Arthur D Little

Mapping current innovation and emerging R&D needs in the food and drink industry required for sustainable economic growth

Final Report

Report to Defra

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0. Executive Summary

0.1 Introduction to this study

Government priorities set out in Defra's current business plan[1] seek to support British farming and encourage sustainable food production by enhancing the competitiveness, resource efficiency and resilience of the food chain to ensure a secure supply of environmentally sustainable and healthy food. Defra has, identified a gap in understanding of how the post-farm gate food and drink industry can use technological innovation (research and development – R&D – and more incremental new product development – NPD) to address the technological solutions needed to achieve this ambition.

This study seeks to fill this gap. It provides an assessment of current technological innovation activity in the UK, and the drivers which influence it. It shortlists nine "hot spot" challenges – long term opportunities or problems that can be solved through technological innovation. It also identifies those areas of technological innovation which could address the challenges, and the barriers which are preventing this from happening today.

The work has involved a literature review of around 50 existing studies and policy documents and consultation with 65 experts from industry, cross-industry bodies, Government and its agencies and the public science base. A core component of this study concerned a cross-industry survey which drew on the opinions of 280 respondents from the UK food and drink industry. This was valuable to inform priorities, whilst recognising that it did not form a statistically significant sample of industry perceptions from across the UK. A horizon scanning exercise involving 10 senior experts from industry, academia and from Government and its agencies was also conducted to help identify future areas for technological innovation.

Both Defra and the authors of this study, would like to express their sincere gratitude to all those who have made contributions.

0.2 Drivers for technological innovation

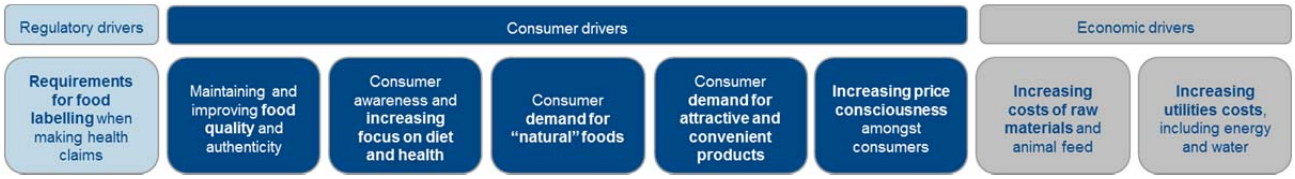
The food and drink sector is the largest manufacturing industry in the UK and contains a high proportion of small and medium sized enterprises (SMEs). R&D expenditure is low compared to other manufacturing sectors, and the majority of effort is focused on the incremental development of new product variants, involving innovation in packaging and reformulation and improvement of existing products and brands, which is a key strength in the UK compared to other countries. However, there are some noticeable gaps compared to other countries, particularly in the food and drink machinery and automation sectors, where there are a multitude of smaller businesses and some strong networks, but few international scale players.

Technological innovation in the food and drink industry is primarily driven by consumer demand, and involves making largely incremental developments to make products: more convenient and attractive; healthier; more natural; better quality, and above all, less expensive, as summarised in Figure 1. Further drivers are associated with the increasing costs of doing business, due to rising and fluctuating costs of agricultural commodities and animal feed, and of utilities, including energy and water.

Regulatory drivers also play a role - for example the food labelling requirements for products seeking to make health claims are currently considered to be particularly difficult to meet. Taken together these drivers have a significant influence on the extremely tight margins that many of the actors experience within the post-farm gate supply chain – even for those which do not seek to differentiate on price, such as artisan biscuits, cakes & breads and other premium products.

[1] Department for Environment, Food and Rural Affairs Business Plan 2012-2015, 31 May 2012

Figure 1: Overview of drivers influencing technological innovation in the UK food and drink industry



Source: Arthur D. Little analysis

0.3 Priorities for technological innovation

The above drivers influence hot spot technological challenges which will continue to be of importance beyond 10 years into the future. These challenges will require a step change in current technology development which may not be achieved without coordinated effort, in a world where achieving shorter term, incremental improvements is the norm.

Nine challenges have been identified, in four main categories:

- Working effectively at the farm gate interface
- Manufacturing healthy and differentiated food products
- Changing manufacturing and supply chain efficiency
- Reducing and reusing waste materials

Working effectively at the farm gate interface

Working with primary producers presents opportunities for the food and drink industry to maintain and improve food quality and authenticity, meet consumer demand for "natural" foods, and respond to volatility in the cost of raw materials, as well as safeguarding food security. The key challenge in this area concerns **sourcing environmentally sustainable and resilient raw materials** – the highest priority challenge associated with environmentally sustainability identified in the cross-industry survey.

This challenge is of greatest significance to those sectors which are closest to primary production and rely on bulk commodities, such as biscuits, cakes & breads, fruit & vegetable processing and oils & fats. Technological innovation to address this challenge will involve: further effort in plant breeding to enhance crop resilience, nutritional value and the processability of raw materials; the identification and sourcing of alternative raw materials with lower environmental impact; the development of means to monitor and detect food quality and contamination online; and enhancing understanding the impact that animal nutrition can have on food products.

Manufacturing healthy and differentiated food products

Current consumer demand for healthier food products is focused on macronutrient requirements as a component of a balanced diet, rather than the development of "functional" foods and nutraceuticals. The development of the latter is made difficult by current regulatory requirements on claims, and consumer perceptions over what is considered "natural". This is against a backdrop of an ageing population with increasing incidence of nutrition-influenced disease, together with increasing consumer awareness of the linkages between diet and health. This challenge also presents an opportunity for the UK to become a leader in offering a diversified range of higher value products.

Specific challenges in this category include **further reducing salt, sugar and fat content of products processed and including healthier components such as fibre**. This challenge was identified by many of the sectors, and amongst all sizes of company, as the highest overall priority for technological innovation. It was of particular importance for the biscuits, cakes & breads, ready meals and meat processing sectors. Much of the incremental development possible in this area has now been achieved, and a step change in technological innovation is required. Further effort to reduce salt, fat and sugar content must be balanced against the need to meet consumer demands for taste and product quality, avoiding the substitution of carbohydrates for fats. This can be achieved through technological innovation in areas such as: formulation engineering; improving understanding of sensory science and taste perception; and the identification of novel substitutes for salt and sugar.

A further challenge concerns the development of **new products aimed at specific consumer groups**, in particular, personalised nutrition to support healthy ageing and lifestyles. This can be achieved through: improving the diagnosis and prediction of nutrition-related illness to help guide programmes of healthy eating; and the development of products targeted at reducing the risk of developing nutrition-related diseases.

Changing manufacturing and supply chain efficiency

Drivers to improve efficiency in both manufacturing and supply chains are closely associated with the need to reduce costs in response to tightening margins. The main factors at play are a combination of consumers (and retailers) requiring cheaper food, and the rising costs of raw materials, animal feed and utilities.

Improving energy and process efficiency in the food manufacturing environment focuses on **reducing costs by minimising processing steps and increasing throughput in order to reducing energy consumption**, as well as seeking opportunities to reduce overall energy consumption through, for example, improved plant design. Efforts here are hampered by the significant capital outlay required for new process technology, which is beyond the reach of many SMEs. In addition, the UK is not an international leader in food process technology – although there are pockets of excellence. Opportunities for technological innovation include: new means of cooling the ambient factory environment; designing factories which are more energy efficient; and the development of new technologies for energy intensive processing steps, such as freezing, chilling and cooking, as well as better use of low grade heat. This will require technology transfer from other geographies (e.g. Italy and Germany) as well as other industries (e.g. the civil engineering or automotive sectors).

Making **improvements to the cold chain to prolong shelf life and reduce energy consumption** also represents a significant challenge, as the majority of energy used in the distribution component of the food and drink supply chain is associated with chilling and freezing, particularly for ready meals, dairy and soft drinks & beverages. There is a general lack of evidence around what the optimum temperature requirements for chilled or frozen foods should be to maximise safety, and opportunities exist to reduce energy expenditure by developing an improved evidence base. Other opportunities for technological innovation include: reducing energy losses within the retail environment, particularly in chiller cabinets, without creating a barrier between the consumer and the product; and reducing the need for chilling throughout the food chain by improving supply chain efficiency.

Achieving **greater efficiency in water use** is not currently primarily driven by efforts to reduce costs, though this remains an important consideration, and is likely to become increasingly important in the future as demand for water increases and consumption is monitored more closely. This challenge is of particular importance to the dairy industry, and one where significant progress has already been made. Technological innovation opportunities include: the development of low water cleaning technologies; and identifying cheaper and more effective measures for water and effluent clean-up, and the recycling of non-potable water.

Reducing and reusing waste materials

Waste reduction and reuse is primarily driven by economic issues associated with maximising efficiency and reducing operating costs. Technological innovation in **packaging to prolong shelf life and reduce food spoilage and wastage** is a key current priority for businesses in the food and drink industry. This includes lightweighting (tempered against lower packaging robustness) and recycling, though the vast majority of current effort involves incremental improvements to packaging to make it more attractive and convenient for consumers, and to reduce costs. Smart packaging – which can signal when food is no longer fit for consumption – also represents an opportunity for technological innovation.

As well as improving packaging, there are opportunities to modify the products themselves to **prolong shelf life whilst maintaining freshness and minimising the use of artificial additives** – particularly for chilled ready meals and biscuits, cakes & breads – though this must be tempered against the desire of consumers for increased freshness, and their desire for less processing which they often believe reduces nutrient content. Identifying alternative means of controlling spoilage organisms could be one way of addressing this

Finally, finding **new applications for off specification and residual products**, particularly those arising from fruit & vegetable processing, dairy, and other primary processing applications, represents a significant opportunity. This includes: converting food manufacturing and domestic waste to non-food materials; decontaminating waste streams for food or feed use; and improving connectivity with small-scale waste production, both within the supply chain and within individual businesses.

0.3 Barriers to technological innovation

Delivering the technological innovations to address these challenges requires a number of barriers to be overcome. This study has identified that **obtaining funding for technological innovation** is the most significant barrier for both companies large and small. In general this is more an issue of access to, rather than availability of funding, although there is a key barrier in the ability of both large and small companies to secure the necessary capex outlay for commercially available new technologies, including scaling up and turn-key plant.

A **shortage of appropriately skilled staff** was the second most frequently cited barrier. This concerned the ability to attract scientists and engineers to the food and drink industry. **Internal priorities and culture** – for example the focus on short term NPD at the expense of longer term or more disruptive technological innovation - was highlighted as key barrier. Food manufacturers tend to focus on “fire-fighting” short term requests from retailers and consumers, and there may be a lack of company buy-in to the business significance of longer-term technology development, leading in some cases to perceived lower status of technologists and lower salaries. There are also difficulties in crossing the “valley of death” between a piece of applied research and a packaged up, deployable new piece of technology.

Whilst consumers are the primary driver for technological innovation, **consumer acceptance of technological innovation** – in terms of a reluctance to move away from familiar products and buying habits, together with a reluctance to “pay for new technology” and the perceived health and safety risks associated with novel food products - can be a barrier. Further barriers concerned **the difficulty of being able to make health claims** – which appears to be one of the main factors constraining the development of nutraceuticals and functional foods. Further difficulties are highlighted in terms of **improving collaboration** within the supply chain to solve common technological problems.

0.4 Areas for further consideration

The recommendations summarised here are aimed at implementing the findings of this study. They seek to further develop the evidence base in this area, address and further diagnose the barriers to technological innovation which have arisen as part of the consultation programme and cross-industry survey, and to find ways to collectively address the set of nine challenges identified in this work.

- **Recommendation 1: Create technology roadmaps to set R&D objectives which will address the "hot spot" technological challenges**. This involves identifying what activities would need to take place, in what order, and by when, to address each of the nine "hot spot" challenges. The roadmaps should be facilitated by Government but industry-led, and should take into account disruptive technologies, as well as those from other industries. They should also seek to draw on different scientific disciplines to address the technological challenges: enabling the further reduction of salt, fat and sugar content of products, for example, is likely to require a combination of sensory science, psychology, formulation engineering and chemistry, amongst others.
- **Recommendation 2: Improve the way in which Government funding regimes for technological innovation are defined, coordinated and then communicated to industry.** There is an urgent and well-characterised need to better coordinate government funding priorities across the currently fragmented funding landscape and to make these as widely known as possible. The industry also needs to be given as much advance warning as possible of each planned new funding initiative to ensure that companies have the opportunity to put in well-considered bids when the call for applications arises. The BBSRC-led Global Food Security Programme (GFS), the role of which is to better coordinate the delivery of multidisciplinary research in all aspects of food production from farm to fork, involves many of the Government departments and agencies tasked with funding technological innovation in the food and drink sector, and could lead this activity, together with the Food Research Partnership (FRP).
- **Recommendation 3: Find ways to attract individuals with technical and engineering skills to the food and drink industry and better understand the skills landscape.** Access to technical and engineering skills of both direct and indirect relevance to the food and drink sector was highlighted consistently across all sectors as a barrier to innovation. This appears to be an issue associated with attracting scientists and engineers to the food and drinks sector, and is primarily an issue for industry to explore further in terms of better understanding the skills landscape. There is also scope for Government and industry to work together in, for example, the co-development of training courses and provision of work experience for science and engineering training courses more broadly.
- **Recommendation 4: Enable technology transfer into industry from the public science base, adjacent industries, and other countries**. Technology transfer is key to enabling technological innovation, but much of the industry appears to lack the capacity at present to be able to do this successfully or to seek novel solutions outside of the food and drink industry, or outside the UK where the UK's science base is less strong than that of other countries. Government and industry need to work together to identify ways to address this important issue.
- **Recommendation 5: Stimulate collaboration within the supply chain to address priority areas of technological innovation.** Many of the challenges identified in this study will require a coordinated effort across the supply chain. In addition, barriers have been identified in terms of the ways in which different parts of the supply chain work together – particularly in terms of the way in which food and drink manufacturers and retailers share technology needs. This gives rise to near-term "fire fighting" as manufacturers seek to address customer and consumer demand, at the expense of longer-term R&D. One way to do this would be to create challenge- or sub-sector specific "innovation ecosystems" or clusters, involving multiple members of the public science base, and multiple companies who can provide a route to market through their supply chains.
- **Recommendation 6: Develop initiatives aimed at helping consumers to understand, appreciate and accept new food technologies and drive new innovation.** Despite consumer requirements being the primary driver for technological innovation, this study has found, somewhat paradoxically that consumer perception and acceptance of new technologies is a barrier. This may go some way to explaining why much technological innovation focuses on incremental new product development, rather

than more radical innovation. There are opportunities for Government to work with industry to better understand consumer perceptions of technological innovation, as well as those associated with environmental sustainability, such as energy efficiency in cooking and refrigeration and waste reduction in the home and to identify ways of raising consumer levels of understanding.

- **Recommendation 7: Build a better evidence base to support minimum temperature requirements for chilled and frozen products.** This study has identified a need to better characterise minimum temperature requirements for frozen and chilled foods across all sectors. The rationale for this observation is that foods are often chilled or frozen to default temperatures (e.g. zero degrees Fahrenheit is considered the standard for frozen foods) whereas in reality achieving temperatures this low is not always required. Increasing the required temperatures for freezing by only 1-2 degrees Fahrenheit could achieve a considerable energy saving during storage, transport and distribution. This could be an area for Defra to consider together with the Food Standards Agency.
- **Recommendation 8: Create universally agreed standards for environmentally sustainable raw materials** There is currently a wide array of different mechanisms which can be used to assess the environmental sustainability of raw materials, including those managed by independent organisations, and those developed internally by companies to control their own supply chains . However, there is no universally agreed set of standards for what should be considered as sustainable. There is scope therefore to agree some basic principles to minimise the amount of effort that individual businesses – particularly SMEs – need to invest in selecting the right systems and processes to use to ensure that raw materials are sustainably sourced, particularly in the event of increased availability of novel raw materials.
- **Recommendation 9: Expand Government's evidence base further to include other sectors of the food and drink industry which are known to be innovative.** The present study focused on seven sectors of the food and drink industry which were selected on the basis of making a substantive contribution to the UK economy and showing a relatively high level of technological innovation. However, there are other sectors which are also highly innovative and could make a material impact on producing more environmentally sustainable, healthy food. These include, in particular, the snacks, confectionary and cereals sectors.

Government should consider addressing these recommendations jointly with the food and drink industry in order to facilitate a significant increase in the amount of technological innovation currently undertaken in this important sector.

1. Introduction

This document sets out the results of a Defra funded study to map the current innovation landscape in the UK's post farm gate food and drink industry. It also identifies the gaps and opportunities which technological innovation could help to address in order to encourage sustainable economic growth through the production of environmentally sustainable and healthy food products.

This study arose from current Government priorities set out in Defra's current business plan[2] which seeks to support British farming and encourage sustainable food production by enhancing the competitiveness, resource efficiency and resilience of the food chain to ensure a secure supply of environmentally sustainable and healthy food.

The UK food system will not be able to meet the challenge of increasing food production and improving the environment over the next 30-40 years in its current form[3,4]. Indeed, meeting food demand without damaging the environment is identified by the Royal Society of Chemistry's 2009 report "The Vital Ingredient" as "*the greatest technological challenge that humanity faces*".

The role of technological innovation in primary food production (i.e. farming) has been the subject of recent focus through studies such as The Foresight Report on the Future of Food and Farming3, the Royal Society's 2009 study on the Sustainable Intensification of Global Agriculture[5] and the Government's proposed 'Agri-Tech Strategy', due to be launched in mid-2013. However, the role of technological innovation in the food and drink industry in increasing food production whilst simultaneously reducing environmental impact has not been well characterised.

Initial work through a post-farm gate workshop, held by Defra in 2010 with the food industry, retailers, funders and consumer groups, began to identify broad challenges which could be addressed through technological innovation – but a need for more work to prioritise these challenges and better understand industry needs was required.

This study is the realisation of this requirement. It answers the following questions:

- What are the main business trends and drivers for the food and drink industry where innovation can help support growth while reducing environmental impact?
- What are the biggest technological challenges which need to be addressed?
- What are the barriers to innovation?
- What are the technical gaps and hence the opportunities for innovation?

1.1 Definitions used in this study

The following definitions have been used within this study:

- **Driver:** Drivers influence the focus and direction of technological innovation. Drivers may include, for example, consumer preference, regulation or economic performance
- **Challenge:** Problems or opportunities that require technological innovation in order to be solved or exploited. Challenges may be linked to one or more drivers. They may include, for example, the need to

[2] Defra Business Plan 2012-2015, 31 May 2012

[3] Office for Government Science, 2011. The Future of Food and Farming: Challenges and choices for global sustainability. Foresight report

[4] Defra, 2012. Green Food Project

[5] Royal Society, 2009. Reaping the benefits: Science and the sustainable intensification of global agriculture

improve energy efficiency in food manufacturing operations, prolong shelf life of food products or improve the nutritional composition of food ingredients

- **Technological innovation:** Activities associated with research and development (R&D) and incremental innovation (new product development, or NPD) which can address one or more challenges
- **Barrier:** An obstacle which is preventing organisations from addressing the challenges. Barriers may not be a specific technology issue. Instead they may include broader issues such as access to funding or appropriate skill sets

1.2 Scope of this study

The scope of this study covers the UK post-farm gate food and drink industry, from the farm gate interface through to consumption, recycling and reuse, as shown in Figure 2. There is a lesser focus on the food service sector, as Defra is currently undertaking other work to examine opportunities here[6]. Pre-farm gate activities are largely excluded, although the influence that the post-farm gate food chain at the "farm gate interface" has on farm are taken into consideration. The scope of this work includes both large companies and small and medium enterprises (SMEs) and sets out explicit implications for smaller businesses where relevant.

Figure 2: Study scope: The UK food and drink value chain

Source: Arthur D. Little analysis

[6] Personal communication with Defra, March 2013

The food and drink sector is large and diverse, and to focus the study, seven key sectors were identified by a Defra steering group at the outset of this work. These sectors were selected on the basis of a relatively high significance to the UK economy, a high R&D spend and a potentially significant impact on creating a greener supply chain, as well as the areas where Defra needed to further inform its existing evidence base. The sectors are:

- Biscuits, cakes & bread
- Meat processing
- Dairy
- Fruit & vegetable processing
- Oils & fats
- Ready meals
- Soft drinks & mineral waters

Despite this sector focus, in reality, the findings of this study – particularly in terms of drivers, challenges and barriers – are considered to be applicable to a much wider audience.

1.3 Approach used in this study

This study took place between November 2012 and April 2013 and used an approach summarised in Figure 3 and expanded on in Appendix 1. It involved inputs from an extensive period of one-to-one consultation between November 2012 and February 2013 with over 65 stakeholders from both large and small companies, trade associations, higher education institutes and research and technology institutes.

The work also involved an online survey administered during January 2013 which was completed by 280 industry respondents. The purpose of the survey was to prioritise drivers and challenges, and to ask for widespread views on what the main barriers to innovation were from the perspective of industry. The survey did not aim to draw on a representative sample of respondents from across the UK and the findings from it are not therefore statistically significant. Nevertheless, the survey results provide a balance of opinion on where gaps and opportunities lie. The results of the survey are provided in Appendix 2 of this document.

The Defra steering group that selected the sectors to focus on then prioritised the challenges based on the results of the consultation and survey programme. The challenges were subsequently validated with a panel of leading science experts drawn from industry and academia, who then participated in a horizon scanning exercise to identify areas of technological innovation which would have a high impact on addressing these.

It should be noted that the majority of consultations and the survey took place before the well-publicised meat authenticity and traceability issues associated with horse meat which emerged in February 2013[7] – and hence these do not feature significantly in the analysis.

[7] Defra processed beef products and horse meat portal. Available at: http://www.defra.gov.uk/food-farm/food/labelling/processed-beef-horse-meat/ accessed March 2013

Figure 3: Overview of the approach used in this study

Tasks: / Activities:	1: Start-up and initial sector prioritisation	2: Map current food and drink industry activity in technological innovation	3: Identification of high level drivers and challenges to innovation	4: Identification of barriers, gaps and opportunities	5: Capture examples of green manufacturing excellence outside the UK
Workshops with Defra	X		X		
Literature review		X	X		X
Survey			X	X	
Consultations		X	X	X	
Horizon scanning			X	X	
Timings:	November 2012	December 2012	January – March 2013		March 2013

Source: Arthur D. Little analysis

1.4 Structure of this document

The remainder of this document sets out the results and findings of this study. It contains the following sections:

- **Section 2: A brief overview of the food and drink industry in the UK**, providing an introduction to the sector and the levels of technological innovation currently taking place within it
- **Section 3: Drivers** which our analysis suggests are the strongest influences over technological innovation
- **Section 4: Priorities for technological innovation**, in terms of the top challenges which need to be addressed to enable the environmentally sustainable production of healthy food and areas of long term technological innovation which could address them
- **Section 5: Barriers** which are preventing these challenges from being overcome
- **Section 6: Recommendations** for Defra to move forwards

This document is accompanied by six appendices which contain:

- **Appendix 1: Methodology used for this study.** Further details on how the results of this study were generated
- **Appendix 2: Survey results.** Analysis of the cross industry survey
- **Appendix 3: Examples of international good practice.** Examples of successful initiatives from Australia and Ireland to support the recommendations of this study
- **Appendix 4: Definitions used in this study.** This section describes what is, and is not, included within each of the seven sectors covered in this study
- **Appendix 5: List of consultees.** Groups and individuals who we have engaged with to develop this study
- **Appendix 6: Assessment of the current UK landscape in technological innovation in the food and drink sector.** Background data to further support some of the findings in this document

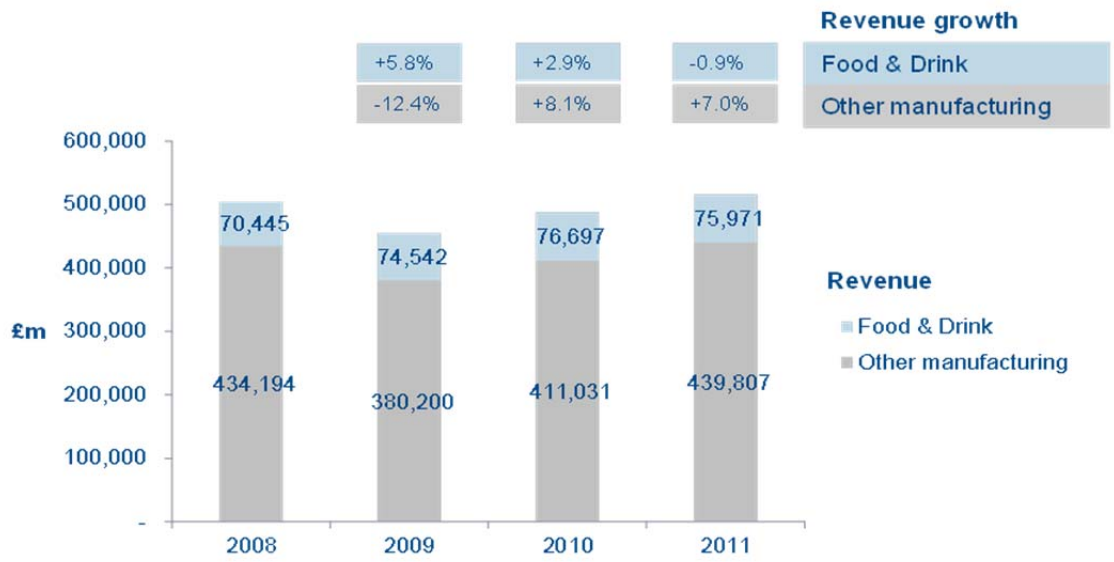
2. A brief overview of the food and drink industry in the UK

This section provides a short overview of the current state of play in the UK food and drink industry in terms of its size, structure and turnover, and the current levels of technological innovation taking place within it. Supporting evidence is provided in Appendix 6.

The food and drink sector is the largest manufacturing industry in the UK. Nationally, the food and drink industry generates a turnover of some £76 billion, as shown in Figure 4. It employs 15.6% of the UK's overall manufacturing workforce[8]. The industry is dominated by SMEs, which account for 95.6% of food and drink manufacturing businesses – though this varies from sector to sector[9]: the bread, biscuits and cakes and meat manufacturing sectors, for example, contains a very high proportion of SMEs, whilst the dairy sector is considerably more consolidated.

Elsewhere in the supply chain, particularly in raw material processing and retail, the picture is more consolidated – indeed, some 80% of the retail sector being represented by four retailers[10]. Of the sectors considered in this study, biscuits, cakes & breads and meat processing are the largest. The ready meals sector is growing the most rapidly.

Figure 4: UK manufacturing sector: Change in turnover by segment (2008-2011)



Source: Office of National Statistics, Annual Business Survey 2011

R&D spending amongst food and drink producers in the private sector is dominated by a small number of large companies (e.g. Unilever, Arla Foods, Danone and Heinz). Many of these multinationals have their R&D headquarters located outside the UK, with subsidiary R&D functions – in some cases focused on local markets – based in the UK.

[8] Office of National Statistics, Annual Business Survey 2011

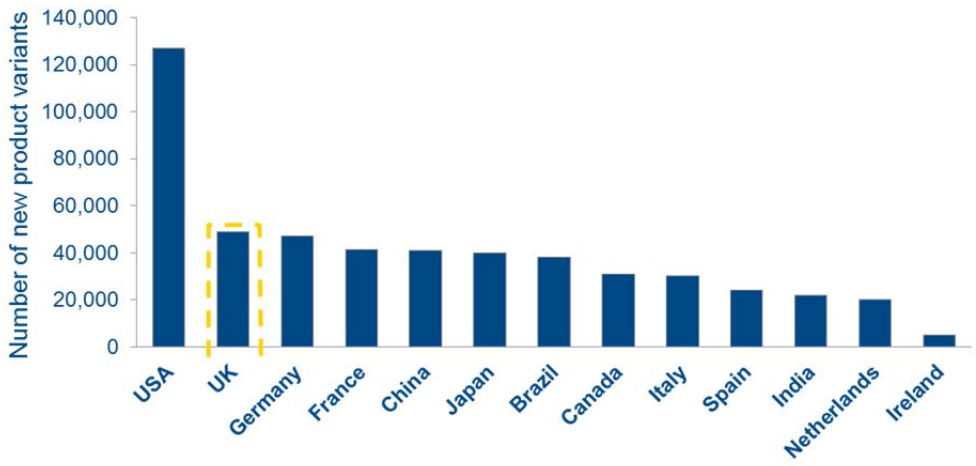
[9] Office of National Statistics, UK Business: Activity, Size and Location, 2012. SMEs defined in this case as those businesses which have less than 250 employees in the UK

[10] British Frozen Food Federation, Personal Communication, December 2012

Perhaps not surprisingly, it has been assumed that larger companies spend the most on R&D. However, the cross-industry survey conducted as part of this study suggests that expenditure in smaller businesses is higher relative to sales – though this only covers a snapshot of UK businesses (see Appendix 2).

Technological innovation activities amongst food manufacturers in particular are focused primarily on the incremental development of new product variants, involving innovation in packaging and reformulation and improvement of existing products and brands. This is a UK strength: compared to other countries, UK businesses produce the second highest level of new product variants per year, as shown in Figure 5. Many companies focus the majority of their resources on near term, new product development such as incremental improvements in packaging, rather than longer term R&D which is further from commercial reality. Compared to other manufacturing sectors, overall expenditure on R&D and NPD is relatively low[11].

Figure 5: New product variants by country (2005-2011)



Mintel NPD database, 2011. From: Food and Drink Federation, 2011. Sustainable growth in the food and drink manufacturing industry

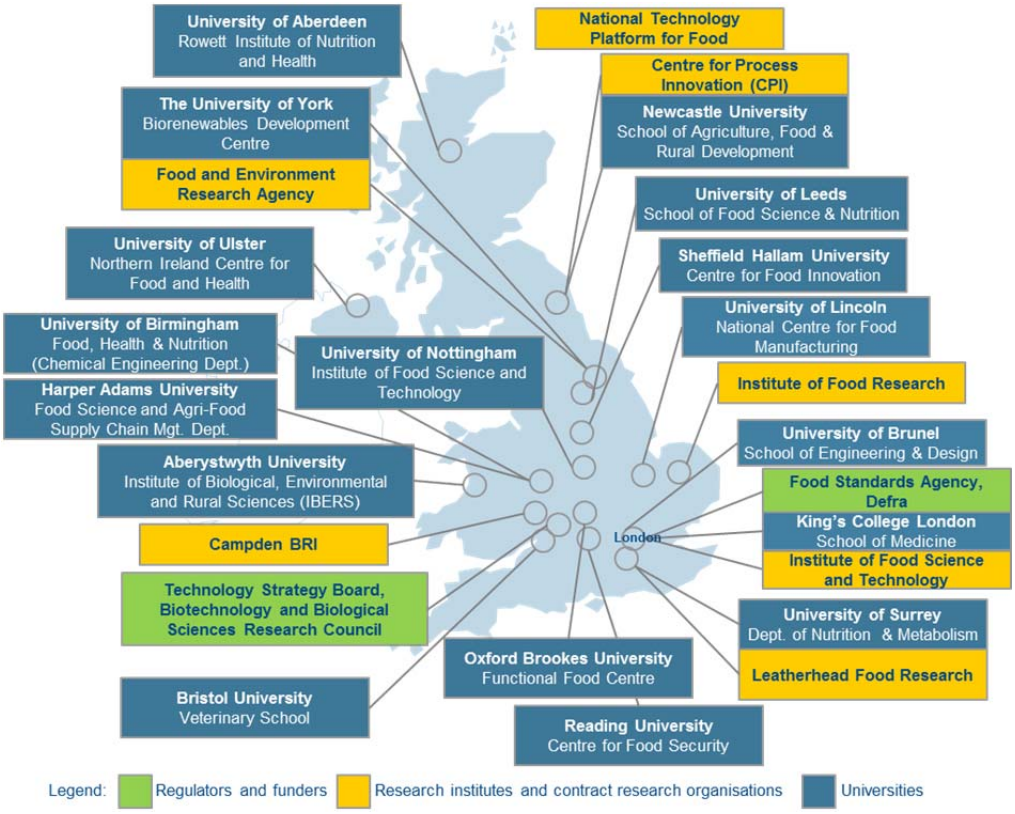
The industry is supported by a strong publicly funded science base, as depicted in Figure 6. This is highly diversified, covers a wide range of disciplines and is characterised by pockets of excellence, especially in the academic sector and at the food and agriculture interface. Many food and drink manufacturing companies, especially the smaller ones, conduct their R&D through specialist third party organisations such as Campden BRI and Leatherhead Food Research, which operate membership based systems.

Industry R&D is also supported by key initiatives such as the knowledge exchange networks run by the Biosciences KTN and the Food and Drink Innovation Network; those run by a wide range of cross-industry trade bodies such as the Food and Drink Federation; and sector-specific trade associations such as the Society for Dairy Technology. Key Government R&D funding measures include the Technology Strategy Board's (TSB's) Sustainable Agriculture and Food Innovation Platform (SAFIP) and the Biotechnology and Biological Sciences Research Council Diet and Health Research Industry Club (DRINC).

There are, however, some noticeable gaps compared to other countries, particularly in the food and drink machinery and automation sectors, where there are a multitude of smaller businesses and some strong networks, but few international scale players, with many manufacturers sourcing their process technology and equipment from companies with their production and R&D facilities domiciled in other countries.

[11] BIS R&D Scoreboard, 2010

Figure 6: Non-exhaustive overview of the UK food and drink R&D landscape



Source: Arthur D. Little analysis

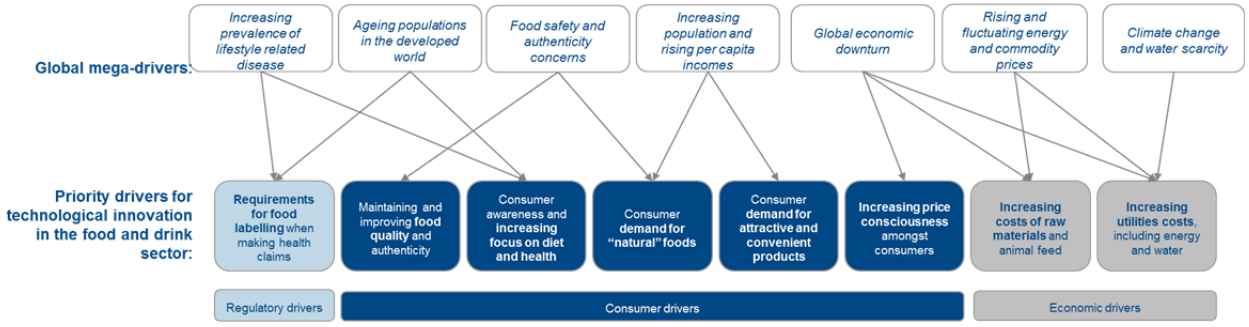
3. Drivers for technological innovation

This study has found that the strongest drivers for technological innovation are those that arise from the need to respond to tighter margins, provide price-conscious consumers with cheaper, healthier food products and address the rising costs of raw materials. Consumer demand also drives short term technological innovation associated with new product development, as organisations seek to differentiate their products in a fast moving and competitive marketplace.

Regulatory issues and the requirement to maintain and improve food quality and authenticity also drive technological innovation targeted at producing healthier and more traceable foods. Improving environmental sustainability is also a key driver, where it can show a material reduction in cost and provide further differentiation from the perspective of increasingly informed consumers. As well as these common drivers, SMEs are also strongly influenced concerns about regulations associated with food labeling and quality

Figure 4 summarises the priority drivers identified by the survey and consultation exercise, classified in terms of regulatory, consumer and economic influences. The drivers are broadly consistent across all of the seven sectors considered as part of this study and are further developed in the rest of this section.

Figure 7: Overview of drivers influencing technological innovation in the UK food and drink industry



Source: Arthur D. Little analysis

Drivers specific to the food and drink industry are influenced by 'mega-drivers' concerning natural resource availability, changes in population and demographics, and the global economic downturn

The drivers are influenced by a complex array of 'mega-drivers', wider market conditions which are not specific to the food industry. The mega-drivers are shown in the upper part of Figure 7, above. A rising global population is a key mega-driver. This is expected to reach 8 billion by 2030, requiring 50% more food production[12]. This increase will be coupled with the development of economies and changing patterns of consumption as societies become more affluent[1314]. Affluence is associated with an ageing population, which combined with a rise in lifestyle related disease such as obesity, diabetes and heart disease puts pressure on healthcare systems[15] and an improvement in the understanding of the link between diet and health has

[12] Beddington, J., 2009. Food, energy, water and the climate: a perfect storm of global events? Office for Government Science

[13] Office for Government Science, 2010. UK Cross-Government Food Research and Innovation Strategy

[14] FoodDrinkEurope, 2012. Environmental sustainability vision: towards 2030

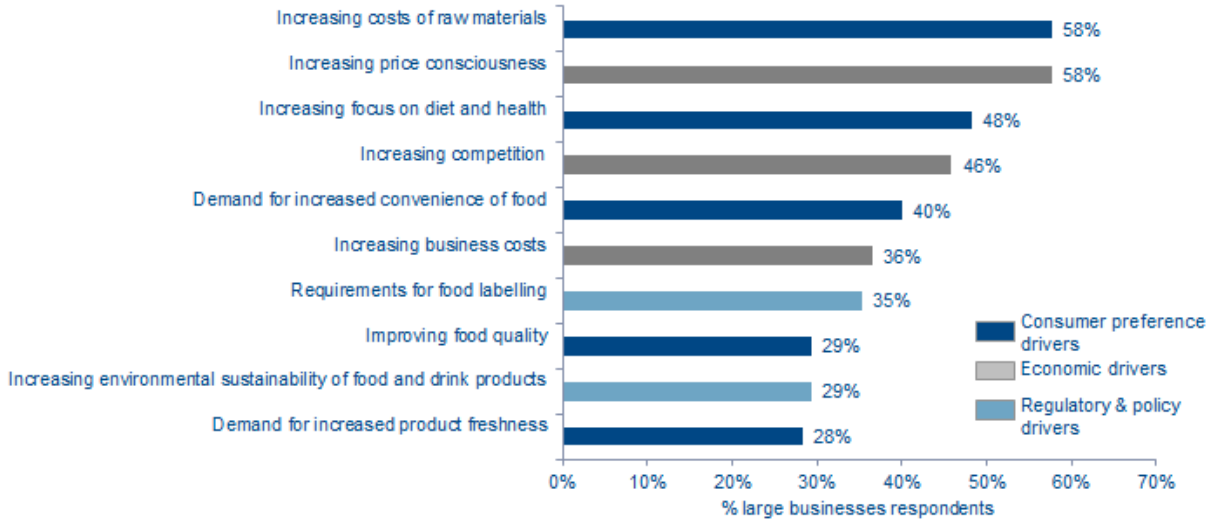
[15] Campden BRI, 2011. Scientific and technical needs of the food and drink industry – 2012-14

stimulated a wide range of Government initiatives associated with healthy eating and other lifestyle factors (for example, 5-A-Day, Change4Life and the Department of Health's salt and saturated fat campaigns[16,17]).

The strongest drivers for technological innovation are those associated with the need to respond to ever tighter margins, whilst providing price-conscious consumers with cheaper, healthier food products and dealing with the rising costs of raw materials

The impact of the increasing costs of raw materials, coupled with increasing price consciousness amongst consumers, creates strong drivers for technological innovation associated with cost reduction, with the aim of meeting consumer expectations for cheaper food, whilst maintaining or where possible improving margins. This was evident in the results of the cross industry survey. Figure 8 shows that, based on the views of the 280 respondents who completed the survey, the costs of raw materials and increasing price consciousness amongst consumers have the strongest influence over technological innovation activities.

Figure 8: Top ten drivers for technological innovation in the UK food and drink industry



Source: Arthur D. Little industry survey, January 2013. In response to the question: "From the following total list of drivers, please indicate the top five across all of the following categories that are influencing the focus and direction of your organisation's R&D / innovation activities in the UK". Drivers falling just outside the top ten focus on issues associated with regulatory compliance and cost reduction, including waste minimisation and food safety.

In terms of the increasing costs of raw materials, global agricultural commodity prices are expected to fluctuate but generally remain on a high plateau throughout the next decade, as shown in Figure 9. This is especially the case for meat products, reflecting reduced livestock inventories and producer margins which have been squeezed over several years by high grain and protein meal prices[18]. Fluctuations in prices for grain and vegetable products have also been apparent, primarily due to swing in climatic conditions and, as a result, variation in the size and quality of harvests and to an increasing worldwide demand for meat.

These fluctuations give rise to concerns over security of food supply – particularly during 2012 where poor UK wheat harvests resulted in significant additional imports from other markets, for example. Food security in relation to changing climatic conditions is of increasing importance amongst Governments, particularly in terms of improving crop yield and resilience and improving the robustness of supply chains[19].

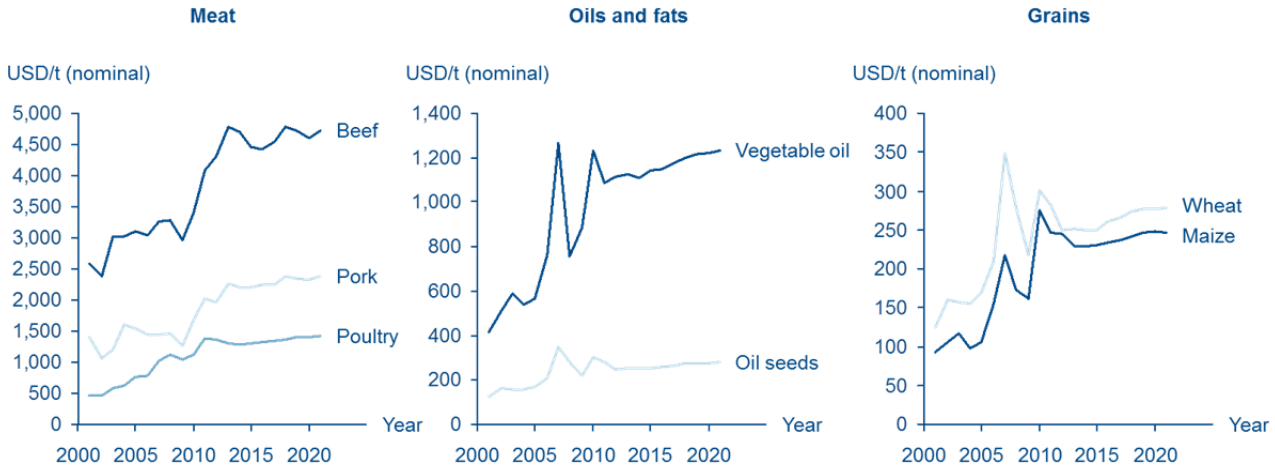
[16] For examples, see http://www.nhs.uk/LiveWell/Goodfood/Pages/Goodfoodhome.aspx accessed February 2013

[17] FSA (2008) Consumer Attitudes Survey

[18] OECD-FAO Agricultural Outlook 2012-2021

[19] For further information, see http://www.foodsecurity.ac.uk/research/future.html, accessed February 2013

Figure 9: Selected global agricultural commodity prices (2000-2020)



Source: OECD-FAO Agricultural Outlook 2012-2021

Simultaneously, consumers expect cheaper food, particularly as household incomes are being squeezed – and price is a key area of differentiation for retailers. This is particularly apparent for those parts of the supply chain which address retailer own brand products, and more so for larger companies. However, some SMEs (such as artisan bakeries, for example) do not seek to differentiate on price, although their markets still tend to be small.

Consumer demand drives short term technological innovation associated with new product development, as organisations seek to differentiate in a fast moving and competitive marketplace

In the food and drink industry, the consumer is the most immediate driver of all. The cross-industry survey revealed that half of the top ten drivers for technological innovation are associated with meeting consumer demand (Figure 8) in a fast moving and competitive marketplace. In addition to cheap food, consumers also require convenient, fresh and appealing products, and raw material processors, distributors, retailers and the packaging sector seek to respond to new ideas and consumer needs as quickly as possible to generate a point of difference.

This creates a requirement to fulfil short term demand whilst responding to competitive pressures, which in turn leads to a focus on short term new product development – an area where the UK is an international leader (see Section 2 Figure 5, above). However, this focus is often at the expense of longer term, more radical "step changes" in innovation activity.

Government regulation, voluntary, industry-led targets and consumer demand drives technological innovation targeted at healthier and more traceable foods

An increasing focus on diet and health also emerged as a top driver for technological innovation. Consumers are becoming better informed about the links between diet and health, and are increasingly demanding healthier, fresher food[20]. In a recent Food Standards Agency survey[21], 99% of respondents said that eating

[20] This view is supported by multiple similar studies, for example: Office for Government Science, 2010. UK Cross-Government Food Research and Innovation Strategy; Campden BRI, 2011. Scientific and technical needs of the food and drink industry – 2012-14

[21] FSA Food and You survey, 2010

fruit and vegetables was very or fairly important, 94% said that eating less salt was important and 92% said that limiting foods high in saturated fat was important. An increasing focus on diet and health, together with demand for more naturally sourced foods, are highlighted as some of the most important drivers for technological innovation, closely coupled with a requirement to meet increasingly demanding regulatory requirements, such as those associated with food labelling.

Food and drink traceability is also an issue. Much of the research and consultation for this study took place shortly before well publicised developments emerged around traceability of meat products in the food chain[22] and issues associated with traceability did not feature highly in either the cross-industry survey or consultations – though it was observed to be of a priority from the perspective of grain traceability. It is likely that in the future, traceability will appear much higher on the agendas of both industry and Government.

Improving environmental sustainability is also a key driver, where it can show a material reduction in cost and provide further differentiation from the perspective of increasingly informed consumers. The costs of energy, transport fuels and raw food and feed ingredients are rising, further impacting on margins of manufacturers and distributors[23]. Consumers are also increasingly aware of the importance of environmental sustainability, and the cross-industry survey indicates that this has become a key point of differentiation in the market for manufacturers – in fact, more so than the costs of energy and water[24].

Retailers in particular set priorities around improving the environmental performance of their supply chains by setting corporate social responsibility targets such as those contained in Sainsbury's 20x20 Sustainability Plan and Marks & Spencer's Plan A, which cover aspects of energy consumption and carbon emissions, and water use, amongst others. In addition, many of the top food manufacturers and retailers sign up to the Courtauld Commitment, which sets target to reduce the amount of waste and the environmental impact of products through the supply chain[25]. These initiatives – though tempered by what is technologically and commercially feasible within the supply chain – are a major force behind technological innovation.

The technological innovation activities amongst SMEs are driven by similar factors, although SMEs are more strongly influenced by a wider range of drivers including regulation associated with food labelling and quality

Looking at SMEs in isolation, the same drivers are at play. However, there is some variation in terms of their relative importance. In particular, SMEs attach importance to a wider range of innovation drivers. The economic issues described above are still present, with competition being the number one driver, but regulation concerning food labelling and food quality tends to be higher-rated, as is consumer demand for both healthy and 'natural' foods.

[22] See http://www.defra.gov.uk/food-farm/food/labelling/processed-beef-horse-meat/, accessed February 2013

[23] Ofgem, 2011. Why are energy prices rising? Factsheet 108

[24] The industry survey received 70 responses indicating that environmental sustainability was a priority (ranked 10th out of 22 drivers) versus 36 responses for increasing cost of utilities (ranked 18th out of 22 responses). See Appendix 2 for further details

[25] The Courtauld Commitment. See http://www.wrap.org.uk/category/initiatives/courtauld-commitment, accessed May 2013

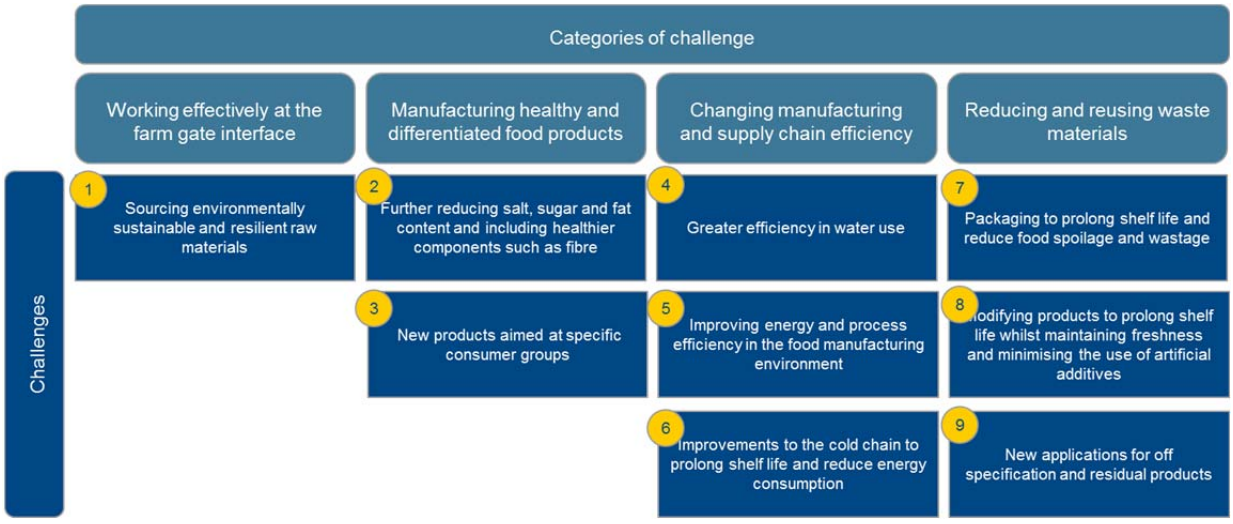
4. Priorities for technological innovation

The R&D drivers described above in Section 3 influence the direction of technological innovation. In particular, they give rise to specific technological challenges - problems or opportunities that require technological innovation in order to be solved or exploited. Given that most existing technological innovation activity focuses on delivering against shorter term goals through the incremental development of new products, the challenges seek to identify those areas which will require more of a "step change" in technology development to overcome.

This study has sought to prioritise "hot spot" challenges. A hot spot is a specific opportunity or problem which is of importance today, and is likely to remain important in the future, beyond a 10 year time horizon. Hot spots represent areas of unmet need or technological difficulty. The approach used to identify these hot spots is described in Appendix 1.

The nine hot spots which have emerged from this analysis are summarised in Figure 10. For clarity, they have been divided into four categories. All of these challenges will become, or remain important in the longer term (i.e. 10-15 years). They concern a range of issues which concern working effectively with primary producers at the farm gate interface, manufacturing healthy and differentiated food products, improving supply chain and manufacturing efficiency, and reducing and reusing waste materials.

Figure 10:Challenges to be addressed through technological innovation – Summary



Source: Arthur D. Little analysis

The extent to which these challenges are applicable to each sector varies considerably, as summarised in Table 1. This section of the document describes each of the hot spots, and how they link to drivers, and their applicability to each sector of the food and drink industry. It also highlights specific areas of technological innovation which would benefit from further near term effort to help to address these challenges in the medium to long term (i.e. 10-15 years plus). Recommendations have been made in Section 6 to develop these areas into a series of industry led technology roadmaps. The implications for inward technology transfer from adjacent industries are considered in Section 4.5.

Table 1: Applicability of challenges to different sub-sectors in food and drink

Sector:	1. Sourcing environmentally sustainable and resilient raw materials	2. Further reducing salt, sugar and fat content and including healthier components such as fibre	3. New products aimed at specific consumer groups	4. Greater efficiency in water use	5. Improving energy and process efficiency in the food manufacturing environment	6. Improvements to the cold chain to prolong shelf life and reduce energy consumption	7. Packaging to prolong shelf life and reduce food spoilage and wastage	8. Modifying products to prolong shelf life whilst maintaining freshness and minimising the use of artificial additives	9. New applications for off-specification and residual products
Biscuits, cakes & bread	H	H	M	L	H	L	H	H	H
Meat processing	M	H	L	M	M	H	H	M	M
Dairy	M	H	M	H	H	H	M	H	M
Fruit & vegetable processing	H	M	M	M	M	M	H	M	H
Oils & fats	H	H	L	L	M	L	L	L	H
Ready meals	M	H	H	M	H	H	H	H	M
Soft drinks & mineral waters	M	H	M	H	M	M	H	M	M

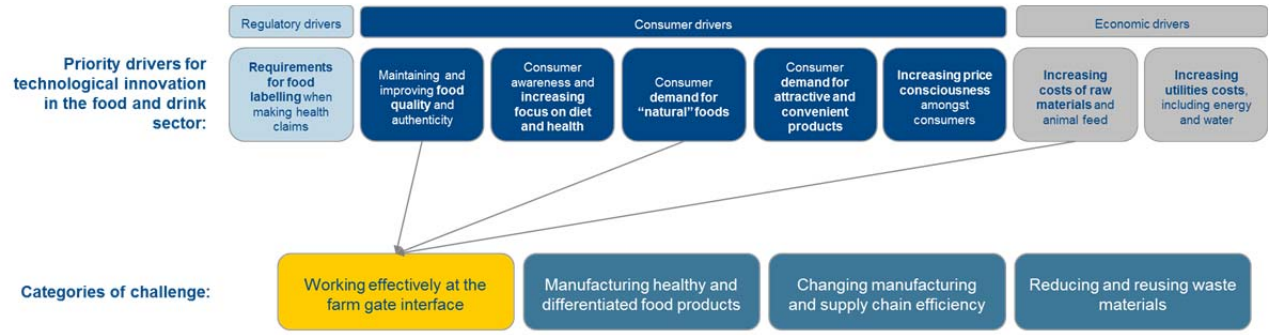
Source: Arthur D. Little analysis and consultation with industry stakeholders. Legend: H: High applicability of challenge to the industry sector. Key area of focus or area of unmet need. M: Intermediate, or secondary priority; other challenges take precedence. L: Limited applicability of this challenge to the industry sector. - : Not applicable to this sector

4.1 Working effectively at the farm gate interface

Food industry sector engagement with the pre-farm gate is driven by a need to maintain raw material and food quality and ensure that those materials which are sourced from farms or groves are traceable, nutritious

and fit for purpose. A further driver is associated with ensuring that raw materials are “natural” from a consumer perspective (e.g. to meet the demand for organic products). Economic drivers associated with finding ways to handle the rising or fluctuating costs of both raw materials and animal feed are also a key influence (Figure 11).

Figure 11:Influence of drivers on challenges associated with working effectively at the farm gate interface



Source: Arthur D. Little analysis

Challenge 1: Sourcing environmentally sustainable and resilient raw materials

The **sourcing of environmentally sustainable and resilient raw materials** was flagged up in the cross industry survey as the highest priority challenge associated with raw material processing – and the second highest overall (Appendix 2). For the UK, this challenge will become increasingly important as a component of improving food security as supply chains become increasingly complex[26]. For individual companies this also has significant implications for securing their own supply chains. The issue is of high priority for – in particular – the biscuits, cakes & breads sector, and the oils & fats and fruit & vegetable processing sectors.

Businesses must be able to handle increasing volatility in raw material prices, which are generally expected to remain under pressure due to a variety of factors including increasing usage demands (e.g. for biofuels), increased input costs (e.g. for fertiliser and chemicals), and pressures on resources, such as water and land availability,[27]. In most areas the effects of climate change will further exacerbate the supply situation by placing stresses on crop plants, potentially leading to catastrophic yield reductions[28].

Simultaneously, consumers – and in response, retailers – will increasingly demand the ability to assure the authenticity and traceability of raw materials. This is especially important at the moment in the meat processing sector. Whilst well publicised issues around meat authenticity and fraudulent food labelling arose after the majority of the work in this study was completed, traceability and thereby confidence in the supply chain is likely to remain a priority throughout the industry[29]. The meat and dairy sectors face slightly different issues, in terms of understanding the implications of animal nutrition and welfare on meat tenderness and milk composition.

There are currently a wide array of different mechanisms which can be used to establish whether raw materials are environmentally sustainable, including those managed by independent organisations, and

[26] Sellahewa, J.N., Martindale, W., 2010. Delivering Food Security with Supply Chain Led Innovations: Understanding supply chains, providing food security, delivering choice. Aspects of Applied Biology 102, pp91

[27] OECD/FAO Agricultural Outlook, 2012 – 2021

[28] Royal Society, 2009. Reaping the benefits: Science and the sustainable intensification of global agriculture, pp11

[29] Defra processed beef products and horse meat portal. Available at: http://www.defra.gov.uk/food-farm/food/labelling/processed-beef-horse-meat/ accessed March 2013

those developed internally by companies to control their own supply chains[30]. However, there is no universally agreed set of principles for what should be considered as sustainable – though efforts are underway at European level to do this for raw materials used for non-food purposes such as biofuels[31].

Specific, long term opportunities for technological innovation which could help with the environmentally sustainable sourcing of raw materials can draw on the UK's strengths in plant breeding and in adjacent industries, particularly the pharmaceutical and medical technologies industries. They include:

- **Plant breeding to enhance crop resilience, nutritional value, and the processability of raw materials:** Plant breeding offers an opportunity to make raw materials more sustainable through developing increased resistance to swings in climatic conditions, reduced need for high inputs such as fertilizers and pesticides, and reduced variation in nutritional content. Examples include the development of crops which exhibit enhanced tolerance to physiological stresses (e.g. tolerance of drought, extremes in temperature, soil salinity and nutrient deficiency[32]). Other opportunities include crop breeding to make raw materials easier to process, especially in the biscuits, cakes and breads sector (e.g. grain with a higher gluten content for improved bread-making; which is more consistent and better targeted to processes to avoid the costs and extra process steps associated with grain blending; or spherical grain more suitable for milling). This was also reflected in the oils and fats sector, where there is interested in using conventional plant breeding to modify fatty acid profiles in oilseeds to favour long chain polyunsaturated fatty acids, and in fruit and vegetable processing in, for example, producing tomatoes with a lower water and higher nutrient content. The UK has a world class plant research base[33,34] and is well positioned to deliver further technological innovation in crop breeding by exploiting increased knowledge of their genetic characteristics and ways to manipulate these
- **Sourcing alternative raw materials with lower environmental impact:** The identification of alternative raw materials presents opportunities to improve environmental sustainability by decoupling production from land use. These may include the use of marine resources, such as algae and the development of meat analogues to further supplement products such as Quorn and act as an alternative source of protein - a recent focus for the Gates Foundation in the United States[35]. This presents an opportunity for greater flexibility for feedstock use, and would need to be coupled with appropriate process technology
- **Online monitoring and detection of food quality and contamination:** There is a need to be able to undertake real time assessment of food quality, authenticity and contamination throughout the supply chain. Several examples were cited where the ability to be able to quickly and cheaply assess the quality of raw materials and to grade them for different uses, would help to reduce waste and reduce costs[36]. In the meat processing sector, improving consistency in meat tenderness and taste was highlighted as the leading technological challenge, one which is strongly influenced by animal nutrition and a topic which has achieved little attention in terms of technological innovation. Opportunities were identified in terms of developing new methods of predicting meat tenderness cheaply and detecting this at the meat cutting stage using techniques such as near infra-red scanning were highlighted as potential opportunities in the meat processing sector[37]. In oils and fats, methods of continuously detecting

[30] For example, Fair Trade products, and the Royal Society for the Prevention of Cruelty to Animals' Freedom Foods scheme

[31] For example, the Global-Bio-Pact Global Assessment of Biomass and Bioproduct Impacts on Socio-economics and Sustainability (http://www.globalbiopact.eu/, accessed May 2013)

[32] Royal Society, 2009. Reaping the benefits: Science and the sustainable intensification of global agriculture, Chapter 3

[33] Office for Government Science, 2011. The Future of Food and Farming: Challenges and choices for global sustainability. Foresight report

[34] Arthur D. Little, 2009. BBSRC/HEFCE Study of Land-Based Facilities and Resources

[35] See http://www.thegatesnotes.com/Features/Future-of-Food, accessed April 2013

[36] Arthur D. Little workshop with the Food and Drink Federation's Sustainability Steering Group, November 2012

[37] Consultations with EBLEX and Hilton Meats, November 2012

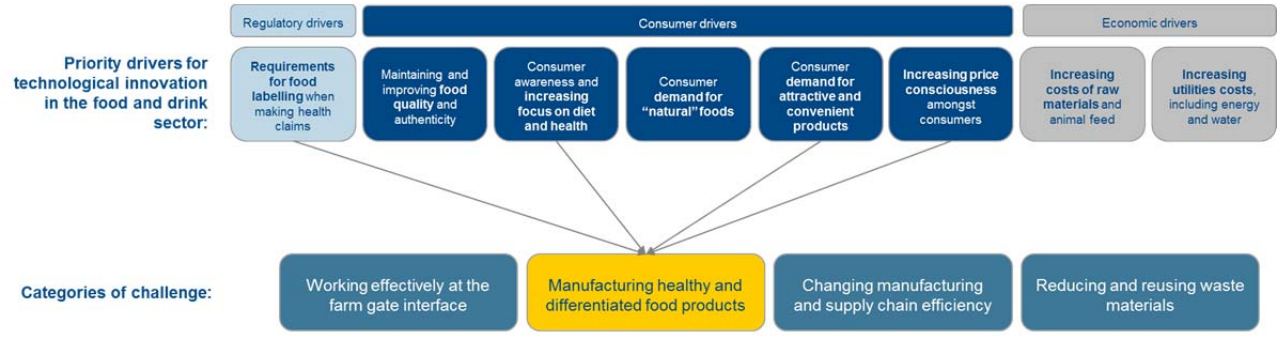
contaminants such as dioxins and mycotoxins were also identified as technology needs[38]. From the perspective of the biscuits, breads & cakes sector, traceability of grain and avoiding contamination from mycotoxin infections was identified as a priority. Online monitoring and detection was also highlighted as a key opportunity where technologies could be transferred from sectors such as the medical technology and pharmaceutical sectors using technologies such as PCR[39] and high throughput screening

- **Animal nutrition and understanding its impacts on food products:** Dairy and meat processing companies, as well as retailers, highlighted the importance of technological innovation in animal nutrition and the impact this can have on food products. In dairy, ruminant feeding regimes were highlighted as an important influence on milk composition, particularly in terms of mineral, protein and saturated fat profiles. Some retailers (e.g. Sainsbury's) are working directly with farmers to address these issues

4.2 Manufacturing healthy and differentiated food products

The challenges associated with the manufacturing of healthy and differentiated products are driven by consumers and Governments becoming increasingly aware of the importance of diet and health, and a general desire for products which are healthier – though this is tempered against them being appealing, attractive, convenient and flavoursome. Driving down product costs is also an issue here, as summarised in Figure 12. The challenges associated with this theme concern optimising macronutrient balance, specifically the further reduction of salt, sugar and fat content whilst increasing the content of healthier ingredients and the development of new products targeted at specific consumer groups. The development of "functional" foods or nutraceuticals which aim to demonstrably convey health benefits barely featured in either the survey or consultations. This is primarily due to difficulties in making the health claims needed to differentiate these products in the marketplace, an issue which is discussed further in Section 5 of this document.

Figure 12: Influence of drivers on challenges associated with manufacturing healthy and differentiated food products



Source: Arthur D. Little analysis

Challenge 2: Further reducing salt, sugar and fat content and including healthier components such as fibre

The **further reduction of salt, sugar and fat** was identified consistently by many of the sectors, and amongst all sizes of company, as a high priority for technological innovation. This was considered to be especially important for biscuits, cakes & breads, ready meals and meat processing. This is an area of particular importance to the Government because of its likely impact on diseases such as diabetes, heart disease and stroke[40].

[38] Consultation with SCOPA on behalf of AAK, Archer Daniels Midland and Cargill, December 2012

[39] Polymerase chain reaction, a means of amplifying and detecting trace levels of DNA

[40] As set out in the Department of Health's Public Health Responsibility Deal, available at www.responsibilitydeal.dh.gov.uk, accessed March 2013

Efforts to reduce salt intakes have been a priority for Government since 2002[41]. The population average intake has decreased over recent years but still remains above the 6 grams per day target considered by experts to be desirable. Manufacturers believe that further reductions in foods will present a significant technological challenge, as many of the "quick wins" (particularly in highly processed foods and ready meals) have now been achieved.

As well as salt, Government's Responsibility Deal voluntary commitments with the food sector also include targets for reducing the fat and sugar content of foods[42]. Meeting these as well as reducing the overall caloric content of food whilst ensuring consumer acceptance will require further technological innovation. Continued fat reduction was highlighted as a particularly significant challenge as fat is an important ingredient in products such as biscuits, cakes and breads, and for meat quality. The need to maintain taste is also likely to provide a significant challenge to reducing fat levels much further. There is a danger that replacing fat with carbohydrates, could lead to an undesirable increase in the overall calorific value of food. A related challenge is how to produce foods with a **high content of healthier components such as fibre**, which emerged as an issue during the horizon scanning component of this study.

Specific areas of technological innovation which could have a substantial impact on solving these challenges include:

- **Formulation engineering:** Formulation offers an opportunity to reduce the levels of components which might impact adversely on health whilst enhancing those such as fibre, vitamin or minerals. There remains however a need for more on research into the structure of foods and the means to alter the bioavailability of nutrients[43] as well as opportunities to further modify the composition of processed foods to reduce their calorific value whilst maintaining taste and increasing satiety, or using more high fibre ingredients in biscuits, cakes & breads, where formulation activity is one of the most significant areas of technological innovation today (Appendix 6). The cross-industry survey indicated that the consumer perception of taste versus health was a particular challenge in terms of maintaining appetite appeal in healthier products, and formulation could play a role in this
- **Sensory science and taste perception:** Better understanding of the impact of smell, taste, texture and visual appeal of food can help to influence food consumption patterns. Sensory science can complement product formulation and ingredient substitution to create products which are perceived as sweet or salty, whilst having a low salt or sugar content
- **Identification of substitutes for salt and sugar:** A significant amount of effort has already been invested in seeking alternatives to salt and combating the impact of salt removal on flavour[44]. Further technological innovation is needed to find acceptable substitutes not only from the point of view of taste but also functionality (e.g. for bread-making). Alternatives to sugar (e.g. through the development of edible zeolites) must also be able to meet these criteria as well as offering opportunities for calorific reduction

[41] Department of Health salt reduction targets. Available at http://www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/documents/digitalasset/dh_125228.pdf accessed February 2013

[42]Department of Health Public Health Responsibility Deal: Food pledges. Available at https://responsibilitydeal.dh.gov.uk/food-pledges, accessed March 2013

[43] Consultations with the Biosciences KTN and Birmingham University, February – March 2013

[44] Food and Drink Federation / Leatherhead Food Research, July 2012. Salt reduction reaching its limit. Available at http://www.fdf.org.uk/news.aspx?article=5918 accessed February 2013

Challenge 3: New products aimed at specific consumer groups

Some activity is already underway to develop products which are targeted at specific population groups such as the elderly, infants and those engaging in sports activities; to use allergen free ingredients (e.g. gluten-free foods); and to produce products which are targeted at consumers with specific health conditions (e.g. diabetes)[45] but with, for example, an ageing population, there is potentially scope for much more to be done here. This will however require a significant increase in technological innovation particularly to maintain healthy ageing and lifestyles. This represents an opportunity for UK based companies to offer higher value and a more diversified range of products to both domestic and international markets.

Longer timescale range opportunities for technological innovation may arise from the genetic screening of population groups. Products could then be tailored to these populations and developed into programmes of personalised nutrition. Specific opportunities include:

- **Diagnosis, detection and prediction of nutrition-related illness:** Considerable activity is underway in the healthcare industries in understanding genetic predisposition to certain diseases. This opens up the possibility of being able to link genomic and metabolomics information with diet in order to predict future nutrition related illness at certain stages of life. However, less work is currently underway in terms of developing "companion" diagnostics associated with nutrition related disease, particularly where associated with detecting allergens in food products during the food manufacturing process (e.g. the use of swabs for detecting food allergens on process equipment lines used for multiple purposes). There are potential interfaces with the clinical science sector through initiatives such as the joint TSB / Medical Research Council (MRC) Stratified Medicine Innovation Platform[46]
- **Personalised nutrition programmes targeted at healthy ageing:** Using genetic diagnostic techniques might provide an opportunity to develop programmes of personalised nutrition and develop specific foods which are targeted at clusters of individuals with the same genotype. As of January 2013, the European Food Information Council has begun funding the Food4Me project to help to achieve this[47]. The horizon scanning exercise conducted as a component of this study indicated that personalised foods could be used to guide a programme of lifelong nutrition, such that particular products could be consumed at a certain stage of life – but that would require significant technological advancement
- **Individual products which are targeted at reducing the risk and emergence of nutrition related disease:** Products and dietary regimes for those already suffering from diseases such as Type II diabetes are already commonplace. However, in a world where predisposition to certain diseases could be diagnosed and predicted, there might be scope to develop products which could be consumed in earlier stages of life in order to reduce the likelihood of these diseases emerging in the future, or at least are delaying their onset
- **Proving product efficacy quickly and cheaply:** a need was highlighted for the development of faster, cheaper methods of testing new products in order to satisfy regulatory scrutiny for efficacy and thereby to support health claims, so helping to overcome the hurdles currently faced by nutraceuticals and functional foods.

[45] Arthur D. Little consultations with industry representatives, January – March 2013

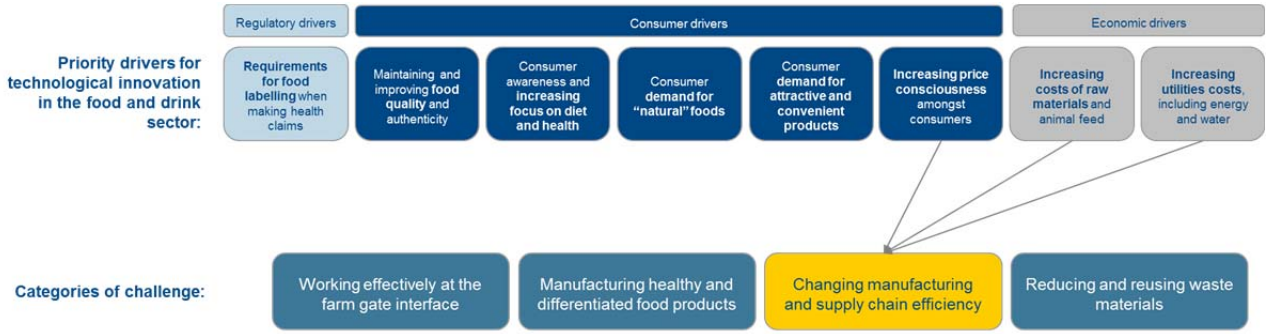
[46] Technology Strategy Board – Stratified Medicine Innovation Platform. Available at http://www.innovateuk.org/ourstrategy/innovationplatforms/stratified-medicine-.ashx accessed March 2013

[47] The Food4Me Project. Available at: http://www.food4me.org/ accessed March 2013. The UK component of Food4Me is being led by Reading University

4.3 Changing manufacturing and supply chain efficiency

Drivers to improve efficiency in both manufacturing and supply chains are associated with the need to reduce costs in response to tightening margins. The main factors here are consumers demanding cheaper food, raw material and animal feed costs rising, and rising costs of utilities (Figure 13). Two key challenges associated with energy and water use lie within this theme.

Figure 13: Influence of drivers on challenges associated with changing manufacturing and supply chain efficiency



Source: Arthur D. Little analysis

Challenge 4: Greater efficiency in water use

The food and drink industry is a major user of water, both from direct abstraction and use of the public water supply with a demand on the latter of about 10% of all industrial use[48]. Greater efficiency in water use – both in food manufacturing and the processing of primary raw materials – is not currently primarily driven by efforts to reduce costs, though this remains an important consideration, and is likely to become increasingly important in the future as demand for water increases and consumption is monitored more closely[49]. Instead, consultations and the results of the cross-industry survey indicate that reputational issues with more environmentally aware consumers are the primary driver at present for efforts to reduce the overall consumption of potable water (see Appendix 2).

The dairy industry was one sector in particular that emphasised water use as a greater challenge than other sectors. This is due to the considerable size of modern dairy facilities and the large volumes of water needed in line changeovers and for washing down process equipment. The ready meals sector also highlighted water use in frequent line changeovers and cleaning as an issue.

Existing initiatives to reduce water use in dairy have focused on clean-in-place methods to enable cleaning without equipment disassembly. More recently, some significant progress has been made in dairy plant design to reduce water use. Arla's new dairy at Aylesbury contains inbuilt water recycling facilities targeted at reducing the water footprint of the facility by two thirds compared to conventional dairies, and Müller – Wiseman's new plant at Bridgewater is able to reuse treated effluent[50].

[48] Defra, 2006. Food industry sustainability strategy

[49] Food and Drink Federation – priorities in water. Available at: http://www.fdf.org.uk/water.aspx accessed March 2013

[50] Arthur D. Little consultations with dairy companies and the Society for Dairy Technology, January – March 2013

There have also been wider initiatives to reduce water use. For example, a voluntary commitment was launched in 2008 by the UK Food and Drink Federation (FDF) and Envirowise to reduce water use in the food and drink sector[51]. Signatories have pledged to reduce their on-site water use, excluding water incorporated into products, and contribute to an industry-wide reduction target of 20% by 2020 measured against a 2007 baseline[52]. All of the UK's largest dairies have signed up to this initiative, measuring progress in terms of a milk:water ratio[53] and the International Dairy Federation has initiatives underway to develop new tools for water footprinting.

Technological innovation themes include the reduction of overall water use, and finding new ways to use non-potable water. Specific opportunities included:

- **The development of novel low-water cleaning technologies:** This included furthering the understanding of the application of surface science (e.g. bacterial adherence to stainless steel) as well as using developments in the field of industrial biotechnology (e.g. enzymatic technology for self-cleaning equipment)
- **Cheaper and more effective water clean-up, recycling and effluent treatment**: This includes the removal of extractives, from water. Phosphate extraction was highlighted as a key extractive, as overall phosphate supplies are dwindling, and this topic is a current area for focus by the Environment Agency[54]

Challenge 5: Improving energy and process efficiency in the food manufacturing environment

Efficiency improvements in food manufacturing focus on reducing costs by minimising processing steps and increasing throughput, and reducing energy consumption. Reduction of overall energy use – and a result, the release of carbon emissions through the burning of fossil fuels – was highlighted in the cross-industry survey as a priority for food manufacturers of all sizes, who face increasing energy costs (Appendix 2). Government carbon reduction mandates such as the Carbon Reduction Commitment (CRC) Energy Efficiency Scheme also exert an influence over large energy intensive businesses such as larger food manufacturers and retailers[55].

In terms of making efficiency improvements in existing buildings where food manufacturing and processing takes place, much work has already been achieved through, for example, integration of more advanced heating, ventilation and air conditioning systems and introduction of low energy lighting.

Beyond this, less progress has been made – due primarily to the significant capital costs associated with introducing new process technology and equipment, which poses a challenge both for businesses with large or high throughput production lines, and smaller businesses which face difficulties in accessing the necessary capex funding[56].

In terms of overall efficiency, the UK's food manufacturing industry is in general less automated than those in other countries such as Germany and Denmark[57]. Activity in food processing equipment and process technology development in the UK is also limited and there is not much domestic capability in equipment

[51] Federation House Commitment. See http://www.fhc2020.co.uk/fhc/cms/, accessed March 2013

[52] FoodDrinkEurope,2012. Environmental sustainability vision: towards 2030

[53] See http://www.edie.net/news/4/Dairy-UK-partners-with-FHC-to-reduce-water-usage/23803/, accessed February 2013

[54] Personal communication with Defra, April 2013

[55] UK Government Carbon Reduction Commitment (CRC) Energy Efficiency Scheme. Available at: https://www.gov.uk/crc-energy-efficiency-scheme accessed February 2013

[56] Arthur D. Little consultations with Premier Foods and the National Association of Master Bakers, February 2013

[57] Arthur D. Little consultations with the Food and Manufacturing Engineering Group, February 2013

design or process control for the high speed, multiproduct manufacturing processes often seen in other countries[58]. Activity which does take place is primarily within smaller businesses – some of which are very successful, and export their technologies widely – and via specialised networks such as the Food Manufacturing Engineering Group.

There are further opportunities to seek ways of reducing energy consumption in some of the more energy-intensive steps involved in food processing – notably in terms of refrigeration when achieving rapid temperature reduction of heat-treated foods and maintaining low temperatures during preparation, packaging, and storage. Other energy intensive steps involve physical aggregation and disaggregation, extraction of raw materials (e.g. protein and fibre) and cooking and thermal processing.

Opportunities for technological innovation to address this challenge include:

- **New methods of cooling the ambient factory environment:** This involves identifying entirely new ways of chilling air, rather than modifying or optimising commercially available heating, ventilation and air conditioning systems
- **Design and build of energy efficient factories:** This involves the design and building of manufacturing environments which are ergonomically designed and more energy efficient. This is particularly important in terms of minimising the cold areas of plants, improving air flow and enabling greater modularisation, flexibility and compactness. This is especially important for the dairy sector and in the ready meals sector – and lessons could be captured from the automotive sector in terms of efficiency with high throughput
- **New processes and techniques for freezing and chilling:** This involves opportunities for freezing and chilling as part of the production cycle, as well as post-process chilling for products such as ready meals. Specific opportunities include novel chilling and freezing technologies (e.g. the use of magnetic freezing and piezo electronics) as well as super insulators and eutectics
- **New processes and techniques for cooking and thermal processing and capture of low grade heat:** This involves adoption of technologies which reduce the most energy intensive steps of food processing, including, for example, alternatives to heat pasteurisation, UV light and the use of molecular sieves in place of boiling and thickening activity and enzyme-based alternatives to drying technologies. There is also an opportunity for the capture and use of low grade heat (e.g. from ovens, using better heat exchangers and cleaning processes)
- **Greater use of dehydration and rehydration:** This allows more materials to be transported in a dry state through the supply chain in order to better control it

Challenge 6: Improvements to the cold chain to prolong shelf life and reduce energy consumption

In comparison with primary processing and food manufacturing, the distribution of food accounts for a relatively small proportion of energy consumption. Of this proportion, up to 47% is attributed to refrigeration[59].This creates a challenge associated with improving efficiency in the cold chain as a component of improving overall energy efficiency. The ready meals, dairy and soft drinks and beverages sectors, as well as retailers, all flagged post-production refrigeration as an important challenge. Those active in the chilled foods sector observed that much cold chain technology is already available, and that new approaches are being developed (e.g. at the Universities of Brunel and Cranfield and via the British Retail Consortium) so the issue is as much about technology transfer as it is about technology development.

[58] FDF, October 2012. Vision for innovation in food and drink manufacturing

[59] Defra, 2012. Green Food Project Curry Sub Group Report, pp4

In particular, one of the most energy inefficient components of the cold chain is energy use within the home and the low efficiency and poor temperature control of many domestic refrigerators – the basic technology of which has remained largely unchanged for many years and which has been the subject of studies by WRAP[60]. However, technological innovation here is more likely to be the responsibility of the manufacturers of white goods. Domestic fridges in France are required by a Decree to have storage compartments able to maintain the correct chill temperature and that they carry visible and legible thermometers to show this, and organisations such as CFA are lobbying to make this the case in the UK[61].

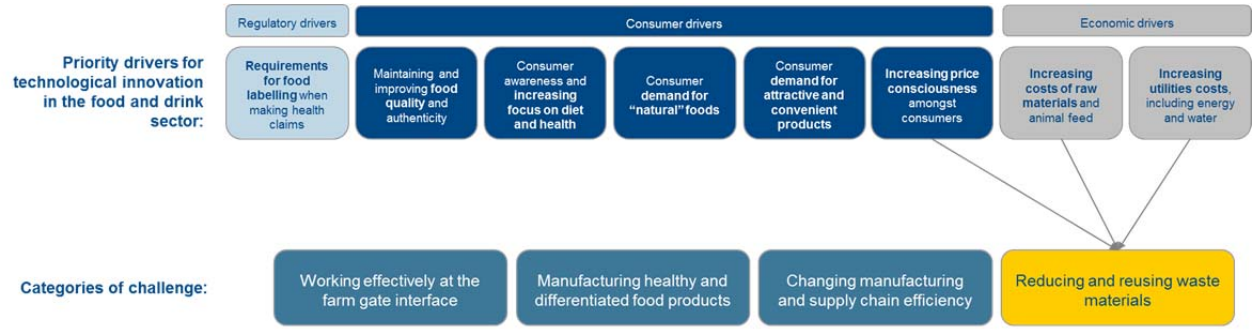
Specific opportunities for technological innovation associated with this challenge:

- **Reducing energy losses within the retail environment**, particularly in retailer chiller cabinets and development of heat reflective packaging materials, cited as a high priority amongst retailers themselves. This is a complex issue, as display cabinets must not create a barrier between the consumer and the product
- **Minimising the need for chilling throughout the food chain:** Improving supply chain and logistics management to minimise the time that chilled foods are in transit and product innovation to develop foods which are ambient stable to point of retail – though care must be taken to ensure that consumers are not misled as to their freshness in line with EU consumer information requirements[62]
- **Maximising production within the supply chain:** Such as, for example, labelling and packing fruit and vegetables whilst in transit and improving understanding of ripening

4.4 Reducing and reusing waste materials

Waste reduction and reuse is primarily driven by economic issues associated with maximising efficiency and reducing operating costs, as summarised in Figure 14.

Figure 14:Influence of drivers on challenges associated with reducing and reusing waste materials



Source: Arthur D. Little

Challenge 7: Packaging to prolong shelf life and reduce food spoilage and wastage

Packaging is one of the main current priorities for technological innovation across all sectors in the food and drink industry, as well as an important consideration for supplier selection and procurement. The cross-industry survey showed that respondents believe that packaging is one of the most significant areas for potential Government support in technological innovation – essentially because it is one of the main areas in

[60] WRAP, 2010. Insights around the domestic refrigerator. Available at: http://www.wrap.org.uk/content/insights-around-domestic-refrigerator, accessed April 2013

[61] Chilled Food Association newsletter, Spring 2013, issue 39

[62] EU Regulation 1169/2011 on the provision of food information to consumers

which companies in the food supply chain currently seek to innovate (Figure 15). Most current technological innovation in packaging focuses on:

- **Improving packaging from a marketing perspective:** Much innovation in packaging is focused on making products more attractive and convenient for consumers – such as making products easier to carry, take up less space when stored in the home, and able to withstand changes in temperature when heated from frozen
- **Reducing production costs:** Efficiency is also important in terms of developing packaging which is suitable for a wide range of products and therefore requires minimal line changeover time

Figure 15: Summary of free-text responses to the question: If you were in Defra's position, what R&D would you fund to encourage the production of environmentally sustainable food?

Source: Arthur D. Little industry survey, January 2013. Image produced using wordle.net. Based on 253 free-text responses to the question: "If you were in Defra's position, what R&D would you fund to encourage the production of environmentally sustainable food? The size of each word is proportional to the number of times the word was used by the respondents

Packaging is a major source of waste, both in the home, and within the food and drink supply chain. As a result of this, minimising or reusing packaging to reduce waste associated with the food and drink industry is established as a known industry challenge and has received significant attention.

Material light-weighting was a consistent near-term theme associated with waste reduction as it provides opportunities to reducing the costs and carbon footprint associated with the transportation and distribution of food and drink products. Companies in the soft drinks and mineral waters sector, which transport large volumes of bulk products and those companies which supply them (e.g. Rexam, Tetra Pak) highlighted the light-weighting of packaging as a key current area for focus – though one which must be tempered against consumer suspicion around lower robustness of packaging and the potential for damaging goods in transit

The use of reusable packaging, particularly as a means of reducing the volume of single trip packaging to manufacturing sites was also highlighted as a priority[63]. A significant body of work has been focused on initiatives to reduce packaging volumes. Commitments are in place amongst several retailers and food manufacturers to reach a zero waste to landfill target by 2015 through the Food and Drink Federation's Five Fold Ambition, together with a similar agreement through the British Retail Consortium. In addition, an on-going voluntary WRAP initiative known as Courtauld 2, due to be revised and updated in May 2013, seeks to reduce waste arising and to reduce the environmental impact of packaging[64].

[63] WRAP, 2011. Opportunities for resource efficiency in the food and drink sector.

[64] FDF's Five-Fold Environmental Ambition aims to send zero food and packaging waste to landfill at the latest by 2015 and make a significant contribution to WRAP's Courtauld 2 target of reducing product and packaging waste in the supply chain by 5% by end of 2012 against a 2009 baseline. The British Retail Consortium's "A Better Retailing Climate" sets out similar provisions, together with the broader environmental impact of retailers

Packaging recycling is also a near-term priority, particularly for those in the soft drink and mineral waters and ready meals sectors, which generate large volumes of potentially recyclable packaging waste (e.g. plastic bottles, aluminium cans). WRAP's Courtauld 2 commitments call for manufacturers to work with consumers to increase recycling rates[65]. Food manufacturers in these sectors raised issues associated with obtaining a consistent supply of recycled materials of the required quality[66]. To some extent this can be attributed to the fragmentation of waste collection and segregation schemes and deployment of waste separation technologies, which have been devolved to local government. Much work is underway to improve consistency in this area, notably through WRAP's best practice guides for local authorities[67].

The main opportunity for further technological innovation in packaging concerned its role in food waste reduction in terms of prolonging shelf life and reducing food spoilage and wastage. Packaging is the main defence against food contamination, spoilage and discolouration[68]. More candidates for protective atmospheres in the fruit and vegetable and meat processing sectors (e.g. nitrogen or ozone rich atmospheres or ethylene absorption technology, such as the "It's Fresh" ethylene management system have been developed in the past), novel barrier technologies, vacuum packaging and methods of effectively resealing opened food containers (e.g. in ready meals) were all identified as important challenges in the consultation programme.

An area for long term focus is the development of **smart packaging** that can signal when food becomes unfit for consumption, taking account of the way that it has been handled during transportation, display and storage in the home, thus avoiding the need for the inflexible ' use by ' or ' best before' date marking.

However, addressing this challenge through technological innovation will be difficult, for an industry constrained by tight margins where expenditure on more technologically advanced packaging which does not attract consumers to buy a product or reduce costs is often not an option. It is therefore unclear who might benefit from overcoming this challenge, as those who hold, or would be required to deploy, the technology are not necessarily those who stand to benefit from the results.

Challenge 8: Modifying products to prolong shelf life whilst maintaining freshness and minimising the use of artificial additives

The consumption of chilled foods, which have shorter shelf lives than frozen or ambient stable alternatives, has risen dramatically in recent years. This is driven by the desire of consumers for increased freshness and less use of artificial additives, or processing which can reduce nutrient content.

Efforts to prolong shelf life without the need for chilling by modifying the properties of processed foods whilst maintaining freshness and nutrient levels was identified as being important by those sectors which typically have to work with fairly short shelf lives, especially in fruit and vegetable processing and ready meals. A wide range of views were expressed amongst consultees about this challenge, and how to best solve it, as if efforts to increase shelf life are to be successful they need to be able to address consumer suspicions about the use of unfamiliar processing technology and the lack of freshness. Opinions were particularly divided on the difficulty of doing this in the ready meals sector. Nevertheless this challenge is significant, and WRAP observe that overcoming this challenge could have significant impact on waste reduction, and that, for

[65] WRAP Courtauld 2 commitments – targets, benefits and progress. Available at: http://www.wrap.org.uk/content/courtauld-commitment-2-targets-progress-and-benefits accessed February 2013

[66] Post Farm Gate Technical Challenges Workshop 14th July 2010

[67] Available at http://www.wrap.org.uk/content/technical-guides-local-authorities, accessed March 2013

[68] Post Farm Gate Technical Challenges Workshop 14th July 2010

example, 1-2 extra days of usable life in food products such as milk is sufficient to reduce household food waste by up to 40%[69].

Technological innovation activities in this area covered efforts not only to prolong overall shelf life extension but also to ensure that products are safe to consume up to and including the use by date, even if they have been opened and re-sealed. The way in which foods are processed can also have an impact and **alternative means of controlling spoilage organisms** are a way of addressing this. Technologies such as ultrasonics, microwaves, irradiation and pressure can be used to do this – though these have seen a low uptake, potentially due to high costs[70]. A key existing initiative here is the Sustainable Shelf Life Extension (SUSSLE) project, which sought to better understand the effects of heat processing on spore-forming pathogens[71].

Challenge 9: New applications for off specification and residual products

Challenges associated with waste reduction are largely covered in other parts of the supply chain, in terms of optimising packaging and improved efficiency in factory operations. However, a specific challenge associated with finding new added value applications for off specification and residual products produced during manufacture has emerged from this analysis, particularly in terms of:

- Fruit and vegetables which do not conform to European guidelines in terms of appearance and quality
- Off-specification dairy products, including milk returned from retailers, end of line or start of line batch runs, mislabelled products, or those which fail quality assurance
- Improving the profitability of components of cereals not wanted by food manufacturers, for example, seeking new opportunities in developing non-food materials such as wheat husks, rather than using it for animal feed, which can produce low – and sometimes negative – returns
- Finding new applications for by-products associated with raw material processing (for example, finding novel or high value applications for residual beet pulp following beet crushing to extract sugar)

The National Industrial Symbiosis programme, originally piloted at the regional level, and scaled up to a national initiative through Government's Business Resource Efficiency and Waste Programme, joins up different parts of the food and drink supply chain with other sectors[72]. Other technological innovation opportunities associated with finding new applications for off specification and residual products include:

- **Improving connectivity with small-scale waste production, both within the supply chain and within individual businesses:** This could include opportunities to better link producers with potential users (a specific example involving linking bakeries with a surplus of egg whites to potential users) as well as seeking opportunities to reuse specific off-streams within or between businesses (by, for example, finding ways to reuse gases with elevated carbon dioxide levels in covered agriculture)
- **Conversion of food manufacturing and domestic waste to non-food materials**, particularly using applications in industrial biotechnology (e.g. advanced enzymes and associated bioprocessing) and scaling up these applications. Examples include the production of materials for use in packaging, and chemicals and fuels for use in transport and other applications
- **Decontaminating waste streams for food use**, with specific examples including, for example, the extraction of hemicellulose from biomass to use as a food product and the extraction of functional ingredients from off specification or residual products (e.g. soluble fibre)

[69] WRAP, 2013. The Milk Model: Simulating Food Waste in the Home; Personal communication with Andrew Parry, WRAP, April 2013

[70] Arthur D. Little workshop with the Food and Drink Federation's Sustainability Steering Group, November 2012

[71] See http://www.chilledfood.org/MEDIA/NEWS/2012/SUSSLE+Project+gets+Top+Marks+from+Defra, accessed March 2013

[72] Case studies available at http://www.nispnetwork.com/about-nisp, accessed March 2013

4.5 Opportunities for technology transfer from adjacent industries

Some of the challenges and areas for technological innovation present opportunities to transfer in technologies from other sectors where the necessary capabilities are already well developed. These include the pharmaceutical, medical device, chemistry and chemical engineering, industrial biotechnology and automotive sectors. The opportunities identified as part of the consultation programme and also the horizon scanning exercise conducted as part of this study are summarised in Table 2.

Table 2: Opportunities for technology transfer from adjacent industries

Challenge	Area of technological innovation	Capability in adjacent sectors
Sourcing environmentally sustainable and resilient raw materials	Online monitoring and detection of food quality and contamination	Clinical diagnostics Medical devices Pathogen and allergen detection
Further reducing salt, sugar and fat content and including healthier components such as fibre	Sensory science and taste perception	Psychological science
	Identification of substitutes for salt and sugar	Microstructural engineering and design
New products aimed at specific consumer groups	Individual products which are targeted at reducing the risk and emergence of nutrition related disease	Personalised medicine and companion diagnostics
	Diagnosis and prediction of nutrition-related illness	
	Proving product efficacy quickly and cheaply	Clinical research
Greater efficiency in water use	The development of novel low-water cleaning technologies	Industrial biotechnology
	Cheaper and more effective water clean-up, recycling and effluent treatment	
Improving energy and process efficiency in the food manufacturing environment	Design and build of energy efficient factories	Automotive manufacturing Civil engineering
New applications for off specification and residual products	Conversion of food manufacturing and domestic waste to non-food materials	Industrial biotechnology
	Decontaminating waste streams for food use	

Source: Arthur D. Little analysis

4.5 Summary of priorities for technological innovation

In summary:

- **There is considerable further scope for technological innovation to address these challenges, some of which will require a step change in current understanding.** Further reducing the salt, fat and sugar content of products – a top priority for healthier foods will require this in particular
- **Some areas will require coordinated effort across the supply chain.** Sourcing environmentally sustainable and resilient raw materials, for example, will require coordinated effort on both sides of the farm gate
- **Much work has been done already – and should be taken into account in future initiatives.** Examples include the array of work that has taken place in packaging minimisation and recycling through the efforts of industry and organisations such as WRAP, as well as key projects through, for example, the LINK programme. There is a need to ensure that these outcomes are taken into account
- **The challenges vary considerably from sector to sector** – such that it would be unwise to attempt to address them collectively in a single, cross-industry initiative
- In addition, **many of the challenges require scientific activity from multiple disciplines**. For example, reducing salt, fat and sugar content could involve chemistry, formulation engineering, behavioural science, psychology and sensory science to address adequately
- There are multiple opportunities to **transfer in technologies from other industries**, and from other countries which have stronger capabilities in some areas of technological innovation, particularly in food process technology and packaging
- However, there are **plenty of opportunities for, and strong capability in, the UK's science base to deliver the technological innovation required to address these challenges**

5. Barriers to technological innovation

Barriers to technological innovation are obstacles which are preventing the challenges described in Section 4 from being overcome. Those described here are mainly of relevance to companies, both large and small, but also have implications for research and technology institutes and universities.

This study has established that access to funding is the most significant barrier to technological innovation. This is both in terms of accessing funding for innovation activities itself, as well as funding for capex outlay for up scaling and the procurement of new plant. Other barriers include industry's ability to access the right technical and engineering skills, striking a balance internally between the immediate demands of consumers and customers and longer term R&D, and – for smaller businesses especially – the ability to identify new technologies that can be successfully deployed quickly and easily at low cost whilst minimising the impact on business continuity.

The barriers were identified through the cross industry survey and consultation programme, as well as by comparing these findings to other similar studies[73,74]. This section of the document describes, and provides evidence for each of the barriers identified.

5.1 Obtaining funding for technological innovation

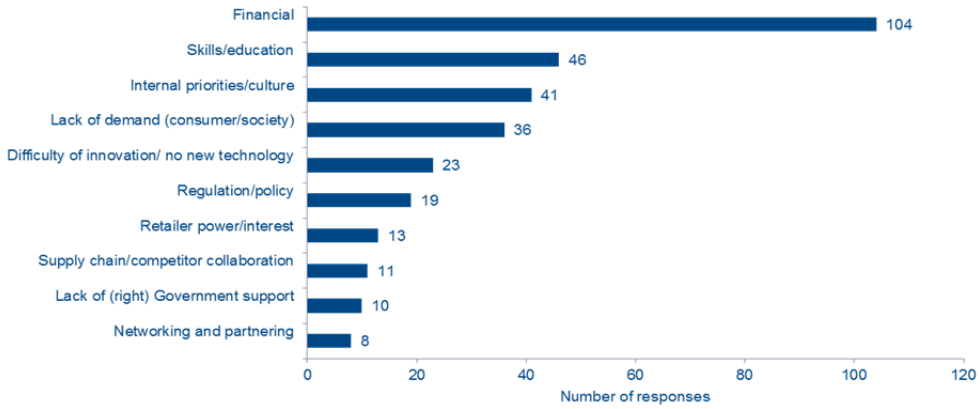
Better access to funding for technological innovation from public sources was overwhelmingly top-rated in the cross-industry survey and consultation programme, as shown in Figure 16. Both companies small and large observed that it was difficult to navigate their way to the right sources of funding and that funding programmes are neither stable nor consistent, and appear to be provided by a wide range of often seemingly disconnected bodies with little apparent coordination or co-operation between them, such that accessing funds can be complex and time consuming.

Interestingly, availability of funding for technological innovation was less of an issue than access to it, suggesting that consultees and survey respondents felt that funding was available, but had difficulties in understanding how it fitted together and in being signposted to that which was likely to be most relevant to them. All this would seem to indicate the need for action to establish an overarching funding policy for food and drink innovation, together with a need to raise awareness of what funding is already available and to simplify the mechanisms to access it.

[73] Personal communication with the Irish Exporters Association, February 2013

[74] Defra Post Farm Gate Technical Challenges Workshop 14th July 2010: Workshop summary

Figure 16:Top 10 barriers to R&D and innovation



Source: Cross-industry survey results, Arthur D. Little analysis

One area where a gap was identified concerned the ability to fund capex outlay for commercially available new technologies, including scaling up and turn-key plant. This concerned difficulties in justifying and committing funding within businesses as well as a lack of externally available funding sources. Section 2 of this report has highlighted the tight financial margins under which food manufacturers must operate because of the intense competition in this sector. A capex outlay in a new piece of technology was identified as being extremely difficult to justify, owing to the requirement to see a guaranteed quick payback due to tight margins. This was particularly evident for SMEs, who find it difficult to justify a high capital outlay on an energy or water efficiency project with a long-term payback to a very short term balance sheet, but also apparent for larger companies who – despite having access to a larger cash flow – often have to invest in much larger scale equipment, and sometimes across several facilities.

5.2 Shortage of relevant skills in technology and engineering disciplines

A **shortage of appropriately skilled staff** was the second most frequently cited barrier. Specifically, this concerned technical and engineering skills, in terms of both practical disciplines at the factory floor level (e.g. meat science, butchering and baking) and also in more supervisory roles. It also concerned the skills needed to identify and develop new innovations.

This barrier did not focus on the availability of appropriately qualified graduates in science and engineering. Instead, it concerned the ability of industry to attract scientists and engineers from non-food industry related backgrounds into the food and drink sector and in particular how to energise young scientists and technologists. Several industry consultees were keen to stress that technical skills food science are not the only discipline required by the food and drink industry. Other disciplines such as process engineering, mathematics, physics, chemistry, biochemistry, mechanical and design engineering and materials science also have critical roles to play in the food and drink industry.

When questioned further as to why this barrier is apparent, some consultees indicated that this was because that the industry was considered to be of insufficient scientific challenge and interest to those with such skills, and to lack clearly defined scientific challenges which would enable scientists and technologists to publish in the best journals and develop a strong scientific reputation. Other consultees observed that it could involve an unattractive working environment compared to other sectors, and that salaries were often higher in other, adjacent sectors (e.g. the pharmaceutical industry). Some organisations had overcome this barrier by establishing their own apprenticeship schemes to train and retain technical and engineering staff, but others indicated that they had neither the time nor the resources to develop similar programmes.

5.3 Internal priorities and culture

The third most frequently cited set of barriers concerned internal priorities and the culture within businesses. A focus on short term product development at the expense of longer term or more disruptive technological innovation was highlighted as a key internal barrier to technological innovation. Consultees and survey respondents indicated that most innovation activities focused on meeting short term demand from consumers and from retailers, and the majority of this work focused on cost reduction, as discussed in Sections 2, 3 and 4 of this report. In some instances, food manufacturers felt that they were expected to wait for retailers to define a technological need, and then were required to respond to it as quickly as possible. The effect of this short term focus is that respondents indicated that they have a lack of time and capacity for longer term technological innovation, and that they were constantly "fire fighting" to deliver incremental benefits, often in short order.

Other barriers concerned a general lack of buy-in from the rest of the business as to the value of technological innovation. Some consultees observed that they did not invest in technological innovation because other parts of the business saw insufficient benefits in terms of the costs involved relative to the benefits which could be realised – and the amount of time taken to see a return on investment.

A further theme concerned the extent to which uptake of new technologies represent a risk to the continuity of day-to-day operations, particularly by those in non-technical positions, or those concerned with ensuring business continuity. This was particularly evident for SMEs, who highlighted difficulties in being able to test and trial technological innovations before deploying them. Consultees also highlighted that the "valley of death" between a piece of applied research and a packaged up, deployable new piece of technology was often difficult to cross[75] with the problem of scale up, both from the point of view of needing to minimise the risks involved and the difficulty of obtaining funding, being particularly acute in the current low margin environment in which food manufacturers have to operate.

5.4 Consumer demand for, and acceptance of, technological innovation

This study has found drivers associated with consumer demand to be the strongest influence on technological innovation in the food and drink sector. However, reluctance amongst consumers to accept new technologies and change existing consumption behaviours and purchasing habits was cited as a barrier, particularly in terms of how consumers perceive the risks associated with novel food products and how open they are to embracing the use of new, unfamiliar technologies. This is one of the factors that cause technologically innovative activities associated with developing new products to be focused more on incremental developments which gradually influence what consumers choose to buy, rather than more radical developments such as completely new products. Some consultees observed that the causes of this reluctance concerned:

- The perceived health and safety risks associated with novel food products, particularly for those with children
- A low consumer desire to move away from familiar products
- Price being the primary driver for food and drink purchasing, such that consumers were perceived as being "unwilling to pay for new technology"

5.5 The ability to make and register health claims

The way in which companies can advertise health benefits has recently been tightened up to better protect consumers from dubious or misleading claims. It is now very costly and difficult to demonstrate proven health benefits, such that only a small number of products (for example cholesterol-reducing spreads, yogurts and drinks) now do so. Consultees and survey respondents observed that this had implications for stifling

[75] Arthur D. Little consultations with companies in the ready meals sector, December – March 2013

innovation, in terms of the volume of expensive data required by the European Food Safety Authority, and the risk of claims being rejected in spite of significant effort. This is part of broader concerns around the way in which research and innovation proposals at the European level can influence businesses[76]. Providers of raw materials and food manufacturers also expressed intense difficulties in making health claims for food ingredients (e.g. milk as a source of calcium and its impact on skeletal health).

5.6 Forming consistent relationships associated with technological innovation throughout the supply chain

A final set of barriers concerned the way in which companies in the food and drink sector are able to form relationships and partnerships with other elements of the supply chain. The linkages between food manufacturers and retailers were highlighted as being particularly strained at times. Some manufacturers felt that they were not in control of their own destiny, with a strong emphasis by retailers on the promotion of own-brand products. Others observed that uncertainty was an issue in deciding where to invest in technological innovation, and worried that the needs of retailers might change at short notice, such that a significant investment in a new piece of equipment might become redundant if the retailers requirements changed (e.g. for a particular type of packaging)

Other issues concerned finding the right organisations to partner with for specific technological innovation activities, and in transferring technologies from the public research base (i.e. research institutes and academia) to manufacturers – though membership based organisations such as Campden BRI and Leatherhead Food Research have helped to achieve this successfully. Others observed that headway is being made in this area – particularly in the relationships between retailers and primary producers.

5.7 Summary of barriers to technological innovation

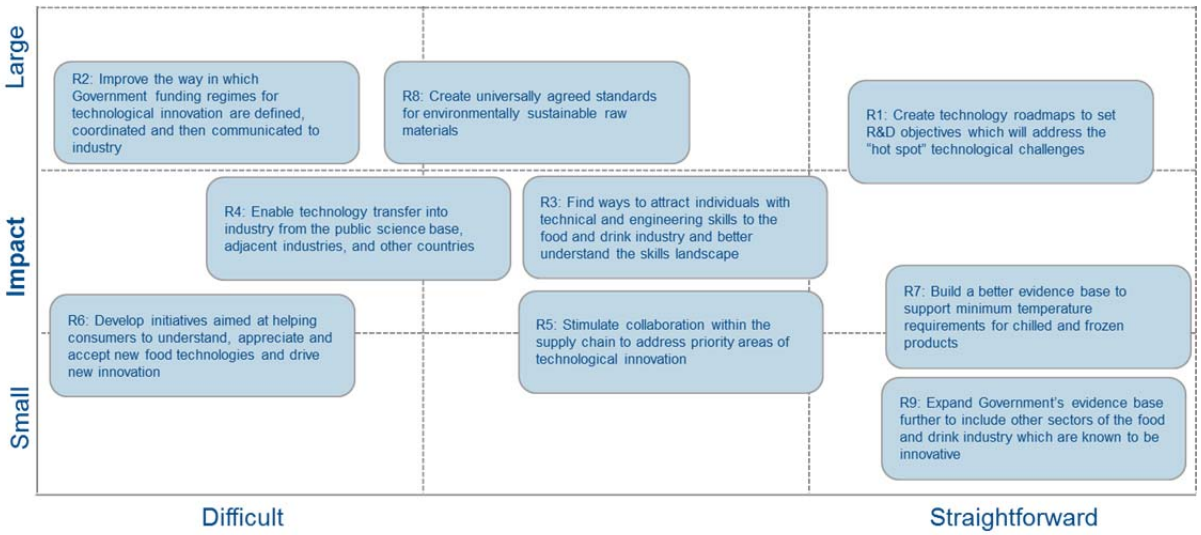
In summary, **obtaining funding for technological innovation** is industry's number one barrier. This is more about identifying where funding is available, being able to plan in advance how best to use it, and how to go about accessing it. A gap is evident in capex funding for businesses both small and large to take up new, potentially expensive technologies. **A shortage of technical and engineering staff seeking to enter the food and drink industry** is apparent, suggesting that effort to make the industry a more attractive and stimulating place to work would be helpful. **A lack of innovation culture** within – particularly small – businesses can hamper technological innovation, coupled with a need to handle short term demand in favour of longer term technology development. **Consumers can be reluctant to adopt new technology** and change consumption and purchasing habits, despite being the main driver for technological innovation. **Forming relationships within the supply chain to address areas of common technology need** can be difficult, and **health claims for food products** are difficult to make. Ways to overcome these barriers are considered in the next section of this report.

[76] House of Lords, 15th report of session 2012-13. The Effectiveness of EU Research and Innovation Proposals, April 2013

6. Areas for further consideration

This section focuses, by way of a series of recommendations, on ways of developing the outcomes of this study, overcoming the barriers identified in the cross-industry survey and consultations, and setting out next steps for addressing the technological challenges. Figure 17 summarises the recommendations in terms of relative ease and impact of delivery. It is assumed that Defra would be the primary delivery agent for these recommendations, working together with other Government agencies and with industry.

Figure 17:Summary of recommendations



Source: Arthur D. Little analysis. R: Recommendation

Recommendation 1: Create technology roadmaps to set R&D objectives which will address the "hot spot" technological challenges

Whilst the current review has identified technological challenges and proposed areas of technological innovation to address them, ways of delivering this innovation will need to be identified (e.g. research projects focused on creating specific technologies or developing capabilities). One way to do this is to develop a series of roadmaps which would identify what activities would need to take place, in what order, and by when, to address each of the "hot spots".

However, when doing so, care must be taken not to "reinvent the wheel" and other existing studies will act as valuable inputs to this exercise. An example includes the outputs from TSB's deep-dive study on the food sector, which contains some themes and timings which are applicable to the challenges identified in the present study[77]. A further example is the Dairy Roadmap, produced by DairyCo and Dairy 2020, which defines targets and a potential future vision for the dairy sector associated with environmental sustainability[78].

The technology roadmaps should take into account disruptive technologies, and those from adjacent industries. They should be led by the food and drink industry, rather than by Government, in order to ensure

[77] Technology Strategy Board, 10th October 2012. UK manufacturing landscape – Food Sector Deep Dive

[78] DairyCo (Agriculture and Horticulture Development Board), 2010. Dairy Roadmap: Our route towards environmental success. For Dairy 2020, see: http://dairy2020.com/about-dairy-2020, accessed April 2013

that they meet industry requirements and that that there is sufficient appetite to deliver them. However, there is a role for Government to facilitate the development of such roadmaps.

Examination of international good practice from CSIRO in Australia, who conducted a similar exercise in 2011, suggests that there should be multiple roadmaps, rather than just one overall roadmap for the food and drink industry(for details, see Appendix 3).

Each roadmap should be targeted at addressing one of the nine specific challenges identified in this study. To help with buy-in, activities set out in the roadmaps should be focused on pre-competitive research which benefits industry, or industry sectors, as a whole, rather than individual companies. In addition, the roadmaps should take into account those areas requiring a multidisciplinary approach that would not be realised through conventional R&D within a single institution. For example, a roadmap to reduce the content of salt, fat and sugar in food products could involve activity in sensory science, psychology, formulation engineering, and chemical engineering.

This would involve a range of activities such as, for example:

- Basic research into the identification of salt analogues
- A programme of sensory science activity to understand what affects the perception of salt
- Research into formulation engineering to identify the implications of fat reduction on increasing carbohydrate content
- A technology scan for areas of activity outside the food and drink sector to identify substances which could provide similar properties to salt in conventional baking

Recommendation 2: Improve the way in which Government funding regimes for technological innovation are defined, coordinated and then communicated to industry

Closely tied with Recommendation 1, and supported by the barriers identified in this work, a need to better coordinate food and drink research funding initiatives across Government departments and bodies, and then communicate this to industry, has emerged.

The production of more environmentally sustainable and healthy food involves a wide range of very different technologies. It therefore spans the remit of several departments and bodies, including Defra, the Department for Business, Innovation and Skills, the Department of Health, three of the research funding councils and many others, as summarised in Figure 18. Many of these operate calls for funding associated with collaborative research in the post-farm gate food and drink industry. For example, TSB operates calls relating to its Sustainable Agriculture and Food Innovation Platform[79] and Nutrition for Life programme[80], whilst BBSRC operates the Diet and Health Research Industry Club (DRINC).

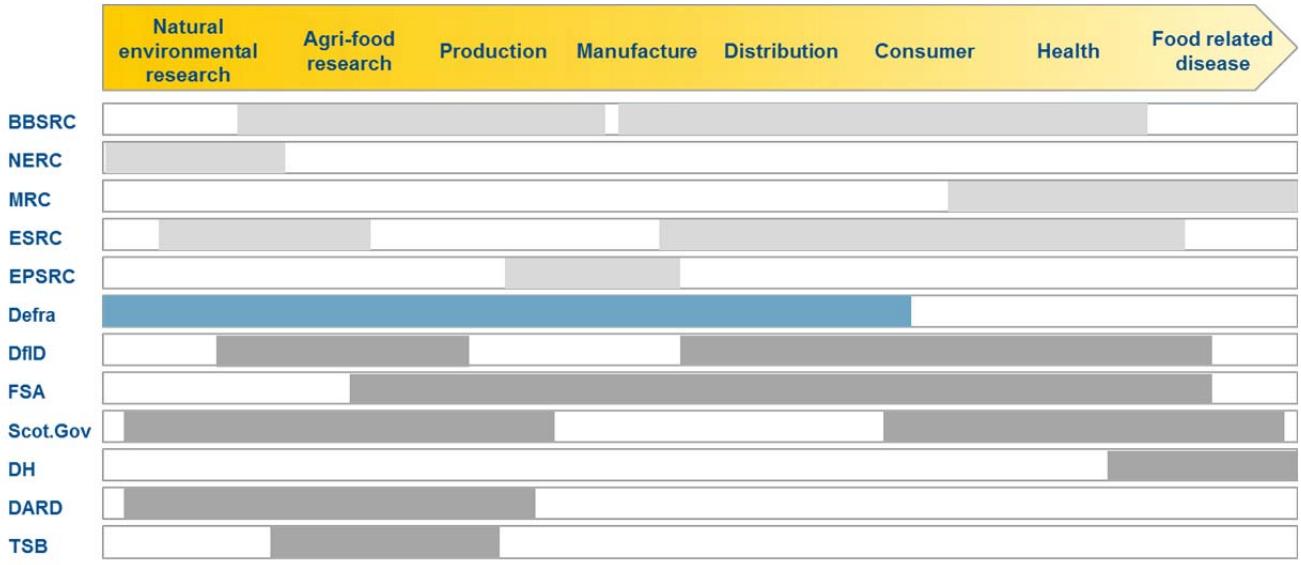
The wide range of funding initiatives available from different agencies can make it difficult for an individual business to track the various funding initiatives available, or indeed to know what to track. At present, some funding initiatives seem to appear without warning and often provide only a small window in which to make an application. Some of these also fix the funding for a number of years ahead so that failing to make an application in the time allowed can potentially restrict access to funds in a particular area for a considerable period. The issue of communication is of particular importance to SMEs, who expressed difficulties in being signposted to the right Government funding initiative.

[79] Sustainable Agriculture and Food Innovation Platform. See https://connect.innovateuk.org/web/sustainable-agriculture-and-food-innovation-platform, accessed April 2013

[80] See http://www.innovateuk.org/ourstrategy/innovationplatforms/sustainableagricultureandfood.ashx, accessed April 2013

Together, this suggests that there is scope for better communicating and coordinating calls for funding to the food and drink industry. Previous studies have also highlighted a need for better coordination[81,82], including in particular the Green Food Project, which identified a need for a more strategic and joined up effort in relation to innovation, research and development[83] on both sides of the farm gate.

Figure 18: Food responsibilities across Government, Devolved Administrations and Research Councils



Source: OGC – Cross-Government Food Research Strategy, 2010. Abbreviations: BBSRC: Biotechnology and Biological Sciences Research Council; NERC: Natural Environment Research Council; MRC: Medical Research Council; ESRC: Economic and Social Research Council; EPSRC: Engineering and Physical Sciences Research Council; DfID: Department for International Development; Defra: Department for Environment, Food and Rural Affairs; FSA: Food Standards Agency. Scot.Gov: Scottish Government: DH: Department of Health; DARD: Department of Agriculture and Rural Development (Northern Ireland); TSB: Technology Strategy Board

In response to these issues, the Food Research Partnership (FRP) (led by the Government Chief Scientist), produced the Cross-Government Food Research and Innovation Strategy[84], which sets out several initiatives including formation of the BBSRC-led Global Food Security Programme (GFS), the role of which is to better coordinate the delivery of multidisciplinary research in all aspects of food production, from farm to fork to maximise its impact[85]. The central Government departments, the Research Councils and TSB are all members of this initiative.

New activity by a Ministerial-led Leadership Council to develop a forthcoming 'Agri-tech Strategy' will work with the FRP and the GFS to improve this coordination in the pre-farm gate sector. However, there is currently no visibility as to how this will influence coordination in the post-farm gate food and drink sector.

[81] MRC Strategic Review of Nutrition. http://www.mrc.ac.uk/Utilities/Documentrecord/index.htm?d=MRC005762 accessed March 2013

[82] Arthur D. Little, 2009. BBSRC/HEFCE Study of Land Based Facilities and Resources

[83] Defra, 2012. The Green Food Project: Conclusions. pp12 (Paragraph 4.9)

[84] Government Office for Science, 2010. UK Cross Government Food Research and Innovation Strategy

[85] See www.foodsecurity.ac.uk, accessed April 2013

There is therefore an opportunity for GFS, the organisations it represents, and the FRP to pull the somewhat fragmented existing initiatives in food and drink more visibly together. In particular there is a need to:

- Seek opportunities to establish a fully transparent and well publicised overarching funding policy for food and drink innovation
- Avoid unnecessarily shifting the focus or ownership of existing programmes, but instead act as a means of coordinating, communicating and disseminating them to industry, likely via FRP
- Raise awareness of coordination activity by the GFS and FRP to industry and spell out what they seek to achieve, as very few consultees seemed to have heard of them
- Ensure that GFS engages with initiatives with a similar remit, such as the National Technology Platform for Food and its members[86]
- Ensure that efforts continue to take into account wider cross-European initiatives, as well as those taking place in other countries

There is also an opportunity to coordinate and broadcast calls for funding in advance, such that industry can plan and align their research activities to make best use of research funding and a need for industry to ensure that they are plugged in to the right communications channels and networks.

Recommendation 3: Find ways to attract individuals with technical and engineering skills to the food and drink industry and better understand the skills landscape

Access to technical and engineering skills of both direct and indirect relevance to the food and drink sector were highlighted consistently across all sectors as a barrier to innovation. This appears to be an issue associated with attracting scientists and engineers to the food and drinks sector, and is primarily an issue for industry to explore further in terms of better understanding the skills landscape.

There is also scope for Government and industry to work together in, for example, the co-development of training courses and provision of work experience for science and engineering training courses more broadly (e.g. mechanical engineering, chemistry and biotechnology).

This has already been successfully done in creating food science-specific training courses Sheffield Hallam University, which has worked together with the Food and Drink Federation and the National Skills Academy for Food and Drink to develop an MEng in Food Engineering[87].

The BBSRC Advanced Training Partnerships may also be a helpful mechanism to do this. This scheme comprises up to £15 million of finding to support the development and delivery of postgraduate training over a five year period through partnerships between consortia of organisations, including universities, agricultural colleges and other research institutions, as well as, supermarkets, levy bodies, private research organisations and the farming community among others. Four awards cover a broad range of areas, including livestock, crops, food science, horticulture and agricultural systems.

Recommendation 4: Enable technology transfer into the food and drink industry from the public science base, adjacent industries, and other countries

Whilst much technological innovation activity takes place in the UK's public research base (much of which is world-class) consultees from both large and small companies highlighted difficulties in being able to transfer technologies into their businesses. There was also an issue associated with being able to transfer in

[86] National Technology Platform for food. See https://connect.innovateuk.org/web/uk-ntp-for-food/our-group, accessed April 2013

[87] See http://www.shu.ac.uk/prospectus/course/1247/, accessed April 2013

technologies from adjacent industries, and in instances where the UK does not have a leading presence internationally (e.g. in food process technology equipment).

The assessment of barriers in Section 5 indicates that this is due to a range of factors, including a lack of organisations which have the ability to act as the bridge between basic research and its application in the industrial setting (particularly in SMEs); the short term focus of internal innovation-related activities; a lack of resources for longer term R&D; a lack of buy-in from non-technical parts of the organisation as to the importance of R&D; and the continuing pressure of tight margins for many parts of the food and drink supply chain. Achieving better uptake of R&D into practice would help to overcome some of the challenges identified in this work, particularly those associated with refrigeration and cold chain.

Areas where further activity is needed to improve technology transfer include:

- **Providing resources to "package up" the results of research in some of the priority areas for technological innovation described in this study and make them more readily implementable in common practice:** This entails taking research emerging from universities and research and technology institutes and translating them into market ready opportunities, helping to ensure that technologies become commercially proven, technologically and commercially de-risked, and meet regulatory requirements. This should include support for studies for products which could make health claims – potentially involving multiple organisations seeking health claims for a commonly used ingredient, as has been the case recently in the dairy sector. Capabilities in modelling, testing, trialling and scale-up for food manufacturing already exist in, for example, the National Food Manufacturing Centre at Lincoln University and at the Centre for Process Innovation in Teesside but need to be more widely publicised and SMEs given help to access them. **Identifying opportunities for process-based technological innovation in smaller businesses to improve efficiency and flexibility:** This involves identifying opportunities for improving existing process technologies used in smaller businesses by diagnosing and recommending opportunities for improvement, a service offered by only a few organisations at present such as the Centre for Food Robotics and Automation (CenfRA)
- **Providing access to capex for the uptake of commercially available new technologies:** This study has found access to capex associated with taking up new technologies (e.g. when procuring a new automated piece of process equipment) to be a significant barrier due to the risk averse culture of many lenders and the potentially lengthy return on investment and the implications of this on a sector characterised by quick turnaround times and low profit margins. This is particularly important for the challenge associated with improving energy and process efficiency in the food manufacturing environment, such as accessing new food processing equipment and process technology There are opportunities for Government to influence the uptake of sustainable technologies through other Government initiatives such as the Green Investment Bank and ensure that such investment bodies have the necessary capabilities to assess technical proposals[88]
- **Seeking opportunities for the inward transfer of knowledge, as well as technology:** Through the expansion of initiatives such as the Knowledge Transfer Partnerships (KTPs) which involve the secondment of post-doctoral researchers into businesses to address specific areas of technological innovation
- **Seeking more opportunities to transfer in technologies from adjacent industries or international geographies:** This is likely to be of particular relevance to challenges associated with improving energy and process efficiency in the food manufacturing environment, which are likely to rely on activities in other countries (e.g. Germany and Italy) or from other industries (e.g. civil engineering)
- **Providing assistance with scaling up technologies once proven:** There is a need to provide technical assistance with scaling up proven technologies, particularly in small businesses. This could be done by expanding the remit of KTPs

[88] See http://www.greeninvestmentbank.com, accessed April 2013

- **Drawing on the outcomes of research that has already been delivered and is ready to take up into a widespread, commercial setting** such as the results of former LINK projects

Recommendation 5: Stimulate collaboration within the supply chain to address priority areas of technological innovation

Many of the challenges identified in this study will require a coordinated effort across the supply chain to address. For example, the sourcing of environmentally sustainable and resilient raw materials will involve close coordination between pre- and post-farm gate. In addition, barriers have been identified in terms of the ways in which different parts of the supply chain work together. In some cases, this works well. For example, retailers are now working directly with farms to stimulate technological innovation on-farm to improve processing efficiency, reduce waste and make raw materials more consistency. The relationship between retailers and food manufacturers appears to work less effectively, particularly in terms of manufacturers citing problems associated with a need to handle short-term or last-minute requests from retailers at the expense of longer term technological innovation.

Together, this suggests a need to stimulate collaboration within the supply chain to address priority areas of technological innovation whilst tempering this against reducing fair trade and competition in the more consolidated areas of the food and drink industry.

In particular, this suggests that activity associated with "socialising" new technologies between food and drink manufacturers and retailers in order to ensure that they are acceptable from the perspectives of quality, product control, branding and corporate responsibility technologies would help to "future proof" new investments in technological innovation. This also suggests that there are opportunities to establish where payors and beneficiaries may lie when, for example, introducing "smart" packaging, which may be more expensive than existing options.

One way to do this in practice – as well as to address some of the specific challenges identified as part of this study as outlined in Recommendation 1 – would be to create challenge- or sub-sector specific "innovation ecosystems" involving multiple members of the public science base, and multiple companies who can provide a route to market through their supply chains. An example of such a successful initiative is the Food for Health Ireland programme, which draws together industry and academia from the dairy sector to address a specific technological challenge associated with functional foods. Appendix 3 provides more details of this initiative.

Recommendation 6: Develop initiatives aimed at helping consumers to understand, appreciate and accept new food technologies and drive new innovation

Despite consumer requirements being the primary driver for technological innovation, this study has found, somewhat paradoxically that consumer perception and acceptance of new technologies is a barrier. This may go some way to explaining why much technological innovation focuses on incremental new product development, rather than more radical innovation. There are opportunities for Government to work with industry to better understand consumer perceptions of technological innovation, as well as those associated with environmental sustainability, such as energy efficiency in cooking and refrigeration and waste reduction in the home and to identify ways of raising consumer levels of understanding. Furthering the work of the IGD New and Emerging Technologies Group[89], an industry forum which builds case studies related to new technologies in food, could be one way to do this.

[89] See http://www.igd.com/Who-we-are/Industry-working-Groups/New-and-Emerging-Technologies-Group/, accessed April 2013

Recommendation 7: Build a better evidence base to support minimum temperature requirements for chilled and frozen products

Several groups of consultees[90] identified a need to better characterise minimum temperature requirements for frozen and chilled foods across all sectors. The rationale for this observation is that foods are often chilled or frozen to default temperatures (e.g. zero degrees Fahrenheit is considered the standard for frozen foods) whereas in reality achieving temperatures this low is not always required. The increasing by 1-2 degrees Fahrenheit of required temperatures for freezing could achieve a considerable energy saving during storage, transport and distribution. There were a number of criticisms that the evidence base in this area is not well characterised, and a better understanding of safety margins and minimum temperature requirements is required. Defra could consider the development of such an evidence base, together with FSA.

Recommendation 8: Create universally agreed standards for environmentally sustainable raw materials

The sourcing of environmentally sustainable and resilient raw materials was flagged up in the cross industry survey as the highest priority challenge associated with raw material processing – and the second highest overall. There are currently a wide array of different mechanisms which can be used to assess the environmentally sustainability of raw materials, including those managed by independent organisations, and those developed internally by companies to control their own supply chains[91]. However, there is no universally agreed set of standards for what should be considered as sustainable – though efforts are underway at European level to do this for raw materials used for non-food purposes such as biofuels[92]. Given the importance of this challenge, there is scope therefore to agree some basic principles to minimise the amount of effort that individual businesses – particularly SMEs – need to invest in selecting the right systems and processes to use to ensure that raw materials are sustainably sourced, particularly in the event of increased availability of novel raw materials.

Recommendation 9: Expand Government's evidence base further to include other sectors of the food and drink industry which are known to be innovative

The present study focused on seven sectors of the food and drink industry which were selected on the basis of making a substantive contribution to the UK economy and showing a relatively high level of technological innovation. However, there are other sectors which are also highly innovative and could make a material impact on producing more environmentally sustainable, healthy food. These include, in particular, the snacks, confectionary and cereals sectors.

[90] Notably WRAP, the FDF's Sustainability Steering Group, the Chilled Foods Association, the Food Manufacturing Engineering Group and other representatives from the ready meals sectors

[91] For example, Fair Trade products, and the Royal Society for the Prevention of Cruelty to Animals' Freedom Foods scheme

[92] For example, the Global-Bio-Pact Global Assessment of Biomass and Bioproduct Impacts on Socio-economics and Sustainability (http://www.globalbiopact.eu/, accessed May 2013)