat individual technologies in isolation. It is essential that costs and benefits of technologies are examined in combination with other developments with which they can be combined. Knowledge and good practice dissemination schemes, such as the successful Monitor Farms initiative[3], could be replicated across much of the food system (not just on-farm production), especially when encouraging the uptake of innovations by SMEs.

9. **A systems approach with full life cycle assessment is essential in all policy decisions**. Pursuit of net zero carbon emissions will impact upon food production and consumption and the associated land use and agricultural practices. Future food policy

[2] For example, auto section control technology is a precision application technology which has some evidence of economic and environmental benefits (approximately 10% less application of agrochemicals). It has seen unexpectedly low uptake.

[3] The Monitor Farms initiative, run by the Agriculture and Horticulture Development Board (AHDB), brings together groups of farmers to share performance information around new innovations and practices around a nationwide network of host farms that commit to a particular innovation over 3 years and to dissemination and sharing activities.

needs to ensure it drives outcomes and agricultural practices that are sufficiently sensitive to local economic, ecological and environmental characteristics.

Summary

10. In this response, the engineering community has begun to map its contribution to advances in the food sector, this draws on previous exercises from across the profession[4]. It show that engineering, working with partners across the chemical and the physical sciences, plays a key role in realising opportunities, developing and deploying innovations across the whole food system. Greater public understanding on how these innovations will realise the ambition for a healthy and environmentally sustainable food system for the future is important.

Annex 1: Production

Technological advances

11. Food and drink manufacturing is the largest manufacturing process industry in the UK and the Office for National Statistics recently identified it as one of four major contributors of growth between 2008-2018[5]. It is a diverse sector, encompassing enterprises from farms to high-tech manufacturers. It involves smaller companies as well as global giants – 96% of the 6,600 or so businesses in the sector range from micro- to medium-sized[6]. Much of the sector is potentially amenable to automation, including micro-production close to points of retail. Wherever digital connectivity and automation is introduced, cybersecurity principles must also be applied[7].

12. The UK has the potential to take a lead role in agri-tech which is currently seeing a confluence between greater capabilities and application in monitoring and data-analytics, smarter machinery, robotics and automation and improving capabilities in precision agriculture and systems optimisation. The four UK Agri-Tech Centres of Agricultural Innovation[8] are leading many of these developments. In their response to the Foresight Future of Food and Farming project[9], the IAgrE presented case studies that demonstrated the impact of these developments, including improvements in:
    - effective weed management with minimal pesticide
    - productivity and welfare issues for animals
    - pesticide efficacy and safety
    - soil quality[10].

13. Monitoring technologies and data analytics are being applied to boost production efficiencies while securing better environmental outcomes[11]. This includes tackling the performance variance across UK farms. Variation management is expensive and analysis of data from the full range of crops and animals produced helps diagnose the causes of

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[4] Agricultural Engineering: a key discipline for agriculture to deliver global food security, Institution of Agricultural Engineers, 2012; The vital ingredient: Chemical science and engineering for sustainable food, Royal Society of Chemistry and Institution of Chemical Engineers, 2009; Health of Physics in UK Food Manufacturing, Institute of Physics, 2016
[5] Manufacturing sector performance, UK; 2008-2018, Office for National Statistics, 2019
[6] Health of Physics in UK Food Manufacturing, Institute of Physics, 2016
[7] Cyber safety and resilience: strengthening the digital systems that support the modern economy, Royal Academy of Engineering, 2018
[8] https://www.agritechcentres.com/
[9] Foresight. The Future of Food and Farming, Government Office for Science, 2011
[10] Agricultural Engineering: a key discipline for agriculture to deliver global food security, Institution of Agricultural Engineers, 2012
[11] See, for example, the Soil Management Information System (SMIS) initiative.

variation and how it might be reduced. This is a core application for sensing technologies and the accompanying data analytics[12].

14. Significant economic and environmental efficiencies are achievable from smarter machinery. Automation is enabled by integrating electronics-based capabilities into farm machinery and the interconnection of different machines[13]. For example, automation can facilitate much smaller on-farm vehicles, eliminating soil damage caused by large machinery. A challenge is to help operators and farm managers adapt and deploy new technologies.

15. Where key machinery components in the farming sector (most notably the tractor) have traditionally been adaptable to many functions, the entry of robotics sector may increase in specialisation in farm machinery. The capital cost of machinery might prove a barrier to adoption. An increased use of service models for machinery provision may help. This also applies to machinery across the food supply chain and is covered further in **Annex 6** (whole supply chain issues).

16. Key opportunities from advances in precision agriculture/precision application are reduced inputs of energy use and agrochemicals, which can equate to a large environmental saving given energy and material inputs into their production[14].

17. To realise the benefits and cost savings offered by the technological innovations detailed above, they need to be examined not in isolation, but concurrently in combination with other developments. Communication and engagement with farmers and practitioners is also needed. One particularly successful mechanism for this, highlighted during our consultation, was the Agriculture and Horticulture Development Board's Monitor Farm initiative.

New methods and models of production

18. Sustainable soil management is essential for farming and, properly managed, soils also act as a key carbon sink. The use of regenerative or eco-agricultural methods can improve soil quality, increase sequestered carbon and reduce fertiliser and pesticide use[15]. Progress is being made in practices that reduce the intensity of tillage. The restoration of soils can also be achieved through the application of digestate, (hydro) compost and biochar; this is a key research area and another where evidence on good practices and their benefits requires dissemination to encourage adoption.

19. Mixed-use farming techniques, such as using animals to serve as fertilisers and to till the soil, have been proven to provide environmental gains through reduced application and use of agrochemicals, increased biodiversity and soil health. Although intensity of farming is reduced, it can diversify revenue streams and such techniques build longer-term environmental resilience into farms and the wider environment.

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[12] Innovation in agri-tech, Royal Academy of Engineering, 2015

[13] For an example of developments in this area, see the Hands Free Hectare and Hands Free Farm project; demonstrator projects whereby automated machines grow the first arable crop remotely, without the intervention of operators or agronomists on the ground.

[14] For example, the use of GPS in the auto-guidance of auto section control technologies, can offer 10-15% savings on chemical inputs and improved crop health and performance. This is a convergence of drone, satellite and tractor sensor technologies.

[15] Soil carbon sequestration to mitigate climate change, Powlson, D. S. et al., 2011; Soil carbon sequestration to mitigate climate change, Lal, R., 2004

20. Deployed appropriately, several innovative, non-traditional models of production potentially offer significant economic and environmental benefits:
    - Aquaponics is a form of integrated fish and plant farming that combines raising fish in tanks (recirculating aquaculture) with soil-free plant culture (hydroponics)[16]. It offers the potential to raise fish and plants in a sustainable way however it requires research into making the fish feed element more circular (e.g. insect larvae, flax seeds, seaweed) and support for practitioners and researchers.
    - Digeponics integrates the products of anaerobic digestion with greenhouse cultivation of vegetables This includes utilising CO_2 and digestate (as growing medium and fertiliser)[17]. Combined with bubble-insulated greenhouses, this approach can offer circa 80% savings on energy demand compared to conventional greenhouses[18].
    - Vertical farming technologies[19] have potential application in rural and urban areas and could conserve water, nutrients and soils, reduce the land-footprint of agriculture and allow a more intimate understanding and awareness of food production particularly in urban areas.

21. Co-operative, employee- or consumer-owned farming and food manufacturing operations can create innovative links between producers and consumers, often supported by common ideas about the environment, consumption and society. These models can provide the means of sharing risk, increasing social and learning outcomes (including reducing 'food alienation' on the part of consumers, which affects food waste and diets/health outcomes) and increase environmental performance[20]. There are examples of existing operations which demonstrate strong triple bottom line performance[21].

Water and food production

22. Adoption of water-efficient production methods that are widely used in water-stressed countries could contribute to a more resilient sector in the UK and lower environmental and production costs. Use of reclaimed water in agriculture would improve resilience and circulate nutrients back into the system. There are currently few incentives for water efficiency and much can be achieved by aspiring to global good practice.

23. There is scope for better utilisation of nutrients from biosolids (treated solid residuals from wastewater treatment plants, rich in nutrients and organics) and reclaimed water. This option should be appraised against the use of human produced fertilisers. England currently makes excellent use of recycled biosolids to land; some 70% of wastewater biosolids are recycled to agricultural benefit under strict standards. However, other countries, such as Germany, have also legislated for nutrient recovery from sewage treatment processes to address point and diffuse sources of phosphorus pollution.

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[16] Small-scale aquaponics food production, Food and Agriculture Organization of the United Nations, 2014
[17] Growing vegetables in the circular economy, Stoknes, K. et al, 2018
[18] Efficiency of novel "Food to waste to food" system including anaerobic digestion of food waste and cultivation of vegetables on digestate in bubble-insulated greenhouse, Stoknes, K. et al, 2016
[19] Vertical Farming for the Future, US Department of Agriculture, 2018
[20] Alternative Food Networks at the urban-rural interface, agrathaer GmbH and Leibniz Centre for Agricultural Landscape Research (ZALF),
[21] An example is Aquascot, a fish farming business using aquaculture in Scotland.

Development of local markets for the recovered nutrient products is key to driving biosolids reuse.

24. Increased scientific identification and investigation needs to drive greater public awareness of the human health and environmental impacts of contaminants which may be of concern in biosolids and reclaimed water products. Examples include micro-plastics and organic compounds such as per- and poly-fluoroalkyl substances (PFAS) which are not removed in current wastewater treatment processes. Work is on-going to improve our understanding of the fate and human health impacts of emerging contaminants such as these.

25. Antimicrobial resistant (AMR) bacteria are of increasing concern in terms of human health. Highly intensive animal farming methods require higher use of antibiotics which can accumulate in farm wastes and the natural environment. Wastewater treatment plants are increasingly recognised as hotspots for AMR bacteria. Lower intensity farming requires less antibiotics and would lower the likelihood of AMR impacts on human and animal health and safety. It would also reduce the costs of addressing this in wastewater treatment.

Annex 2: Processing and packaging

'Healthy Manufacture'

26. Much can be achieved through engineering innovation in food manufacturing to prevent disease and produce better health outcomes. This includes:
    - minimal but sufficient refining of raw materials to ingredients, leaving minor nutrients in place
    - retaining preferred sensory properties in healthier formulations using advanced manufacturing techniques and processes[22]
    - formulation and structuring of food for more effective delivery of nutrients to the digestive tract with minimal degradation or loss of nutrients from the point of manufacture to the point of delivery within the tract[23].

Water and the environment

27. Key innovations that can increase the environmental performance of food processing include:
    - Retaining the sensory properties of shelf-stable food products that would otherwise require refrigeration. This saves energy and reduces food waste in the supply chain.
    - Zero waste processing that reduces upstream and downstream waste.
    - More energy efficient and milder food processing e.g. for preservation.

28. Cleaning processes account for as much as 60% of water consumption in food and beverage manufacturing plants. Clean in place (CIP) systems[24] and heat exchanges such

[22] For example, food technology company Miraculex uses fermentation technology to produce sweeteners from natural proteins derived from exotic fruits. This is with the aim of reducing sugars in food and drink products.
[23] For example, Sugarlogix aim to provide better nutrition for formula-fed babies, using yeast-based technologies to produce rare, functional sugars currently only found in human breast milk.
[24] CIP systems provide a method of cleaning the interior surfaces of process equipment, pipes and vessels without disassembly and manual cleaning. It has the advantages of being faster, less labour-intensive and poses less of a chemical exposure risk.

as cooling towers account for 66% of all non-product water consumed in manufacturing plants, while the remaining one third is split between manual cleaning, sanitation and miscellaneous utility demands[25]. Good design practices and optimising CIP equipment can save water as can installing systems that close the water cycle as much as possible. Such systems include anaerobic digesters, aerobic systems, reverse osmosis systems, membrane filtration systems, disc filters and clarifiers and some of these can yield valuable by-products such as biofuels, nitrogen or phosphorus rich fertilisers[26]. The Waste Resource Action Programme (WRAP) have produced an in-depth guide to help companies in all sectors of the food and drink industry improve their water efficiency[27].

29. A key priority is the reduction of single-use plastic packaging and novel, biodegradable materials as a replacement to plastic packaging; this is addressed further in **Annex 5**.

Productivity

30. Enhanced productivity can be achieved through:
    - Process sensors and imaging for quality monitoring and optimisation. This includes novel in-process chemical sensors for improved process control, the optimisation of conditions and inputs during food processing, and chemical addition during effluent treatment. It also includes non-invasive imaging technology[28]. This technology allows producers to deliver food of consistent quality and prevents supply chain waste.
    - Flexible process/production lines
    - Intensification of food production processes by scaling down and combining process steps.

31. The food sector can learn a lot from other manufacturing and processing industries. Within the food sector, a framework for greater co-operation, rather than competition, and a better interface with academia is needed. This may present a 'market failure' suggesting the need for government intervention.

Annex 3: Storage and distribution

32. Reducing energy use per unit area of distribution centres and retail space is a key environmental objective. This will involve state of the art low carbon technologies, renewable energy generation and energy-efficient practices. Reduced energy in refrigeration is a major opportunity; improved efficiency and finding alternatives to hydrofluorocarbons (HFCs) are high priorities. Refrigerants to replace HFCs include carbon dioxide for larger fridges, freezers and air conditioning units. A new technology, the transcritical carbon dioxide heat-pump, is being used for commercial refrigeration. It can provide refrigeration at temperatures below 0 °C, and simultaneously use waste heat to produce hot water at temperatures up to 90 °C. This can reduce greenhouse gas emissions by 25% compared with conventional, separate heating and refrigeration systems[29]. Transcritical carbon dioxide could provide sufficient hot energy to provide all the heating for the supermarket and power additional cooling with an absorption system.

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[25] Reducing water usage in food and beverage processing, Schug, D., 2016
[26] Reducing water usage in food and beverage processing, Schug, D., 2016
[27] Water minimisation in the food and drink industry, Waste Resource Action Programme, 2013
[28] For example, ImpactVision have developed non-invasive image-recognition technology and predictive learning to provide real-time food quality information such as freshness, shelf-life or contamination.
[29] The vital ingredient: Chemical science and engineering for sustainable food, Royal Society of Chemistry and Institution of Chemical Engineers, 2009

A focus for research should be finding other formats, particularly ambient storage, that provide the product advantages of chilled storage with lower consumption of energy[30].

33. Trigeneration (the simultaneous production of mechanical power, heat and cooling from a single heat source) and combined heat and power technology (CHP) for retail and distribution centres can be more widely harnessed. These systems allow for capture and reuse of heat created through power generation thereby reducing the overall footprint. Retailers have developed a range of management and technical systems for application in primary agriculture. These include assurance schemes based on welfare and environmental standards, and integrated farm management. An example can be found in the horticultural sector, where suppliers of tomatoes use CHP to heat greenhouses and send excess energy to the National Grid. Carbon dioxide is recycled in the greenhouses and absorbed by the crop, reducing carbon dioxide emissions and improving the tomatoes[31].

34. Where applicable, re-distributed food manufacturing (RDM) can play a role in developing more localised, sustainable food supply chains. A wider geographical spread of food manufacturing can be favourable in socio-economic (e.g. job creation) and environmental terms, for example reducing food miles and enabling the utilisation of local renewable energy and water resources[32]. For RDM to penetrate well established markets, the right opportunities will need to be identified, in terms of products and components in value chains and innovation in technology, business models and policies[33]. It should be acknowledged that locally-produced food is not automatically more environmentally sustainable, for example, production in heated greenhouses can significantly increase environmental footprint. Any potential environmental benefits therefore require verification through careful life cycle assessment of supply chains.

Annex 4: Retail and consumption

Waste in retail and consumption

35. Control and reduction of waste is frequently beyond the capability of the individual farmer, distributor or consumer and instead linked more to societal and economic norms that drive consumer expectations and wasteful practices. In meeting consumer expectations, major supermarkets often reject entire crops because they do not meet exacting marketing standards for their physical characteristics, such as size and appearance. Up to 30% of the UK's vegetable crop is never harvested due to such practices[34]. Commonly used sales promotions frequently encourage customers to purchase excessive quantities which, in the case of perishable foodstuffs, inevitably generates wastage in the home. Overall between 30% and 50% of what has been bought in developed countries is thrown away by the purchaser[35]. Zero waste retailers,

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[30] The vital ingredient: Chemical science and engineering for sustainable food, Royal Society of Chemistry and Institution of Chemical Engineers, 2009
[31] The vital ingredient: Chemical science and engineering for sustainable food, Royal Society of Chemistry and Institution of Chemical Engineers, 2009
[32] Greenhouse tomatoes grown in the UK using waste energy from another industry may also use local water resources with lower embedded energy: Re-distributed manufacturing and the food-water-energy nexus, Veldhuis, A. et al, 2019
[33] For an overview of innovations in food technologies that could support the wider adoption and application of RMD, see: Innovative food technologies for redistributed manufacturing, Gimenez-Escalante, P. and Rahimifard, S., 2016
[34] Global Food: waste not, want not, Institution of Mechanical Engineers, 2014
[35] Global Food: waste not, want not, Institution of Mechanical Engineers, 2014

as being currently trialled are to be welcomed, the key question being how this can be supported and scaled?

Public awareness of food-environment links

36. Public awareness of the links between agriculture and food production and the environment is poor and significant opportunities exist for improved public awareness on the links between healthier, safer food choices and better environmental outcomes. For example, highly processed foods have a generally have a greater water requirement than less processed foods. Also, phosphorus compounds are added to highly processed foods including processed meats and bakery products, as well as carbonated drinks. People then consume more phosphorous than their body requires and excrete the excess in urine and faeces. Phosphorus pollution is one of the most significant environmental issues currently facing our rivers and streams and this is primarily from point source discharges from wastewater treatment. As well as offering significant health and wellbeing benefits, a diet lower in processed food would lower water consumption and phosphorus pollution in the water system.

37. There are significant opportunities within the customer consultation and outreach the water industry undertakes to help facilitate greater understanding of the links between healthy food choices the natural and urban water environments. Consultation and awareness campaigns around fats, oils and grease, and wet wipes are good examples of influencing consumer behaviour. The current and increasing focus on leakage, per capita consumption and water efficiency within the water industry may offer beneficial tie-ins with the water footprint of foods and the many benefits of a healthier diet.

E-retail

38. E-retail offers opportunities for growth for smaller companies but this will require technological support to produce safe, stable, healthy and cost-effective products and processes. It also carries implications of logistical inefficiency, requiring many small door-to-door deliveries. Measures to alleviate transport congestion in urban centres include the retiming deliveries to be off-peak, horizontal collaboration between operators (combining deliveries to reduce 'empty running') and the use of urban consolidation centres[36].

Annex 5: Reuse, recycling, waste and disposal

Circular economy in the food sector

39. As detailed above, waste in the food system is a key challenge. WRAP estimates that the sector produces 10 million tonnes of food waste annually and that food and drink accounts for 20% of the UK's greenhouse gas emissions[37]. Part of the move toward circular, regenerative systems in the food system is exploiting opportunities to valorise food waste – the extraction and application of valuable ingredients from food waste e.g. enzymes, hormones, phytochemicals, probiotics and chitin. It also includes developing closed-loop recycling of carbon and other nutrients, for example, using agricultural waste to provide energy and fuel for local farms and businesses. Effective implementation of the circular economy requires a systematic change across supply chains, involving technological and non-technological innovations[38].

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[36] The Transport Congestion Challenge, Royal Academy of Engineering, 2015
[37] Food waste reduction, Waste Resource Action Programme, 2017
[38] Backcasting and eco-design frameworks can help companies develop sustainable business models that translate circular economy principles into industrial practice: Integrating Backcasting and Eco-design for the Circular Economy, Mendoza, J. et al., 2017

40. The Royal Society of Chemistry and Institution of Chemical Engineers also identified the following areas where chemical engineering in particular can contribute[39]: innovation relevant to reuse, recycling, waste and disposal include:
    - Further development of the biorefinery concept, to make maximum use of raw materials and by- and co-products, by making a range of products at a single site and maximising energy efficiency
    - Improving yield and efficiency of anaerobic digestion and the generation of biogas by greater understanding of the fundamental chemistry and biochemistry. The Resources and Waste Strategy for England[40] positions anaerobic digestion as the best environmental outcome for food waste, once efforts have been made to reduce food waste in the first place.

41. Farm waste and food waste can be used as a feedstock for anaerobic digestion (AD) and produce biogas, which can be used to generate electricity and heat. Organisations such as WRAP are facilitating the growth of a sustainable organics recycling sector through the development of new AD infrastructure. As well as helping to develop markets for biofertiliser by-products to ensure nutrients can be returned to the field to grow new crops. The Anaerobic Digestion Bioresources Association (ADBA) have identified low gate fees due to competition for feedstock and the lack of clarity on government support following 2021 as barriers to growth in AD[41].

Waste from packaging

42. Packaging is necessary to protect food and prolong its life through the supply chain, preventing food waste and threats to human health. Current poor recycling supply chains, poor packaging design and inefficient manufacturing processes all contribute to spent packaging sent to landfill, overpackaging or over-specification of packaging in terms of its thickness.

43. In the first instance, there is an opportunity to introduce re-use of packaging where it is possible to achieve durable, sterilisable packaging. Where re-use is not possible, processes and systems for improved recyclability of plastics, glass, paper and cardboard should be developed e.g. by enhancing the properties of recycled cellulose fibres. Product design for recyclability also needs to be much more widespread[42].

44. Addressing plastic waste is a priority. A systems approach is required that brings relevant stakeholders together to develop packaging that minimises plastic content makes it multiply reusable and to ensure it is manufactured in a sustainable manner[43]. Steps could be taken immediately to establish properly functioning supply chains for packaging that is currently easy to recycle and produced in large volumes, such as HDPE

[39] The vital ingredient: Chemical science and engineering for sustainable food, Royal Society of Chemistry and Institution of Chemical Engineers, 2009
[40] Our Waste, Our Resources: A strategy for England, HM Government, 2018
[41] Anaerobic Digestion Bioresources Association (ADBA). 'Anaerobic Digestion: Decarbonising Food Waste and Agriculture'. Presentation delivered at the Royal Society of Chemistry Roundtable Summit on Future Waste. (20 May 2019)
[42] The Waste Resource Action Programme and the Confederation of Paper Industries have outlined the design considerations for increased recyclability of paper and card packaging: Paper and Card Packaging, WRAP and the Confederation of Paper Industries
[43] Such stakeholders include food technologists, packaging designers, marketing functions, consumers, waste management companies, plastics recyclers and plastic product designers

milk cartons and PET drinks bottles. A Pareto analysis of plastic packaging by volume would help in identifying where to start.

45. Single use containers used for takeaway food represent a significant source of waste and negative environmental impacts due to their low recyclability. Comparing the life cycle impacts of three of the most widely used containers (aluminium, polypropylene and extruded polystyrene) shows that single use polypropylene containers are the worst option for 7 out of 12 impacts considered, including global warming potential[44]. This is followed by aluminium packaging while extruded polystyrene has the lowest impact due to lower material and electricity requirements in manufacture. Life-cycle assessment also demonstrates the importance of increased recycling. Extruded polystyrene containers are not currently recycled and, if recycled in accordance with the European Union 2025 policy on waste packaging, most of their impacts would be reduced by more than 18%, while also reducing littering and negative effects on marine organisms. Increased recycling of polypropylene and aluminium would reduce most impacts by over 20%[45].

Annex 6: Whole supply chain issues, information, traceability and security

Life cycle assessment

46. This submission has highlighted the need systems thinking and life cycle assessment as a crucial tool in appraising the impact of decisions and innovations across the food system. Many studies have been carried out to assess the impacts of everyday food items[46]. A study of commercial and homemade sandwiches and their estimated carbon footprint illustrates the value of life cycle assessments[47]. The study showed that the average impact from home-made sandwiches are two times lower than readymade equivalents with the same ingredients. The greatest contributor to the carbon footprint for both types of sandwich is the agricultural production of ingredients; for readymade sandwiches the preparation and retail stages are also significant. The study identified options for improvement with reductions in the carbon footprint of readymade sandwiches of up to 50% possible. The study also suggested information on the carbon footprint be combined with nutritional data to assist consumers in making better informed food choices. Use-by dates were found to be conservative; the British Sandwich Association (BSA) estimates that relaxing use-by dates would help save approximately 2000 tonnes of sandwich waste annually. This can apply to other short shelf-life food items[48].

Supply chain information, traceability and security

47. Engineering innovations can radically improve data sharing, traceability, transparency and disclosure throughout the food supply chain[49]. Prompted by scandals such as the 2013 horse meat scandal, concern for the ethical dimensions of the food supply chain is increasing. Increased transparency and disclosure can drive:

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[44] Environmental impacts of takeaway food containers, Gallego-Schmid, A. et al, 2019
[45] Environmental impacts of takeaway food containers, Gallego-Schmid, A. et al, 2019
[46] Life cycle environmental impacts of convenience food, Schmidt Rivera, X. et al, 2014; Life cycle environmental impacts of carbonated soft drinks, Amienyo, D. et al., 2012; Environmental impacts of chocolate production and consumption in the UK, Konstantas, A. et al., 2018
[47] Understanding the impact on climate change of convenience food: Carbon footprint of sandwiches, Espinoza-Orias, N. et al., 2018
[48] Understanding the impact on climate change of convenience food: Carbon footprint of sandwiches, Espinoza-Orias, N. et al., 2018
[49] For example, blockchain technology can be used to trace agri-food through the supply chain by making every transaction transparent, traceable and verifiable with no third party oversight.

- better food safety and protection against fraud, including assurance of provenance
- efficiency, productivity and sustainability
- improved diets and health
- waste reduction[50].

48. Realising benefits from improved data sharing and traceability will involve work to:
    - Determine the trustworthiness of organisations and data sharing models and identifying what encourages or inhibits data sharing. Work to encourage data sharing in different sectors can be instructive[51].
    - Better understanding of how digital technologies are driving the transformation of traditional food supply chains and what this means for power relationships and value capture.
    - Determine and ensure the veracity, relevance and significance of data and information capture and the best data management technologies for this[52].
    - Integrating data pertaining to the food industry with data from the health sector in such a way that government and other bodies have clear insight into operations and the health impact of food types. This will require management of complex trust relationships[53].

Technology provision as a service

49. The provision of technology as a service has existed for a long time in the farming sector but the service model is becoming increasingly important for allowing uptake and deployment of new technology across the whole food supply chain, where technology is advancing rapidly and becoming more specialised but capital costs remain a prohibitive factor in technology adoption and process improvement.

Naturally occurring chemical and their uses

50. Potentially impacting the whole supply chain, the Royal Society of Chemistry and Institution of Chemical Engineers[54] identify the development of a better understanding of naturally-occurring chemicals and their use in the supply chain as a key area for the chemical sciences and engineering. This offers the potential to develop new antimicrobials, natural disinfectants, antioxidants, colours, flavour chemicals, salt replacers, emulsifiers, encapsulating agents and preservatives.

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[50] Digital Collaboration in the food and drink production supply chain, Internet of Food Things Network Plus, 2019
[51] For example, see: Toward trusted data sharing: guidance and case studies, Royal Academy of Engineering
[52] There are various data management technologies emerging as innovation drivers, including blockchain and distributed ledgers.
[53] Digital Collaboration in the food and drink production supply chain, Internet of Food Things Network Plus, 2019
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