EUROPEAN TECHNOLOGY PLATFORM

FOOD FOR LIFE

STAKEHOLDERS' PROPOSAL

FOR A

STRATEGIC RESEARCH AGENDA

2010-2020

Working document, 24 April 2006

This is an Interim Document developed by individual ETP Working Groups (see page 72) following consultation with stakeholders. In order to ensure maximum relevance to the needs and opportunities of all European stakeholders it will be subjected now to an extensive national-, regional- and web consultation process, with the aim of publishing the **ETP Strategic Research Agenda** and associated **Implementation Plan** in March 2007.
This document should be regarded as a working document, *it does not represent an official document of the ETP Food for Life*.

Acknowledgement
We would like to convey our thanks to the participants of individual ETP Working Groups and all other individual and organisational stakeholders whose inputs, comments and experience have contributed to this document.

Foreword

The **European Technology Platform (ETP) Food for Life** was created under the auspices of the Confederation of the Food and Drink Industries of the EU (CIAA) in 2005 to strengthen the European-wide innovation process, improve knowledge transfer and stimulate European competitiveness across the food chain. The vision of the ETP, published in July 2005, aims at an effective integration of strategically-focussed, trans-national, concerted research in the nutritional-, food- and consumer sciences and food chain management so as to deliver *innovative, novel and improved food products for, and to, national, regional and global markets in line with consumer needs and expectations*.

These products, together with recommended changes in dietary regimes and lifestyles, will have a *positive impact on public health and overall quality of life* ('adding life to years'). Targeted activities will support a successful and competitive pan-European agro-food industry having *global business leadership securely based on economic growth, technology transfer, sustainable food production and consumer confidence*. The ETP unites a wide variety of stakeholders around this common vision including agriculture, food processing, supply and ingredient industry, retail, catering and consumers with academia. The direct connection with consumer needs makes it unusual amongst all other ETPs, and offers a unique opportunity to integrate the natural sciences and humanities.

This interim document represents the Stakeholders' Strategic Research Agenda (SSRA) of the ETP Food for Life for the coming 15 years, wherein a specific focus has been given for input into the initial phase of the European Commission's Framework Programme 7 (2007-2013). The SSRA has been developed by six different Working Groups focussing on the scientific and technological requirements in *Food and Health, Food Quality and Manufacturing*, *Food and Consumer*, *Food Safety*, *Sustainable Food Production* and *Food Chain Management*. A further Working Group has developed an outline for needs in *Communication, Training and Technology Transfer* where the evidence base is more fragmentary, whilst the *Horizontal Activities* Working Group has, amongst other responsibilities, that of optimising internal and external contacts and co-operations. The outputs from these Working Groups have been combined to focus on key challenges that will need to be addressed if the agro-food industry is to be in a better position to respond to consumer's likely demands and concerns. A Board consisting of high-level representatives from the stakeholders has overseen this work. The Board, like the ETP itself, is industry-led but has a composition reflecting the diversity of food chain stakeholders.

The next stages of the ETP Food for Life will be directed towards national and regional consultations on the SSRA to set priorities and align with national activities and on the basis of this devising a detailed Implementation Plan. In the course of developing this SSRA, good links have been established with other ETPs, especially those addressing agriculture and biotechnology. These links will ensure that the knowledge-based bio-economies of FP7 can combine to address effectively the serious challenge of global competition that Europe currently faces.

We are convinced that this SSRA represents a unique opportunity for the stakeholders in the European food chain to increase their competitive strength and ensure the continuing welfare of consumers across Europe. Success will, however, require the long-standing commitment of all these stakeholders. Thus far, the indications are very positive.

Mr Jean Martin
President of CIAA

Professor Dr Peter van Bladeren
Chairman, Board of ETP Food for Life

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Executive summary

The European agro-food industry is the largest manufacturing sector in Europe. The food and drink industry itself had a turnover of 840 billion euros in 2005, transforming over 70% of the EU's agricultural raw materials and employing over 4 million people, the majority within the SME sector. The European agro-food industry is a leading global exporter and affords significant value addition; it also offers scope for economic growth within new EU Member States, development of regional economies and exploitation of Europe's rich cultural diversity and traditions. *The agro-food industry is thus central to the wider, economic development of Europe as it will develop over the next two decades.*

There is an increasing societal awareness of the opportunities to improve the quality of life through healthy eating and of the contribution that sustainable production can make to improvement of the overall environment. The preferences of consumers for quality, convenience, diversity and health, and their justifiable expectations of safe, ethical and sustainable food production serve to highlight the opportunities for innovation. In some sectors of the food chain, such as food safety, process engineering and sustainability, Europe is already a world leader and innovation and investment are both high. However, in many others this is not the case.

Within the **ETP Food for Life Vision document** a coherent strategy for the future of the food chain was developed based upon the shared vision of its diverse stakeholders. Key elements of this flexible strategy are initiatives in *food and health, food quality and manufacturing, food and consumer, food safety, sustainable food production* and *food chain management.* These elements needed support from an effective input from *communication, training* and *technology transfer*. This SSRA has developed the vision document into a coherent series of research challenges to ensure that the R&D is conceived with perspective of the consumer as the major driver (fork-to-farm).

The seven key challenges that are developed here are considered to be crucial for innovation in the food chain. In addition, four complementary tasks have been identified that will need to be undertaken to ensure that there is an effective implementation of the SSRA. The SSRA is structured such that it addresses the key challenges in the various areas, denotes the research topics to be undertaken and the deliverables that can be expected in the short-, medium- and long term. Close contact has been developed with other relevant ETPs, including *ETP Plants for the Future* since one of their three challenges, *Healthy, safe and sufficient food and feed*, is closely linked to aspects of the programme of this ETP. In this way, gaps and overlaps have been prevented and synergistic opportunities identified.

It is very clear from the initial stages of ETP development that a step-change in research intensity and investment, together with effective technology transfer, is a prerequisite for ensuring that the European agro-food sector will remain innovative and competitive, and be better able to address the global challenges that will arise not just from its traditional competitors (Japan and the US) but also from the fast-growing economies of China, India and Brazil.

The private and public resources available for food research at the national level are insufficient to meet the challenges that will arise if the objective of adding 'life to years' is to be achieved. The **European Technology Platform Food for Life** *must galvanise the resources available at the national and EU level and from private and venture capital to ensure effective co-operation under the umbrella of a coherent Strategic Research Agenda*

and its associated Implementation Plan. These will be published early in 2007, and the present document represents an important, but interim, stage in the development of these long-term activities.

Seven challenges are presented, each of which will require targeted and managed trans-disciplinary activities if they are to be addressed and delivered with maximum impact. Challenges 2 and 3 are pivotal for delivering innovation and competitiveness.

Challenge 1: Ensuring that the healthy choice is the easy choice for consumers.
To be able, through a better understanding of food consumer behaviour, to strengthen the consumer involvement in healthy foods and their production and to ensure that food products are adapted to consumer demands for nutrition, health and pleasure.

Challenge 2: Delivering a healthy diet.
To develop new and effective food-based strategies to optimise human health and to reduce the risk, or delay the onset, of diet-related disease. The focus will be on the emerging areas of brain function, immune and intestinal function and metabolic function.

Challenge 3: Developing value-added food products with superior quality, convenience, availability and affordability.
To provide the consumer with the type of food demanded, at the right time, in the right place and at the right price. Food products, process and packaging design and process control, are considered within the overall context of understanding and exploiting process-structure-property relationships and consumer behaviour in respect of food quality and manufacturing.

Challenge 4: Assuring safe foods that consumers can trust.
To develop and promote an integrated approach to food safety that encompasses the complexity of the food chain, consumer concerns and trust, lifestyles, globalisation and competitiveness.

Challenge 5: Achieving sustainable food production.
To place sustainability at the centre of future European food production, to develop and exploit the tools necessary to better understand the sustainability of food chains, optimise sustainable primary production and identify consumer attitudes towards sustainable food production.

Challenge 6: Managing the food chain.
To better manage the efficiency and delivery by the food chain, develop and exploit outputs of scenario studies to most effectively position Europe's food chains and to reduce the overall complexity of value chains.

Challenge 7: Communication, training and technology transfer.
To conduct research necessary to improve the process of food regulation and to develop and exploit innovative strategies in communication, training and technology transfer to optimise the impact of Innovation in the food sector.

The Chapter entitled "Towards implementation" identifies complementary activities need to deliver innovation, and include increasing financial resources committed to innovation of the European food industry, improving education, skills and facilities in Europe, optimising stakeholder understanding and commitment and initiating scenario studies.

It is these challenges, and the opportunities associated with their delivery that will provide the basis of the consultations that will be entered into over the coming months. Given the level of

enthusiasm and interest already expressed by stakeholders of the food chain for this ETP the inputs, which will inform the **Strategic Research Agenda**, are likely to be both stimulating and diverse.

Introduction

The **European Technology Platform on Food for Life** seeks to deliver innovative, novel and improved food products for, and to, national, regional and global markets in line with consumer needs and expectations through an effective integration of strategically-focussed, trans-national, concerted research in the nutritional-, food- and consumer sciences and food chain management.

The **ETP Food for Life Vision Document**, published in July 2005, set out some of the issues that are considered necessary to sharpen the innovation edge of the EU agro-food industry. It also highlighted the threat the industry faced if effective and timely measures were not taken to improve its innovative power in order to ensure that there was no adverse impact on the European economy; this is a significant challenge given the key importance of this industry across the European Union. The Vision Document presented the research areas required to reach the vision of the ETP Food for Life (Figure 1).

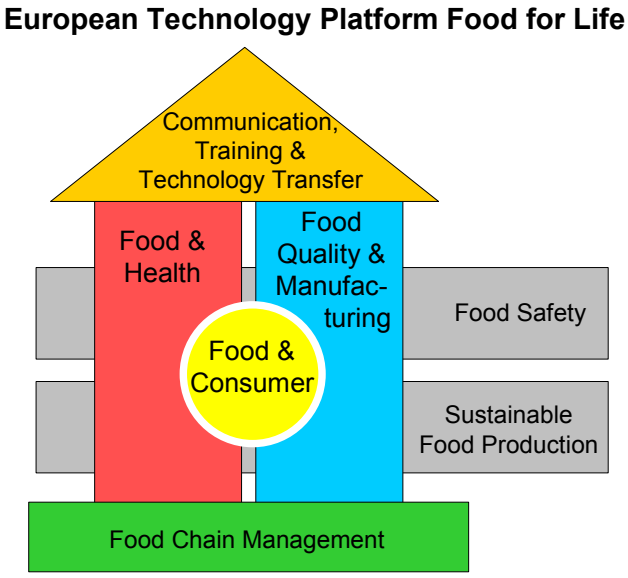

Figure 1. Schematic presentation of the research areas required to reach the vision of the ETP Food for Life

Foods and drinks, in the right amounts and proportions, make a *major contribution to the well-being and healthy ageing of citizens*. The European population is ageing and future changes in both population demographics and life span demand a 'healthy ageing' approach. Healthy behaviour is related not only to a higher chance of survival but also to *a delay in the deterioration of health status*. The key challenge for the long-term will be to influence an individual's state of ageing and to deliver a personal regime of nutrients, lifestyle and advice for healthy longevity (Figure 2) or, as stated in the Vision Document, to '*add life to years*'.

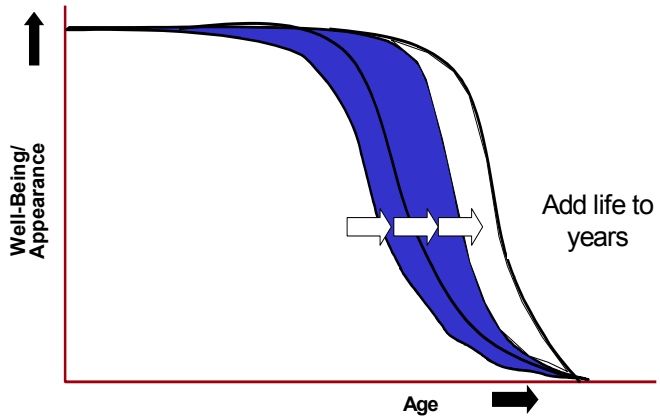

Figure 2. Healthy ageing

The food sector is unique … and under pressure

The European agro-food industry is the largest manufacturing sector in Europe. The food and drink industry itself had a turnover of 840 billion euros in 2005, transforming over 70% of the EU's agricultural raw materials and employing over four million people, the majority within the SME sector. The European agro-food industry is a leading global exporter and affords significant value addition; it also offers scope for economic growth within new EU Member States, development of regional economies and exploitation of Europe's rich cultural diversity and traditions. *The agro-food industry is thus central to the wider, economic development of Europe as it will develop over the next two decades.*

The food sector differs from other manufacturing industries in a number of ways:

- although large, the sector is overwhelmingly populated by SMEs with a relatively small number of big players,
- its products are highly diverse and often production methods (especially in SMEs) are based upon craft rather than technology,
- the technological/production issues faced by the industry are equally diverse and impact directly upon public health and safety,
- food SMEs are, in general, not research-aware (often lacking specific R&D functions) and do not appreciate the contribution innovation could make to their business. This lack of awareness impacts upon both their competitiveness and on their ability to generate wealth within their community,
- the resource available to implement innovation is highly restricted,
- the timescale by which innovation must produce a return on investment is short,
- the food sector should produce safe foods that fit into a healthy diet and will add to the quality of life of European consumers.

These differences suggest that *transfer of 'best practice' from other sectors is likely to, at best, produce only limited benefits*.

The extent of the challenge facing this sector may be seen from data recently published by CIAA in its *2006 Benchmarking Report on food and drink industry competitiveness*. Investment in European R&D was only 0.32% in 2003, lagging behind Norway, Japan, US and Australia (Figure 3). In addition, most innovation indicators of the food and drink sector are below the manufacturing industry average. In summary, CIAA identifies:

- **slow growth in total production value** - European growth over the last 10 years was similar to that of the US but *lower than many of its competitors, especially Brazil*,
- **constant growth in value addition** - Europe performs slightly better than US *but worse than Australia, Canada and Brazil*,
- **slower growth of labour productivity** – since 2002 *European productivity has slowed and the gap with the US has widened; between 200 and 2004, European productivity increased by 16% compared with 27% in Brazil*.

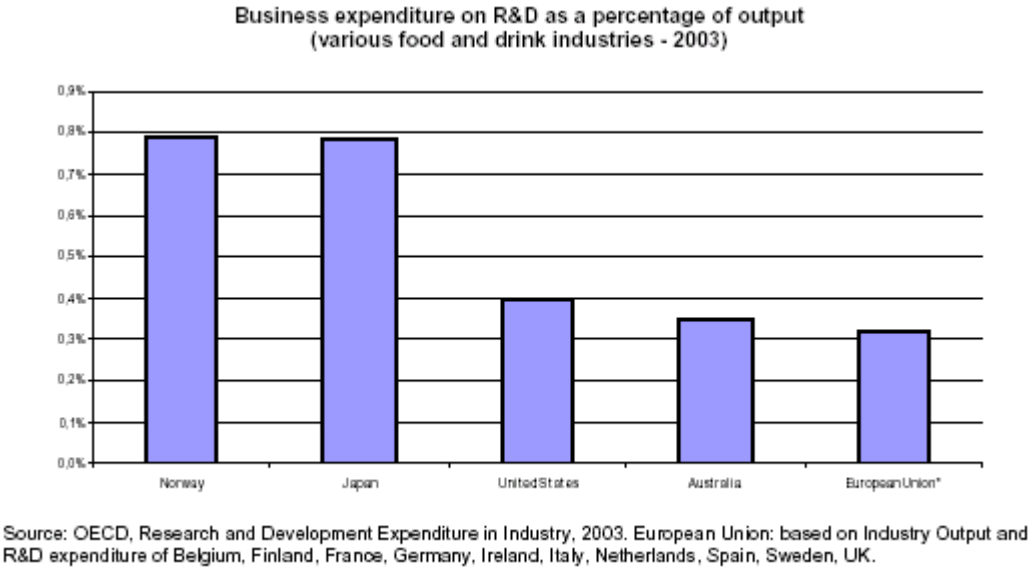

Figure 3. Business expenditure on R&D as a percentage of output (2003 data)

Unsurprisingly, the Report identifies an "urgent need for an increase in R&D investments in order to support innovation and promote a shift to higher value-added production". The developing strategy of the ETP Food for Life, presented here in an interim form, provides one response to this urgent situation.

Currently the food sector is under close government and legislative scrutiny, and consumers are requiring high levels of accountability and innovation. This situation will not lessen in the future as calls for the reduction in fat, salt and sugar in the diet intensify, and consumers seek products with shorter preparation times and 'fresher', more enjoyable and healthier characteristics.

In addition to these issues the industry is faced with another set of challenges. These are:

- food products are difficult, if not impossible, to patent,
- products can only be marketed for a short time before similar products appear, and so have only small added-value compared with other manufacturing sectors,
- the market in Europe faces limited growth for demographic reasons (low population growth and an ageing population).

All these factors make the food sector unique and unique solutions are required to ensure a competitive industry.

Opportunities for the food and drink industry

The interest in the food we eat has never been greater than it is today. Many consumers feel passionately about it, be its method of production, its quality (or lack of it), its price, and its effect on our health. In no other industrial sector are there so many factors contributing to a direct consumer involvement in the outcome of the agro-food industry. *This provides both an enormous challenge and a huge responsibility*.

Whilst some consumers long for the bucolic days of old and would prefer to see the clock turned back on the industrialisation of food production, others accept and welcome the variety of choice, the ready availability of products that, until quite recently, were seasonal and the convenience that these products offer. Such changes may be seen to have contributed significantly to the changing role of women in Europe. However, many consumers remain suspicious about the effect that the industrialisation of food production has on their health and that of their families; such concern is difficult to dispel even though these same consumers are increasingly accepting that, together with their overall lifestyle, the choice of food that they and their families eat will have the greatest effect on their health and well-being.

No longer is it possible to determine the research agenda through the activities of the scientific community alone. Scientists in industry and academia must engage with the public and involve society as a whole in determining the research priorities. Only in this way will the legitimate concerns of the consumer be embraced, and an agenda developed that is in the interests of all. *This Technology Platform will develop and drive such an agenda*.

This challenge is not an easy one. Consumers seek clear messages, not ones that are qualified or difficult to relate to. In turn, the media and politicians also expect to convey complex issues in a simple and direct way. But it is rarely possible to express issues that relate to food safety or nutrition in black or white terminology. When consumers are told a food is 'safe to eat' they do not understand that there still might be associated risks, depending on the individual or the amount of food consumed. If this situation is to be addressed effectively, better communication and an environment of trust and mutual confidence are required.

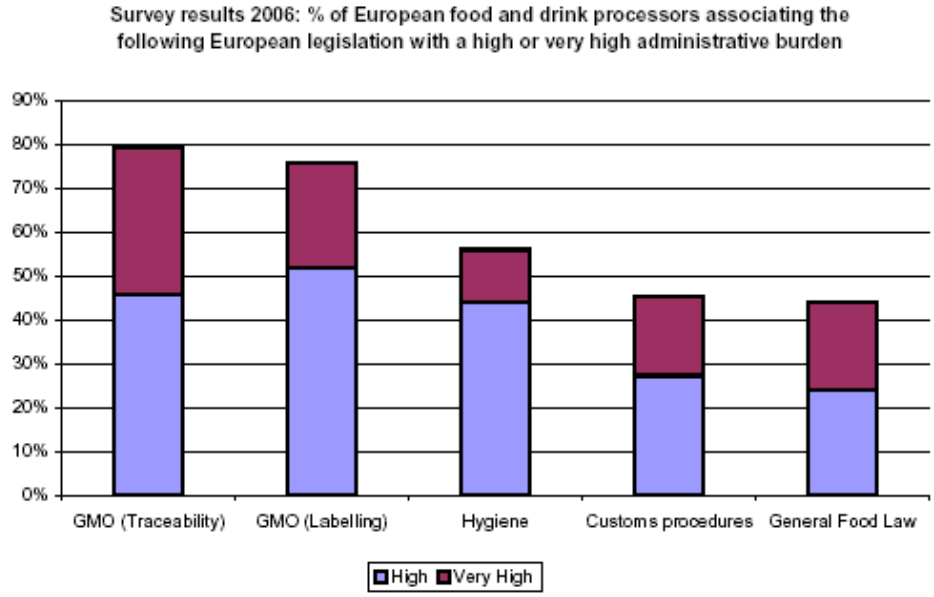

Figure 4. Survey results 2006: percentage of European food and drink processors associating the following European legislation with a high or very high administrative burden (source: CIAA, 2006)

The increasing tendency to legislate to ensure all risks are minimal places a heavy burden on the food sector (Figure 4) and, in particular, upon its ability to innovate and this is especially true for small and medium-sized enterprises. Legislation should be evidence-based but it can be introduced when the evidence is still uncertain, or when concerns are expressed that are not valid. These actions fuel consumer's concerns and may be heightened if there is a failure to communicate in an appropriate way. There remain many obstacles to effective communication and *this is a priority that must be addressed*. Advances in understanding consumer's needs and concerns, and how to effectively portray positive messages without being accused of bias, are critical research needs that affect the food industry to a greater extent than is the case for many other production sectors. *Effective solutions will only occur if effective interactions are established between the humanities, natural sciences, the media and industry*.

Opportunities to enhance public health

The relationship between diet, health and lifestyle has become a top priority issue for many EU governments as they struggle to deal with the major increase in obesity and the rise of diet-related chronic disease among their ageing populations. *Such issues affect national economies in both a direct and indirect manner*. In the UK alone the incidence of obesity has risen amongst children from 9.6% in 1995 to 13.7% in 2003. Once established in the young there is good evidence that obesity continues into adult life with all the associated problems that this can lead to, including type 2 diabetes, cardiovascular disease, hypertension and an increased risk of certain cancers. The need to understand the determinants of a healthy diet and how to assist in its adoption by all sectors of society, and not just those with 'purchasing power', will open up new challenges and new opportunities for the food and nutrition sector.

Europe's ageing population is faced with an explosion of chronic diseases and accompanying increase in the costs of health care. *Even when the public is made more aware of how to eat 'more healthily', patterns of food purchase and food consumption are only slightly altered*. This challenges the food industry to find new ways to introduce foods that are tasty, affordable and contribute to a healthy lifestyle. This situation also offers significant opportunities to work with social scientists to identify the key barriers to change, and to develop, validate and disseminate such information.

Many people are suffering from an increase in disease risk, mainly due to a high food intake and a wrong choice of foods. The food industry has a clear impact on the health of consumers through *the quality, cost and availability of its products*. Scientific advancements are rapidly producing new, in-depth insights into the relationship between nutrition and health and the resulting impact on health creates a common interest among many stakeholders. In the Netherlands alone, the public cost of food-related chronic diseases amounts to 5 billion € per year. If food products supporting a healthy lifestyle could reduce this figure by just 10%, it would provide significant health and financial benefits. If a similar reduction were to be forthcoming across Europe, these benefits would be correspondingly greater. At present, the opportunities and benefits offered by good food and healthy diets are only just being realised.

The health effects of food that indirectly related to disease are important for a much larger target group. The financial and non-financial effects are hard to measure at this moment, as many of the developments are recent and reliable market information is scarce. Typical examples are improved infant nutrition (higher nutritional value and thus improved development of bone and brain), avoidance of cramps and allergies, avoidance of dental erosion, sustained mobility for the elderly, enhanced sleeping patterns, less fractures; many more examples might be given.

Improving public health through a healthy diet is not, however, simply a matter of food and nutrition research. For the consumer to purchase and consume a food, it simply must taste good, be easy to consume, convenient to prepare, convenient for use on-the-move, readily available and affordable. This requires also much better insights in consumer behaviour, sensory aspects, structure engineering, packaging, safety and preservation; and the *effective integration of such diverse data*.

In order to better express the burden of disease and to allow comparison of diseases and disorders on public health, the World Health Organisation has introduced the concept of *Disability-Adjusted Life Years* (DALYs), which represents the number of healthy years, which a population loses as a result of disease. Determination of DALYs takes into account differing aspects of disease (such as the number of persons suffering from the disease, its seriousness and the mortality, and the age at which the disease occurs). Chronic diseases all have an important effect on the quality of life and some have a direct relationship with food intake and diet.

An analysis from the Swedish Institute of Public Health suggests that *4.5% of disability adjusted life-years (DALYs) is lost as a direct result of poor nutrition in EU Member States, with an additional 3.7% and 1.4% due to obesity and physical inactivity, respectively*. The total percentage of DALYs lost related to poor nutrition and physical inactivity is, therefore, 9.6%. This figure clearly indicates the scale of the problem, but also the scope for improving health and well-being across Europe.

Improving population health

Good health is an integral part of thriving modern societies and is closely intertwined with economic growth and sustainable development. Achieving good health for all means not just curing diseases, but also *preventing* diseases. Food, eating habits and physical activity are the *most important non-genetic contributors to age- and lifestyle-related diseases*, including obesity, diabetes, cardiovascular disease, hypertension and stroke and some types of cancers, which are becoming increasingly significant causes of disability and premature death.

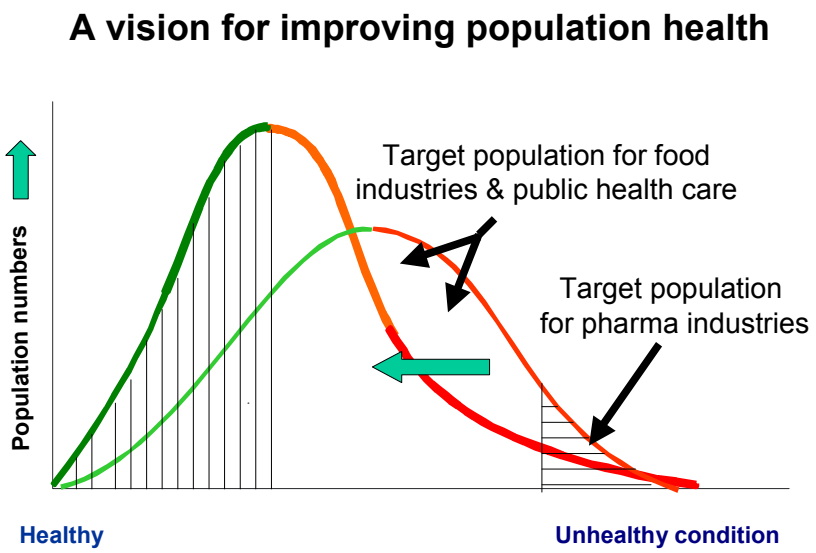

Figure 5. A schematic presentation of improving population health. Target areas of the food and pharma industries in public health (source: Green MR and van der Ouderaa F, Nature Pharmacogenomics, 2003)

Such lifestyle-related diseases will increase to unacceptable levels, as will the costs associated with these diseases, unless appropriate measures are taken now. *Prevention* of these diseases is becoming increasingly important, and represents one of the major targets for the agro-food industry. Particular emphasis should be placed on preventing these diseases by delaying the initiation process; that is, *reducing the risk rather than curing* (Figure 5). *Healthy diets, changing eating habits and increased physical activity* are all key determinants that will influence the rate of ageing and disease.

Science, societal and consumer needs and benefits

One important barrier to success in the food, nutrition and health sciences is *the lack of understanding of the mechanisms underlying the effects of food intake on health*. New technologies that have become available, including genomics, post-genomics and high-throughput tools, and novel insights that will be gained as a result of their application will be able to provide mechanistic explanations for effects of foods. Changes in legislation that will require *health claims to be substantiated, will also require a better understanding of the mechanisms underpinning the physiological functionality of food components*. The discovery and validation of biomarkers based on epidemiological studies, cellular- and physiological studies (including the outputs of systems biology) and intervention studies will all be essential elements of this substantiation process.

There is a pressing need to develop food and nutrition policies which protect and promote health and reduce the burden of food-related disease, *whilst at the same time contributing to socio-economic development and a sustainable environment*. A multi-sector approach, embracing agriculture, the environment, the food and drink industry, local government, transport, consumer communication and commerce is essential to ensure that food and nutrition policy is high on the political agenda.

Even when the public is made more aware of how one can eat ‘more healthily’, patterns of food purchase and food consumption are found to change little. This observation requires the food industry to find new ways to introduce foods that are tasty and accessible and contribute to a healthy lifestyle. Also, this situation offers significant opportunities to work with social scientists to identify the key barriers to, and key drivers for change, and to develop, validate and disseminate such information to all sections of society.

Population-based nutrition programmes are required to translate population targets into practice. Nutritional goals have been set traditionally at the population level but genomic technologies are revealing that the balance of risk/benefit will vary according to genotype/phenotype, and that there will be differing requirements for different sectors of the population, including ethnic and immigrant groups. In the long term, nutritional advice will be able to be focussed on the individual consumer. As a consequence there could be an increasing development of specialised food products in addition to those currently classified as ‘foods for specific nutritional purposes’.

Such niche market opportunities would be particularly attractive to SMEs and to enterprises larger than SMEs who represent something of a ‘missing link’ within actions to support innovation that are promoted at national and regional level. These new opportunities expand the size of the global market and would be identified by better assessing and identifying consumer needs, recognising emerging consumer trends earlier, disentangling the complex relationships between food choice/indulgence/health and optimising novel processing.

All of these issues are addressed in this SSRA which is based upon consideration of these issues as well as of the nature of the challenge that faces the research providers (Figure 6). It must be emphasised that this is an *interim document* that, while reflecting the opinions and

ideas of experts, has not been subjected to the range of consultation and discussion that are necessary for it to reflect the interests, needs and challenges of the European food chain as a whole ands its many and diverse stakeholders. *Such consultation will be carried out over the next nine months, culminating in the publication of the Strategic Research Agenda and Implementation Plan in March 2007*.

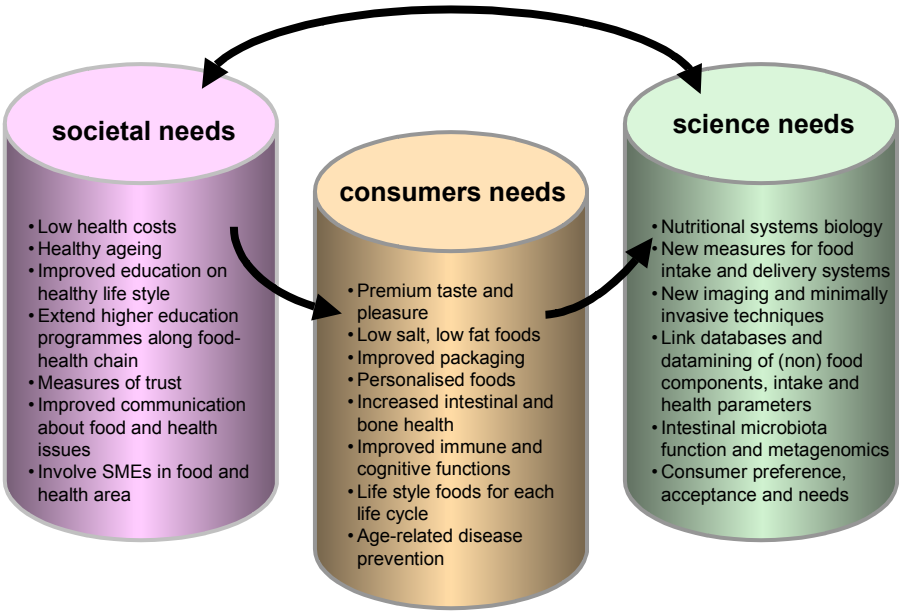

Figure 6. The integrated picture: societal-, consumers- and science needs

Challenges and opportunities

The objective of future research in the food sector should be *to develop safe, high quality and affordable food that offers a wide variety of healthy nutritional products that are enjoyable to eat*, and that can be targeted to both specific groups of consumers and consumers in general, including the significant numbers of ethnic minorities that are frequently omitted from campaigns on 'healthy eating', or only poorly informed about the dietary changes they would need to make.

As a consequence of this background, **seven challenges** have been identified representing the issues that research will need to address in order to ensure the above market and consumer needs can be met. These drivers for innovation are:

1. **Ensuring that the healthy choice is the easy choice for consumers,**
2. **Delivering a healthy diet,**
3. **Developing value-added food products with superior quality, convenience, availability and affordability,**
4. **Assuring safe foods that consumers can trust,**
5. **Achieving sustainable food production,**
6. **Managing the food chain,** and
7. **Communication, training and technology transfer, competitiveness and consumer interaction.**

In addition there are **four additional tasks** that need to be addressed if the research undertaken is to be successfully implemented and to deliver the anticipated benefits to stakeholders. These are:

A. **Increasing the financial resources committed to innovation of the European food industry,**
B. **Improving education, skills and facilities in Europe,**
C. **Optimising stakeholder understanding and commitment,** and
D. **Initiating scenario studies.**

The activities to be developed as a response to these issues will be developed within an overall context that addresses *gender equality and ethics*. In addition to addressing specific issues within this ETP, effective dialogues will be established with other regional and national experts and networks, including those within the European Commission, so as exchange, incorporate and disseminate best practice.

Challenge 1.
Ensuring that the healthy choice is the easy choice for consumers

Food and drinks bring pleasure to the consumer and, if consumed in the right amounts, they should make a major contribution the well-being and healthy ageing of European citizens. Consumer confidence in foods is also of paramount importance and can be enhanced by appropriate communication and public participation that results in an effective dialogue.

The objective of this challenge is to enhance the consumer orientation of the European food industry by strengthening the fundamental understanding of food consumer behaviour, by increasing the consumer involvement in healthy foods and their production.

Although food consumer science has progressed considerably during the last few decades, there are still a number of areas that require further development, both in terms of capabilities and competencies. Several of the consumer science competencies are addressed within the other challenges. Here we focus on the core capabilities, which are structured around four key elements of the so-called consumer research cycle (Figure 7):

- Improved methodologies for measuring and quantifying consumer behaviour,
- Advanced consumer understanding by integration of social and biological sciences,
- Effective and efficient ways of involving consumers, addressing information provision, education and public consultation,
- Interaction with consumers based on a sound understanding of what drives their (re)actions (requiring effective communication models and practices as well as public consultation methodology), and
- Effective strategies to induce behavioural change (requiring an understanding of habit-breaking and formation).

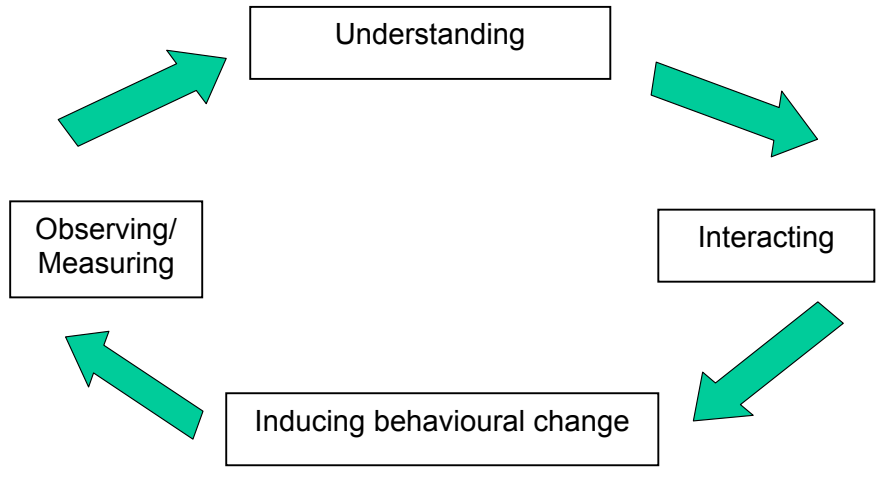

Figure 7. The consumer research cycle

This cycle emphasises both the importance of being more responsive to consumer needs and preferences, and the strong need to connect or re-connect with consumers through

active participation. Whilst acknowledging the need and benefits, the European Commission and national governments have had only limited success in bringing together the expertise bases in the natural and social sciences. The ETP Food for Life provides an excellent opportunity not only to achieve this (and gain the subsequent added value), but also to develop and promote best practice for achieving these interactions and integration. In addition, it also provides the opportunity to address the needs and expectations of all consumers and not just those within the mainstream ethnic and cultural populations. There are four different goals that need to be addressed.

Goal 1. Measuring consumer behaviour in relation to food

Eating behaviour is a complex process, which goes beyond the single act of selecting one food and eating it; eating habits differ a lot across different populations (different cultures and cuisines) and population groups (e.g. age, gender, economic status, education, family lifestyle, etc.). All these different aspects provide formidable challenges to the measurement and quantification of food choices. Measurement takes place at different levels of abstraction without too much integration and synergy among them.

Accurate measurement of purchase and consumption behaviour is a pre-requisite for theory development, strategy development and strategy evaluation. The cross-cultural diversity adds an extra dimension to this challenge.

Major research challenges
- Improve measurement approaches in terms of their validity and accurateness,
- Develop strategies to make better use of available large scale databases (e.g. scanner and purchase, and consumption panel data),
- Develop methodology that is cross-culturally valid and sensitive,
- Further develop behavioural measures (e.g. observational research) to complement the current focus on self-report measures of attitude and purchase intent.

Deliverables
- Integrated data sources, synergised to quantify food intake (including epidemiological data, retailer data bases and consumer data) (**2010**),
- Methodology for determining cross-cultural validity and sensitivity in order to quantify food-related concepts across Europe (**2015**),
- European food cultures mapped using large-scale purchase and consumption data, which includes similarities and differences in large-scale purchase data. This should include values, attitudes, beliefs, personality and behaviour, but also different sub-populations, such as low-income consumers (**2015**),
- New modelling approaches to understand the discrepancy between actual versus optimal dietary behaviour over time (**2020**).

Goal 2. Developing comprehensive models of consumer food choice processes

Understanding the fundamental processes that lead to the actual food choice behaviour of consumers is the crucial challenge for the research field of consumer science. This is a complex task given that consumers' food related behaviours are determined by a variety of influences, which include, amongst others, psychological, sociological, cultural, biological and economic factors).

Major research challenges
- Comprehensive models of consumer behaviour integrating the various disciplinary perspectives, including the role of advertising and marketing on food choices,
- Attention to sub-conscious processes in food choice behaviour that consumers are less likely to self-articulate,
- Analysis of determinants of eating patterns and consumption baskets,
- Analysis of cross-cultural similarities and differences in consumer behaviour and particularly in emerging markets, regions and countries,
- Attention to socio-economic and cultural determinants in family decision-making, and
- Enhanced attention to ethical considerations in consumer behaviour and consumer research.

Deliverables
- A pan-European multi-disciplinary food consumer science resource (overcoming fragmentation and building critical mass) (**2010**),
- An integrated framework created for the analysis of food consumer behaviour, which integrates the various uni-disciplinary approaches to food choice with particular emphasis on understanding the process and determinants of repeat choices (**2015**),
- The feasibility of multidisciplinary and cross-cultural analysis of consumer behaviour of specific subpopulations in Europe (e.g., children, adolescents, elderly) demonstrated through proof-of-principle projects (**2015**),
- Large-scale retailer databases of actual purchase patterns analysed to understand the integrative influence of retailers on food consumer behaviour (**2015**),
- An improved understanding of the trade-offs between personal and societal consumer motivations, including insights from neurosciences (**2020**).

Goal 3. Promoting effective interaction with consumer groups and consumers directly through communication and public participation

Adequate understanding of consumer behaviour should form the basis for how consumers can best be informed (communication) and how they can be actively engaged (e.g. public participation) regarding new developments in the food domain. This requires that communication and public involvement are organised in a way that optimally aligns to consumer interests and consumer levels of understanding and learning. Both communication with the consumer and public participation are areas where important progress is required to help consumers make informed choices and to actively involve them in developments in the food area so as to enhance transparency and ultimately consumer confidence in food.

Major research challenges
- Quantifying and understanding how consumers process information in the field of food and nutrition,
- Developing better tools for effective communication with the consumer, including insights from semiotics and persuasive communication through different media,
- Developing effective tools for public participation in food and nutrition issues allowing being optimally informed and having maximum transparency and consumer confidence in the food industry.

Deliverables

- Consumer needs, expectations, knowledge and attitudes with regard to food and food production mapped in a pan-European context (**2010**),
- Validated models and methods for effective public participation and engagement with consumers from different backgrounds on new developments in food and the food industry (**2015**),
- A set of validated methods, models, practices and tools for effective consumer information and education regarding food and nutrition (**2020**).

Goal 4. Developing strategies to induce behavioural change in order to improve consumer health and social responsibility (through healthier food choices)

One of the important challenges in both public health and commercial policies on food and nutrition is to induce behavioural change in (informed) consumer choices in such a way that long-term private, public and societal interests are better served by those choices (e.g. better personal pleasurable diets at affordable prices and improved public health and well being). For consumers, these choices emerge in a 'battle-field' between their short-term personal needs for taste, convenience and low price and the longer-term societal needs for safety, sustainability, ethics and public health. Also, many of the existing choices are deeply rooted in habits and cultural practices.

Major research challenges

- Understanding the process of habit formation and habit change and the key motivations that trigger vs. hamper change particularly in relation to 'risky' eating behaviour,
- Understanding consumer trade-offs between personal and societal motivations drawing on insights from cognitive science, neuroscience, marketing and other disciplines,
- Analysis of changes in meal patterns and consumption habits over time,
- Development of foresight studies to identify emerging or latent needs in consumer behaviour.

Deliverables

- Intervention strategies for inducing long-term behavioural change towards better dietary habits (**2015**),
- Foresight studies on emerging issues in consumer behaviour (**2020**).

Challenge 2.
Delivering a healthy diet

The objective is *to develop new and effective food-based strategies to optimise human health and to reduce the risk or delay the onset of diet-related diseases*. New enabling technologies and infrastructures within the EU will be optimally used to:

- create technological leads for the food industry,
- strengthen their competitive power, and
- enable research partners to consolidate their leading research position.

The nutritional sciences are now at an important turning point. In the past, nutrition was above all a question of ensuring food intake and remedying dietary deficiencies, and was largely based on observational research. With the recent advances in genomic and molecular technologies and know-how, a new paradigm is created on the interaction between nutrition and health. The ability to link the impact of food to health at a cellular level, as well as at a whole body level, creates a new horizon for the food industry and offers benefit to the individual consumer. The exploitation of such technologies can change general nutritional guidelines into more tailor-made personalised nutritional advice. Furthermore, the benefits can be made visible on food products by health claims that are based on sound scientific evidence, which is likely to be required as part of a strict legislative framework being developed by the European Parliament.

Consumers are becoming increasingly aware of the relationship between food intake and health, and also the relationship of inappropriate diets with major chronic diseases such as obesity, type 2 diabetes, cardiovascular diseases, cancer, sarcopenia (muscle wasting) and osteoporosis. Healthy ageing must be one of the key topics in the research efforts for the coming years. Leveraging knowledge for the prevention of diet-related health disorders and generating knowledge on the impact of nutrition on the quality of life of individuals at all ages will also lead to innovation and breakthrough, thereby increasing the competitive advantage of the EU food industry.

To reach this milestone of improved daily quality of life at all ages, *a new food concept is needed, which includes nutritional value, food safety and emotional values of taste and convenience. Physical activity is an integrated part of a healthy lifestyle* and close contacts will be developed between this ETP and the **European Platform on Diet, Physical Activity and Health**.

The progress in life sciences from the level of DNA up to systems biology and incorporating the technical sciences (for example imaging, nanotechnology) provides the opportunity *to focus on a few emerging areas* which in the past lacked the necessary technologies to generate knowledge on the interaction between diet and quality of life (Figure 8). This is particularly true for the *function of the brain*. Cognitive decline with ageing and diseases such as Alzheimer's and dementia, are emerging areas for nutritional research.

One common factor in most, if not all, of the currently important diet-related chronic diseases is low-grade chronic inflammation. *Immune and intestinal function* is strongly related to nutrition, starting at the first contact of ingested food within the gastrointestinal tract. So far it has been difficult to study this important interaction due to a lack of valid biomarkers and diagnostic tests. Given the recent advances in life science technology, a more focussed

research approach will have great breakthrough potential leading to diet-induced immune modulation and improved quality of life.

One of the major nutrition-related health threats for the coming decade is obesity with all its related metabolic impairments, such as type 2 diabetes, cardiovascular diseases and metabolic syndrome. Arguably, the greatest challenge for the food industry for the coming years will be to deal with this. Therefore, the need for improved knowledge of the *metabolic function* at all ages associated with obesity and related diseases must have a high research priority.

To reach these goals in the coming years a number of nutrition-related infrastructures are required and specific enabling technologies must be developed (these are addressed on pages 65-67).

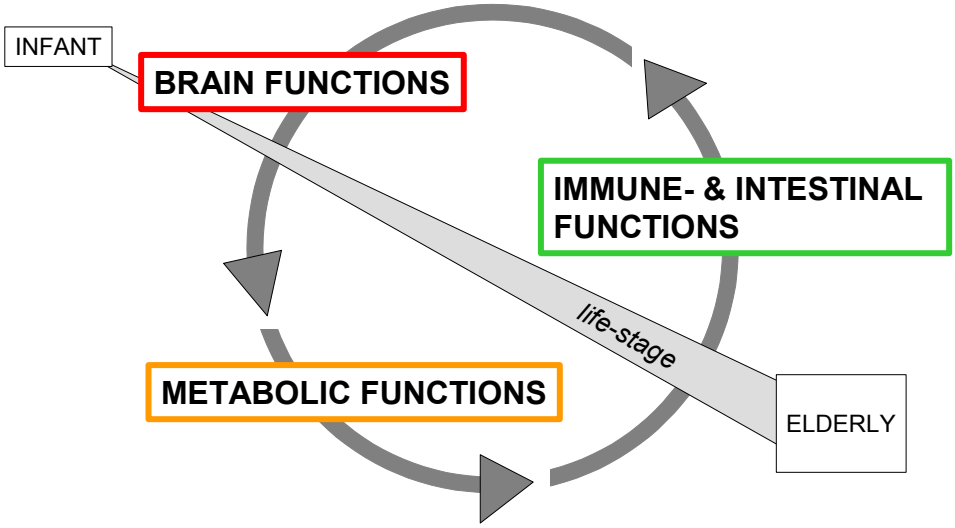

Figure 8. Priority research areas in food and health

Goal 1. Understanding brain function in relation to diet

It is well established that diet can have both a positive and a negative impact on our physical health and performance. Although significantly less scientific data are available, there are clear indications that the same holds true for our mental health and cognitive abilities. Several studies indicate that diet can influence brain and cognitive development in utero and in neonates, infants and young children. Food intake can also affect brain function (in all age groups) in terms of cognitive processes, mood-, and brain performance. Reciprocally, brain function can affect components of food intake such as type of food and amount of energy consumed. Although the relationships between brain function and nutrition are still relatively poorly understood, it is generally accepted that the former does impact significantly on overall health and well-being.

Major research challenges

- To chart the scope of diet and individual nutrients to influence brain health and performance. To interpret these results and maximise the impact, mapping will be required of the underlying mechanisms through which dietary components are capable of

modulating brain development, cognitive performance and preventing depression and ageing-associated cognitive decline,
- To increase understanding of the neural pathways controlling functions like food intake, hunger and satiety will provide powerful new insights to combat the obesity epidemic.

Deliverables
- Diet and cognitive function – understanding the impact of nutrition on brain and cognitive development in utero and in neonates, infants and young children (**2015**); achievement of healthy ageing by nutritional strategies in childhood (**2020**); establishing the relationship between nutrition and learning abilities and other cognitive attributes (**2020**),
- Brain conditioning – understanding of how early exposure to dietary components leads to taste perception and food preferences later in life (**2010**),
- Mood and optimal performance – mapping the impact of specific food ingredients on mood and mental performance through building an understanding of the mechanisms underpinning these effects (**2015**),
- Prevention of cognitive decline – mapping the scope of diet to reduce or prevent the decline in cognitive functioning with ageing and charting underlying mechanisms (**2020**),
- Food intake regulation and hunger/satiety – identifying the brain pathways that regulate hunger/satiety (**2015**); identifying dietary components that can help control food intake (**2020**); understanding of the molecular and cellular mechanisms behind neuroprotective effects by dietary compounds (**2020**),
- Nutrition and inter-organ signalling with a key role of the brain – understanding the mechanism of gut-central nervous system interaction (**2010**).

Goal 2. Understanding dietary effects on immune and intestinal function

An optimal immune system is pivotal for a person's health, preventing acute and chronic disorders and determining how the body reacts to and copes with environmental stimuli and physiological and psychological stresses. Food is an important factor able to affect immune reactions in either a negative (e.g. allergy) or positive manner (e.g. probiotics). The immune system is intimately involved in several pathophysiological processes including cancer development. The human immune system controls the so-called innate/native immune functions (such as the intestinal barrier function) and the acquired or adaptive immune functions (like inflammatory regulators).

The intestine, which possesses a metabolic activity equivalent to the liver, is regarded as the key organ able to maintain health and influence resistance to disease and immune function in relation to food. The intestinal tract is the primary site for food intake and is colonised from birth by a microbial community that contributes to food conversion, production of host-active compounds and stimulates a variety of relevant functions, including the immune system. It has proved difficult to define a 'healthy intestine', because of its complexity, the large inter-individual variability and the active interactions between the host, its microbes and the diet. However, recent applications of innovative holistic systems and subsystems approaches, including metagenomics, have provided tools for determining microbial activity and its impact on intestinal function in health and disease.

An emerging body of knowledge now points towards the benefits of several bioactive food components (including microbes and their constituents) interacting with the immune system and the intestine, as well as to the importance of chronically-increased inflammatory activity in the body - partly due to immune deregulation - as a key detrimental factor in the development of obesity-related disorders, chronic inflammatory disorders (including rheumatoid arthritis, chronic obstructive lung disease and chronic inflammatory bowel

disease), functional bowel diseases, and the ageing process. It has been demonstrated that diet is able to affect these and other inflammatory processes (not induced by immune activation) by means of, for example, probiotic microbes, fatty acids and antioxidants.

Major research challenges

- To enhance the knowledge of the relation between the immune system and other organ systems such as the brain, the endocrine system and the intestine and their relation to physical activity,
- To study fetal and neonatal nutrition in relation to immune (de)regulation during later life by metabolic/immunologic imprinting,
- To identify and validate minimally invasive biomarkers of the immune system and related systems in order to achieve and accelerate progress. The limited availability of widely accepted and effective pre-clinical model systems for screening purposes must also be addressed to improve mechanistic understanding and stimulate scientific progress, innovation and regulatory decisions.

Deliverables

- Knowledge and tools to positively modify systemic inflammatory activity by diet, especially with regard to the intestinal system, metabolic disorders such as type 2 diabetes, cardiovascular diseases and the ageing process (**2010-2015**),
- Identification of dietary factors that improve the barrier function of the intestine (including the impact of intestinal microbes) and the resistance to infections (common, food borne, etc.) and its inflammatory sequelae (**2010-2015**),
- Development of biomarkers of intestinal and related functions to define and improve 'intestinal health'; improvement of e.g. 'abdominal comfort', digestive function, systemic immune function and decreased risk of colorectal cancer (**2010-2020**),
- Determination of a healthy diet in terms of type and timing of introduction of specific dietary constituents with regard to the mother, before and during pregnancy and lactation, and with regard to the newborn during early life, in order to optimise immune function and decrease the risk for allergy (**2015-2020**),
- Improvement of the allergome databases of plant- and animal-derived food, knowledge of allergen post-translational modifications and allergenicity increase by additives or contaminants, and persistence after cooking; detection of allergens derived from human gastrointestinal or hepatic metabolites (**2015**).

Goal 3. Understanding the link between diet and metabolic function (obesity and associated metabolic disorders)

Obesity rates have risen three-fold or more since 1980 in many areas of the globe. Currently at least 300 million of the world's one billion overweight adults are clinically obese and. Obesity occurs when energy intake is greater than energy expenditure, therefore physical activity, diet-induced thermogenesis and food intake regulation must all be addressed to reduce the prevalence of obesity.

Obesity plays a central role in the metabolic syndrome, which includes hyperinsulinemia, hypertension, hyperlipidemia, type 2 diabetes and an increased risk of atherosclerotic cardiovascular disease. In order to develop preventive strategies it would be important to identify biomarkers including polymorphisms of early metabolic changes utimately leading to metabolic syndrome. There is today a growing body of evidence that obesity is associated with a chronic low-grade inflammation, and a better understanding of inflammatory pathways

could be critical in the mechanisms underlying obesity and its complications. However, triggers of the inflammatory process in humans have not yet been clearly identified.

Interestingly, some of the metabolic alterations linked with ageing, such as decreases of insulin sensitivity, bone quality (e.g. mineral density), and muscle mass (sarcopenia), and increase of body – and visceral – fat are associated with increased systemic inflammatory activity. Dietary measures that could counteract these ageing-related metabolic disorders would offer a real breakthrough in an ageing society.

Maternal and post-natal nutrition is not only central to the growth and development of infants but may also condition health later in life (programming/imprinting). The alarming increase in the incidence of overweight and obesity reported in children has renewed the interest of determining the influence of the maternal and infant diet on the risk of developing excess fat mass and metabolic disorders later in life. The relationships between early nutrition and increased obesity risk are poorly understood and not well established in humans. Research should deliver dietary recommendations for both mothers and infants.

Major research challenges
- Understanding the genetic background of individual metabolic profiles in relation to body weight control and the risk for development of co-morbidities such as type 2 diabetes and metabolic syndrome with increasing weight,
- Developing effective food ingredients and dietary strategies to prevent weight (re-)gain,
- Defining the effects of diets and nutrients early in life for health outcomes in later years,
- Tackling the nutrition-related wasting diseases in the elderly population and understanding the role of nutrition in healthy ageing.

Deliverables
- Early biomarkers of metabolic syndrome (**2010-2015**),
- Knowledge of individual variations in metabolic energy efficiency and in susceptibility to high energy intake and sedentary lifestyle (**2020**),
- Identification of specific food components for regulating food intake and increasing diet-induced thermogenesis (**2015**),
- Development of intervention strategies to align research on exercise physiology/physical activity and obesity/metabolic syndrome (**2010**),
- A dietary strategy to counteract ageing-associated muscle wasting (sarcopenia) and decrease of bone quality (**2015**),
- Identification of food components alleviating chronic low-grade inflammation associated with obesity and determination of their impact on the prevention of insulin resistance and metabolic syndrome (**2015-2020**),
- Knowledge on the contribution of epigenetic events on chronic diseases later in life and the contribution of nutrition (**2020**),
- Maternal and infant dietary recommendations for optimal metabolic health (**2015**),
- Insight into the effects of meal composition, size and frequency on energy uptake and satiety (**2015**),
- Understanding drivers (diet, genes) that regulate chosen levels of physical activity (**2010-2015**).

Goal 4. Understanding consumer behaviour in relation to health and nutrition

The translation of scientific insights into consumer-relevant innovations requires understanding of the consumer's perception and his relation to food, nutrition and health. How can consumers be motivated to move towards a healthier lifestyle and take advantage

of the scientific progress within the life sciences? Among other challenges this will require transparent and consumer-aligned communication of the importance of nutrition and the desirability of specific food products being incorporated in healthy eating patterns. Building on a fundamental understanding of how food choice habits are formed, how they can be changed and on the key motivations that trigger or hamper positive behavioural change, intervention strategies are required to break unhealthy habits and develop them into healthier food lifestyles. In the next decades, breakthroughs may be expected in the fundamental understanding of the biological and cognitive drivers of eating habits and lifestyles particularly from the fields of (nutri-)genomics and cognitive neurosciences. This, together with a better understanding of food-related consumer behaviour, will make it possible to develop product and communication strategies that, by their joint effect, will make it much easier for consumers to live a healthy lifestyle.

Major research challenges

- Understanding the process and key determinants of food habit-formation, habit-breaking and behavioural change towards healthier food choices (including the use of social marketing and role models),
- Understanding the role of biological determinants in food choice (including the role of genomics and brain functions),
- Better methodology to quantify and understand the determinants of healthy/unhealthy choices (role of out-of-home consumption; availability; influence of other lifestyle factors; sensory properties of food; etc),
- Understanding the perception and determinants of a 'healthy food lifestyle', analysing the cross-cultural and subpopulation group differences,
- Developing better tools for effective communication with the consumer and intervention strategies, including insights from semiotics and persuasive communication through different media,
- Understanding consumer knowledge of nutritional concepts and responsiveness to communication formats, including health schemes (e.g. pyramids etc), health claims, simplified labelling (e.g. sign posting) as well as personalised food recommendations (e.g. on the basis of nutrigenomics).

Deliverables

- Assessment of consumer understanding of nutritional concepts and communication formats, incl. health schemes (e.g. pyramids), claims and labelling (e.g. signposting) (**2010**),
- A quantified model for consumer interpretation of (un-)healthy food lifestyles and its interaction with other lifestyle factors (**2015**),
- A quantified model for determinants of (un-)healthy food choice habits (**2020**),
- Effective intervention strategies for habit-breaking and behavioural change toward healthier food choices (**2020**),
- A quantified framework model for the role and relative importance of biological determinants in consumers' food choice, including brain functions and genomics, together with the identification of potential intervention routes to affect these biological determinants (**2020**).

Challenge 3.
Developing value-added food products with superior quality, convenience, availability and affordability

The concept of 'food quality' in Europe has changed significantly over the years and will continue to do so. From the basic availability of food, via uniformity, food safety and production circumstances, *food is now increasingly associated with enjoyment, health and anticipated well-being*. Continuous changes in society and demographic trends (such as increasing participation of women in the workforce, decreasing family sizes and increasing number of households, the ageing society and increases in proportion and integration of ethnic groups in many EU Member States) will impact significantly on the ways in which food will be prepared and where it will be consumed in 2020.

Although manufactured foods are safer than ever, excessive food intake, in conjunction with a decrease in physical activity has led to an increase of lifestyle-related diseases in European society. In the medium- to long-term, lifestyle-related diseases will increase to unacceptable levels unless appropriate measures are taken now to reduce intakes of energy and salt. Since taste is the most important enabler that facilitates the intake of healthy products, the challenge facing industry is the production of tasty foods that:

- are consistent with a healthy lifestyle,
- address the consumer's preferences, and
- ensure repeat purchases.

Convenience is another obvious factor of concern to consumers: grazing, eating on the move and ease of container-opening for children and the elderly are all demands that, when met, increase the enjoyment of food. It is also notable that food is increasingly being consumed away from home, in canteens, catering establishments and restaurants.

Changes in eating habits and a clear demand for improved quality food create opportunities for primary producers to add value to their produce and for the food processing industry to develop new and personalised foods. Although diversity will be of key importance for future food production and product developments, by itself will be insufficient to create the required innovations. Increased R&D investments are necessary to develop new process equipment, processing lines or distributed manufacturing systems.

On the one hand, exporting traditional, regional products from the rich and diverse European cuisine, will be enhanced and supported through a longer product shelf life that will be obtained with mild preservation technologies developed by the leading European equipment manufacturers. On the other hand, new products on the market will be based increasingly on novel ingredients and processes. New (natural) ingredients could be produced by improved, mild separation technologies, or by novel bioprocessing schemes. New structures and textures will be produced as a consequence of developments in micro- and nano-technologies.

A challenge for the European food and drink industry over the next two decades will be to provide the consumer with *the right type of food (i.e. that required by the individual) at the right time and in the right place*. Innovative processes, value-added products, new marketing concepts, novel ways of selling products and novel ways for the production and supply chain to co-operate to create products targeted at consumer needs should all ensure that the

consumer is provided with safe products possessing the required taste characteristics at maximum convenience and, always, at an affordable price. Modern technology can make an important difference in increasing the availability and affordability of food.

To respond successfully to these opportunities, the food industry will need to adapt and incorporate modern production philosophies, such as Lean Manufacturing and Agile Manufacturing, which have proved successful in other market sectors and which allow producers to remain at the forefront of Markey change. Close contacts will need to be established between this ETP and others addressing, for example, textiles and automobiles which are sectors that have already benefited from minimising processing steps that fail to add value for the consumer. For the same reason, establishing close links with the ERA-Net on Manufacturing is also a priority.

Overall, attention must be paid to the complete process line and production plant as well as to ways of optimising their individual elements. In this manner, 'quantum leaps' may be achieved that would both secure niche markets and exploit uncontested market situations. It is recognised that this will be an enormous challenge for a sector that has a poor record of investment in comparison with its global competitors and with other sectors in Europe. However, the benefits from such increased investment are also enormous.

Goal 1. Producing tailor-made food products

The creation of *tailor-made food products* that entail all consumer preferences, acceptance and nutritional needs, requires a complete redesign of the way food is produced. Food in 2020 will be tailor-made to the specific *Preference, Acceptance and Needs (PAN)* of consumers. Consumer science will deliver reliable data on consumer preferences and acceptances and provide a basis for new product development. Nutritional science will deliver the needs with respect to energy intake and also identify any need to fortify foods with e.g. bio-ingredients, and suggest appropriate levels of fortification.

The PAN concept (Figure 9), developed here, should evolve in the long term to a completely reversed engineering approach, in which the total product development is modelled back through the chain from consumer to raw material. This innovation will lead to faster product development and more flexible processing possibilities. However, for this revolution to achieve maximum impact, an increased understanding is required on the dynamics of sensory perception from receptor to the brain, including cross-modal interactions of the senses, flavour release and structure breakdown. In addition, an improved understanding of 'quality' has to be delivered from trans-disciplinary studies into the relation between 1) the compositional and structural features on different levels of scale and attributes of the product and 2) the gastrointestinal, (oral) physiological and neural effects in the body. Structure engineering, a better knowledge (including prediction) of ingredient interactions and the complex reactions in food will all be necessary to deliver the compositions and structures desired and demanded by the consumer.

The trend for addition of bioactive compounds to foods so as to benefit consumer health has been strong during the past decade and, in all likelihood, will expand further in the future in parallel with an increased knowledge base on the impact of individual food constituents on human health. Close links with the ETP Plants for the Future and with the plant science community in general will help to ensure that any perceived need to optimise dietary bioactive compounds can be considered from the perspectives of the plant, its cultivation and its post-harvest treatment and processing. Such contacts will also be necessary to most fully exploit the diversity of plant raw materials and incorporate their products within traditional,

novel and ethnic foods. Ultimately, the PAN approach might be used to identify 'quality' targets for plant scientists, agronomists and breeders.

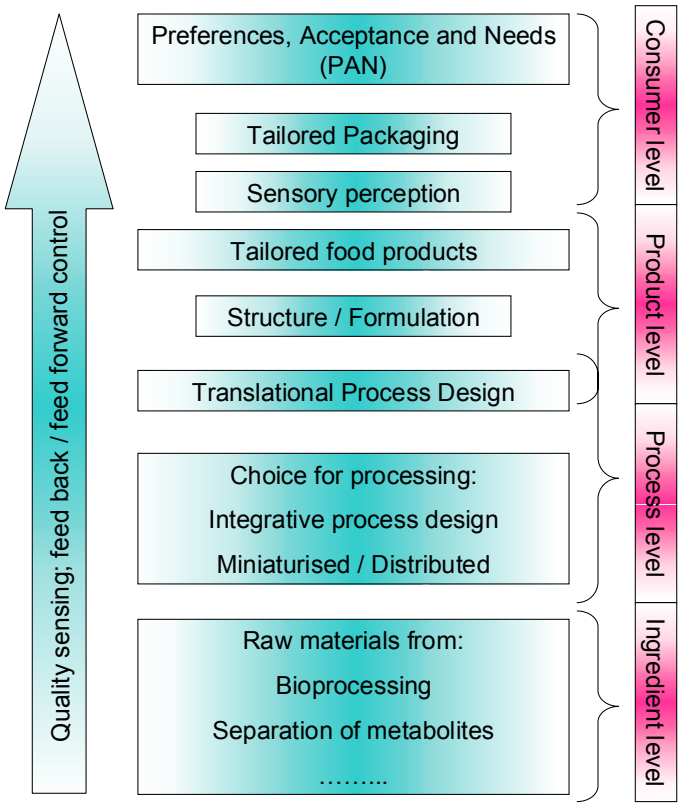

Figure 9. Schematic presentation of the food production process

Major research challenges

If consumers are to benefit fully from bioactive food constituents, and if industry is to effectively deliver such foods, much more emphasis is needed into:

- Identifying bioactive food constituents and their mechanisms of action,
- Improving bio-processing, targeted delivery,
- Tailoring food formulation to new types of bioactive-containing products of good sensory properties,
- Determining/predicting the effect of food structure on bioactive delivery and transfer to the target site,
- Optimising production of live microorganisms used as delivery vehicles for bioactive components,
- Identifying and exploiting new approaches able to deliver personalised products in large volumes, whilst minimising losses associated with change-overs of products and systems.

Deliverables

The tailor-made food approach should lead to new and integrated concepts of food product innovation leading to the production of high quality, interesting, and nutritionally-balanced, safe foods for promoting health. To enable such products to be developed, a deeper knowledge is required in the short-term on all levels of scale (molecular to macroscopic).

Such foods will be derived from raw materials and obtained without the use of additives and chemicals, and by techniques that are consumer acceptable and involve minimal processing. The new products should be diversified towards specific groups, such as children and the elderly.

- Integrating the consumer definition of quality with the physical / chemical definition of quality (**2010**),
- New physical methods to assess sensory attributes; in-mouth measurement and breath analysis of flavour- and taste release from products; physical methodologies for describing and understanding the mechanics of chewing and structure degradation (**2010**),
- New ingredients and products to deliver bioactive products (**2010**),
- *In vitro* assays and biomarkers to predict *in vivo* functionality of bioactive components (**2010**),
- Models for PAN patterns as a function of quality factors to diversify to specific consumer groups (**2015**),
- New ingredients (metabolites from biotechnology, nanotechnology etc.) possessing beneficial health properties; targeted delivery of selected bioactives (**2015**),
- Modelling of physiological and neural impact of structure and composition of a product; understanding of cross-modal interactions (**2015**),
- Non-invasive methods to assess structural changes *in situ* and in real time during digestion (e.g. degradation of structures in gastrointestinal tract); biomechanical models of the mouth and its processes of mastication and swallowing (**2015**),
- Direct mechanistic understanding between the composition and structure of a product on its physiological and neural impact; understanding of satiety and satiation as mutual brain-intestine neural feedback system and the possibility to integrate this knowledge in product development (**2020**),
- Knowledge in the individual variation of sensory perception on composition and structure (**2020**),
- Toolbox for PAN patterns (**2020**),
- PAN relationship to physical/chemical properties and structure (either nano-, micro- and molecular) of products, and packaging concepts; integration of PAN concept into relevant production philosophies (**2020**),
- Expression of quality in terms of PAN profiles, to be used in communication to consumers (**2020**),
- Personalised quality foods targeted at individual consumers (**2020**),
- Toolbox for understanding impact of food bioactives on human health; understanding of the effect of food matrix formulation (structure, components) on the activity, delivery and transfer of bioactive compounds (**2020**).

Goal 2. Improving process- and packaging design and process control

Process design

In order to improve the competitiveness of the European food industry innovations in *process design and process control* are required. In addition, the consumer demand for convenience foods with a long shelf life and a fresh appearance will increase. Mild preservation technologies together with appropriate packaging concepts will enable industry to comply with this demand and stimulate the export possibilities of traditional and regional products, and contribute to the growth of the wider European economy.

Pressure to reduce the time of processing will increase, and one response to this will be to develop models that incorporate increasing flexibility. Advanced mathematical modelling will

also have a role to play in optimising production lines and plants, and even extend to the supply chain. Such 'supply chain engineering' approaches are likely to be increasingly adopted in diverse manufacturing sectors and it will be important to identify, capture and adapt emerging best practice.

Novel, emerging or future food technologies are required for development of foods to meet demands of consumers due to their changing lifestyles and expectations for fresher, more natural foods to promote human health. In addition to sustained attention on mild manufacturing, this will require:

- the development of new products, based on a completely new processing routes, using new components from plants (and animal resources) and from biotechnology and processing,
- new, efficient and sustainable processes that deliver personalised quality products, based on cascades of existing unit processes and on output demands,
- increased flexibility, through the redesign of both processing and logistics. Food process design will need to exploit a lean manufacturing approach in order to optimise user value and minimise losses. Introduction of agile manufacturing will increase the likelihood of competitive advantage.

Packaging design

With the rising demands of consumers for quality, health, security and convenience, and with regulatory requirements for environmental protection, very significant needs and opportunities for novel packaging concepts are emerging. Optimisation and improvement of conventional packaging is still important to reduce use of expensive products and minimise wastage of packaging and packaging materials. The development of recyclable or biodegradable packaging materials is also anticipated so as to offer new and environmental-friendly packaging solutions.

Simultaneously, new concepts such as active and intelligent (A&I) packaging will offer numerous innovative solutions for extending shelf life and maintaining, improving or monitoring food quality and safety. A&I packaging will be developed that incorporate active or intelligent components intended to release or to absorb substances into, onto or from the packaged food or the environment surrounding the food, or to provide the information on the product and/or the conditions for its use. Active packaging will be combined with new mild preservation methods to provide optimal pathways for quality enhancement and for in-package processing and in-home preparation of foods.

Process control

Robust and reliable quality sensing systems must be researched and developed over differing time scales so as to assess quality throughout the life history of a product. In-line, preferably non-destructive, and integrative quality sensors are a prerequisite for a modern process control. It will be essential to adapt read-outs of such quality-sensing systems to generate useful parameters for the design of new processes and for the creation of new food systems. An important new area will be the development of quality sensors to be used by consumers; one route will be through integrated sensing systems container within the packaging.

Deliverables

- Mild preservation technologies to deliver products with long shelf life and a fresh appearance; direct freshness indicators on packaging (**2010**),
- New ingredients from biotechnology, and plant and animal extracts (**2010**),

- New packaging materials with optimised functionality and controlled biodegradability; optimised ways to combine active packaging with others preservation technologies; improvement of properties, potentialities and usage of currently existing A&I packaging concepts (**2010**),
- New processing routes based on output demands, with minimal impact on environment; decoupling of processing steps (distributed processing); introduction and promotion of lean manufacturing/agile manufacturing concepts within food production (**2015**),
- Nanotechnological sensor systems compatible with food systems allowing the direct and *in situ* assessments of quality within products (**2015**),
- Production, use and disposal of eco-friendly packaging (**2015**),
- Identification of prioritised A&I packaging concepts to meet needs and trends in foods preservation, processing, retailing and domestic use (**2015**),
- Bio-processes to optimise viability, activity, and functionality of bioactive compounds in finished foods (**2020**),
- New in-line non-destructive control systems to assess the quality and safety of food through processes (**2020**),
- Integrated and pervasive sensor networks throughout factories recording fluctuations of quality and safety during processing (**2020**),
- Machine-readable tracing and quality tags on raw materials and ingredients for rejection or acceptance of material in process; robust sensor systems for farmers and ingredient producers to control quality at the source (**2020**),
- New active packaging concepts acting on different reactions of degradation or as vector of compounds of interest and integrated on the whole food technology itineraries (synergistic hurdles technologies) for maintaining or improving qualities of food products (**2020**),
- Intelligent packaging using tags as miniaturised analytical tools with wireless communication for monitoring food quality during transport, storage and processing, from producer to consumer (**2020**),
- Tailor-made packaging for perishable, diverse and complex foods such as fresh, living, composite or traditional foods (**2020**).

Goal 3. Improving understanding of process-structure-property relationships

Food microstructure can be identified as a 'generic aspect' with a close functional relationship to food quality (including sensory/taste, nutritional and health-related functions), convenience and safety characteristics relevant for the consumer. Knowledge on *process-structure-property relationships* will allow creation of the desired tailor-made food products by new processing technologies. During the past decade food and other biomaterial microstructures have been produced at the molecular level, through the exploitation of, amongst others, genomics, proteomics and high-resolution spectroscopic- and microscopic techniques. As a result it is now possible to understand and assess the impact of formulation-based (specific molecule addition-based) conventional food technologies on resulting food quality and safety. This enhanced knowledge triggers the development of new processes and processing tools for the manufacture of food with properties based on tailored microstructure from the molecular to the macroscopic level.

By 2020 available knowledge on phenomena, mechanisms, driving forces and kinetics responsible for changes of physical, chemical and biological and structural properties will allow food to be produced through processes that are flexible and easily adaptable to PAN patterns. Rules for structure/formulation-property functions and structure-processing functions, and tools for translational and precise process design and processing in order to adjust PAN profiles within processed food systems will then be available. Mathematical

models will be available to calculate how the structure–function relations at different levels of scale will evolve during processing in order to deliver the desired end characteristics. Improved understanding of process-structure-property relationships will be the basis for all food quality characteristics and the respective application to Translational Process Design.

Improved understanding of process-structure-property relationships as the basis for all food quality characteristics and the respective application to Translational Process Design will build a broad platform for innovative research.

Major research challenges

- Understanding relationships of molecular to macro food structures on food product properties under (quasi-)static (e.g. storage) and dynamic (processing, preparation, perception) conditions,
- Advanced property/function-selective separation processing to obtain ingredients or compounds with narrowly-distributed property distributions; investigation of 'mixing rules' for such systems with respect to property tailoring,
- Development of new processing techniques for improved micro-homogeneous (HTC) functional structure formation and investigations of process-induced micro-structuring mechanisms from molecular to macro structure level,
- Investigations on new/new combinations of processing principles (magnetic, electro magnetic, electric, mechanical (pressure/shear/ elongation) force-/stress fields, resulting structure formation mechanisms/-kinetics and received structure-quality characteristics,
- Investigations of optimised scaling laws for micro-structuring processes from the lab to the industrial scale with focus on micro-devices.

Deliverables

- Laboratory and process analytics developed to quantitatively prove process-structure-property relationships (**2010**),
- Highly integrated and robust sensors developed around microfluidics and force microscopy (**2010**),
- Structure/formulation-property functions and structure-process function for selected PAN quality criteria (**2010-2015**),
- Structure/formulation-property functions (SFP) and Structure-ProCess functions (SPC) available and coupled with the major PAN quality criteria (**2015**),
- Rules for structure/formulation-property functions and structure-processing functions, and tools for translational and precise process design and processing in order to adjust PAN consumer profiles within processed food systems (**2020**),
- User-friendly and embedded quality sensors for consumers to assess in shop and domestic quality (**2020**),
- Original trans-disciplinary and global approaches for designing breakthrough innovative A&I packaging concepts (**2020**),
- Original trans-disciplinary and global approaches for designing breakthrough innovative A&I packaging concepts (**2020**).

Goal 4. Understanding consumer behaviour in relation to food quality and manufacturing

Ultimately, the quality of food is in the eye of the beholder. Consumer understanding can serve to both inform new developments in food quality and manufacturing as well as help to guide further optimisation of new technological opportunities. Consumers in contemporary society become further separated from the food production system which requires more

formalised approaches to make the voice of the consumer heard in the product, process and packaging design. A better understanding of how consumers react not only to different product qualities, but also to different production technologies, will enable the food industry to align both food quality and food manufacturing processes to consumer wishes and demands.

Major research challenges

- Understanding the consumer response to new product, process and packaging technology, particularly in terms of cost/benefit considerations, perceived risk and perceptions of uncertainty,
- Development of a consumer research methodology for validating the effect of new ingredients, such as those that enhance consumer preference, stimulate satiety, enhance brain functions or, affect mood in real life situations,
- Development of improved consumer research methodology to steer consumer/customer-orientation in new product development practice and the establishment of management systems to ensure that consumer needs and insights are incorporated within new product development,
- Understanding and addressing gaps in consumer knowledge on how food is produced, related to trust in 'modern' food industry,
- Understanding the role of food and sensory expectations across different cultures and ages,
- Development of new formats and designs to communicate and enhance attractiveness of healthy foods,
- Understanding consumer response to industry efforts to reduce 'undesirable' ingredients in food.

Deliverables

- A model for consumer knowledge and appreciation of how food is produced (**2010**),
- A quantified model for the role of food and sensory expectations in different cultures and age groups (**2015**),
- A validated model and actionable methodology for effective incorporation of consumer understanding into new product development (**2015**),
- A quantified model of how product, process and packaging features affect the complex consumer response (appreciation, cost/benefit, perceived risk and uncertainty) (**2020**),
- A validated methodology to qualify and quantify the consumer-relevant (i.e. beyond experimentally controlled situations) effects of new ingredients and their manifestation in real life consumer situations (e.g., affective and neuro-scientific effects) (**2020**).

Challenge 4.
Assuring safe foods that consumers can trust

Europe has an absolute necessity for a safe food supply; it is a social and economic imperative. That the food produced and consumed in Europe is now safer than ever is a dry fact rather than a properly useful statement. The industry and the responsible official institutions have failed to gain and retain the confidence of the EC consumer. Consumer perception has evolved to a high level of awareness and a much-reduced certainty, a combination which has led to a generalised lack of confidence.

That food safety concerns are more and more centred on the consumer and his or her perception of how safe the food supply is a healthy state of affairs. The constant need to inform, hear, protect and defend the consumer is a duty which underpins all of society's activities in this area. The food sector has a very clear interest in facing the challenges it represents head on. Properly identified, co-ordinated and executed research programmes will, when successfully communicated, form the basis of this response. There are no areas relevant to food safety which could not be better dealt with if more relevant knowledge were available; the key is to decide what will be most relevant in the coming years and prepare ourselves accordingly.

Key forces in food safety

The underlying drivers which will shape the way for the European food sector to approach food safety in the coming years are listed below. The European research effort should be directed at supporting the sector's response.

Lifestyles

The modern consumer demands natural, fresh, functional and nutritious foods, all with the added convenience that is a necessary part of today's lifestyle.

Globalisation

The production of foods has become the result of an interactive process of worldwide dimensions with actors from all continents interacting in all stages of the food production chain.

Competitiveness

Food safety is an essential element of a competitive strategy for the European industry. The capacity of member states to contribute to the maintenance of a safe food supply in an increasingly science and technology driven society, is intrinsically linked to its scientific resources in areas relevant to food safety. The desired model of a united but diverse continent, requires that food traditions be both preserved and modernised.

A key aim of this ETP is to maintain and build on the competitiveness of the European food industry as a whole in the global market, thus the challenges presented here, identified as Europe-wide, should most properly be met with a genuinely co-ordinated research effort. The very significant advances occurring in science and technology (e.g., biology and molecular biology, especially 'omics' technologies, measurement science, etc.) provide us with the cutting-edge tools necessary to face these challenges. This ETP, therefore, fully supports the exploitation and creation of new scientific breakthroughs for the benefit of European industry and consumers. The approach defined here will put Europe in the forefront of science and technology development related to food safety.

It is realised that research on several aspects in the ETP has been supported by the EC or member-states, but that the outcomes of this research are generally fragmented. It is not proposed to duplicate existing research outcomes but to, as part of the activities covered in the ETP, combine existing knowledge, close key knowledge gaps and transfer the knowledge into a form that it can be used in practice by industries of all sizes (e.g. managed within their HACCP systems) and in an integrated fashion across a food chain.

Trust
All this is built on a platform of trust which determines how and whether the consumer will buy processed food products and also be receptive to newer technologies to make them safe.

The European industry's response: an integrated approach to food safety. Safety is not guaranteed only by 'safe' product manufacture; the total chain has to be taken into account. Designing safety into foods requires an integration of knowledge and interventions along the 'research to market' continuum.

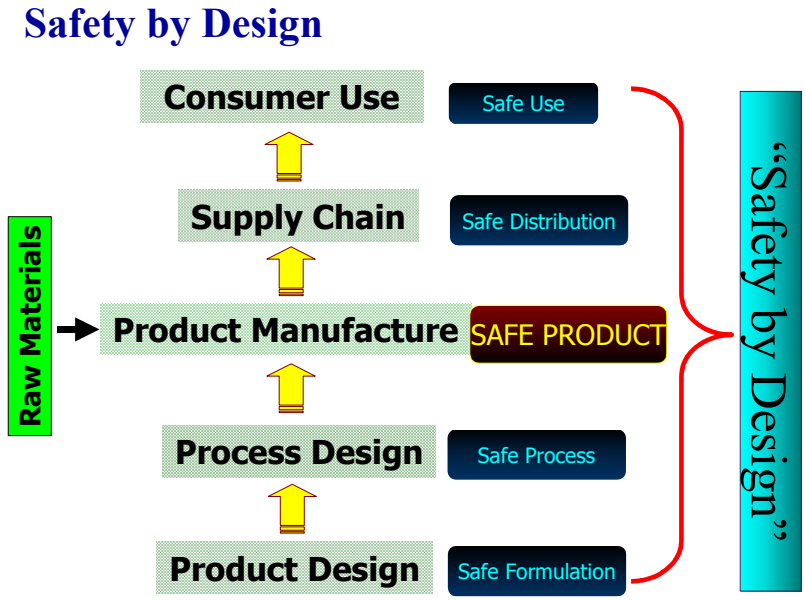

Figure 10. Safety by design

Research which addresses the European food industry's needs over the coming years in relation to food safety will be applied through this integrated approach. Hence well-focussed research will have a framework for rapid incorporation into practice in a manner, which will bring maximum impact.

The research broadly follows two lines:

- Improved understanding of hazards in the food chain, e.g. the knowledge base needed to support the rational application of control measures and the development of new methods and systems,
- Tools to further secure the food chain, e.g. the development of methods and systems for continuously improving the safe production and supply of foods.

Two separate problems face the food industry in ensuring food products are safe - *contamination by biological agents and chemical risks arising from contamination or natural toxins present in food. Both affect all stages of the food production chain.*

There is a major challenge to understand hazards individually, in combination, and in the context of their multiple environments throughout the food chain. This includes their behaviour in complex ecosystems and (in the case of pathogenic microorganisms) their interaction with host, both animals and humans.

Understanding the hazards includes a full evaluation of the risks associated with exposure of the consumer to these hazards (risk assessment). Complementary to this is the evaluation of risks versus benefits of food products, and food consumption patterns.

Goal 1. Predicting and monitoring the behaviour and fate of relevant known and emerging biological hazards

Behaviour of microorganisms in the food chain
Knowledge is required about the nature and behaviour of food-borne pathogens and other undesired microorganisms, both to enable specific control measures and to support risk assessment.

Major research challenges
- Improved understanding of ecological behaviour (growth, survival, inactivation and contamination, matrix effects, matrix and processing effects, adherence and biofilm formation) and predictive modelling of behaviour in food systems,
- Interactions between communities of microorganisms including the potential role of non-pathogenic food organisms to modulate the risk of colonisation by pathogenic microorganisms (this includes links to the genomic analysis of human intestinal microbial communities – intestinal microbiome),
- Molecular biology of pathogens to understand their behaviour in the food chain,
- Understanding and predicting the risks of resistance development.

Virulence and risks of microorganisms in the food chain
Improved understanding of behaviour and virulence traits of food borne pathogens is essential to determine requirements for providing safety without unnecessarily affecting desired characteristics (flavour, etc.). This will require research into host-microbe interactions.

Major research challenges
- Gathering and analysing epidemiological data combined with typing and characterisation methodology - special care will be taken to gather and analyse these data in a population-disaggregated manner including gender,
- Monitoring virulence traits and understand virulence mechanisms,
- Understanding mechanisms of emergence.

Deliverables
- Models developed by mining of existing data (**2010**),
- Design and monitoring of microbial communities in food to control pathogens (**2015**),
- Validated models predicting resistance developments to heat, high hydrostatic pressure and one other emerging preservation technique (**2015**),
- Functional mammalian cell culture systems for determination of virulence (**2015**),

- Validated protocols to study microbial behaviour in such infection models (**2015**),
- Rules/models to minimise risks from biological hazards based on predicting interactions between foods, the ecosystem and microorganisms (**2020**),
- Artificial organs, both cell culture based and mechanical (computer aided) to limit and, if possible, replace animal testing (**2020**).

Goal 2. Predicting and monitoring the behaviour and fate of relevant known and emerging chemical hazards including toxins of biological origin

Fate and occurrence of chemical contaminants in the food chain
Chemical contaminants, as a general category should include crop protection agents, veterinary pharmaceuticals, persistent organic pollutants (POPs), heavy metals, and biological toxins, represent known and potential health hazards to humans, most commonly by long-term exposure, through the consumption of contaminated foods.

The manner in which these hazards are currently controlled is not optimal for two main reasons: firstly, large knowledge gaps exist as to the importance of specific hazards at the quantities at which they appear in foods, and secondly, detection and monitoring are often so complex and expensive and control measures required so early in the food chain, that they cannot readily be incorporated into current food safety assurance schemes.

Efficient control of chemical hazards within food safety assurance schemes requires new knowledge about the risks they represent and new tools for their management.

Major research challenges
- Improved toxicological exposure assessments for key potential hazards, including the migration of chemicals from packaging materials into food,
- Studying the effects of conditions of primary production on incorporation of chemical contaminants into the food chain,
- Understanding the fate of chemical hazards (production, persistence, destruction, (re)contamination) and predictive modelling,
- Finding novel biomarkers of exposure to key contaminants.

Toxicology and risks of chemical hazards in the food chain
Knowledge is required on the effects of chemical hazards on those who consume them.

Major research challenges
- Determining what concentrations of potentially hazardous chemicals do have an adverse physiological effect because the body's detoxifying mechanisms are not able to cope with the quantity entering the body,
- New approaches to hazard assessment in the determination of chemical risks, including the need to improve the prediction of the risks at very low levels of exposure,
- Gathering and analysing epidemiological data - special care will be taken to gather and analyse in a population-disaggregated manner including gender,
- Artificial organs and cell culture based experiments to determine toxicological effects in order to limit and if possible replace animal experiments.

Deliverables
- Well-validated predictive models for the behaviour of relevant hazards in foods (**2015**),

- Robust and reliable alternatives to animal testing for key toxicological endpoints, based on artificial organs and cell culture to determine toxicological effects in order to limit and possibly replace animal experiments (**2020**).

Goal 3. Improving risk assessment and risk-benefit evaluation

Quantitative risk assessment is the knowledge base on which society builds its food safety strategy. The tools being developed within this area (including predictive modelling) will continue to be important competitive instruments that underpin innovation in the development of novel products. Research in this area will be important both to develop the science further and to make these tools more widely available within the food industry. The approach will need to adapt to the complexity with which foods are currently being viewed and it is certain that the trend will be towards risk/benefit assessment.

The European Union already possesses, at national and regional level, highly credible public organisations with responsibility for food safety and which are capable of identifying their own R&D needs to support their legislative and control functions. The food industry cluster has a history of healthy 'antagonism' with the official 'food control' cluster and the rationality in the current legal and control environment has been greatly moulded by this. It is therefore important that the food industry continue to identify and promote its own research into aspects of food safety, which might influence the development, and application of control measures.

The challenges here deal with *Risk* (pertaining to negative effects), *Benefit* (pertaining to positive effects) and *Communication*. European society will need to approach these research challenges in a fully integrated manner. Elements of this overall task are dealt with in other key challenges of this ETP.

The food sector needs to be able to:

- evaluate the risks and benefits associated with the consumption of specific foods, food categories including traditional foods, and based on consumption patterns (knowledge), and
- communicate this information in an appropriate form to the various stakeholders of the food chain (knowledge and skills).

The overall objective is to build a science and skills base that successfully supports the development and communication of risk-benefit analyses on specific raw materials, food products, product categories and to develop further knowledge on consumption patterns.

<u>Major research challenges</u>
- The gathering and generation of epidemiological and analytical data to support and model scenario studies on trace contamination of current and unidentified hazards associated with specific food consumption,
- Studying the fate of chemicals in the human body as a function of quantity,
- The development and validation of science based models (*in vitro, in vivo, in silico*) which describe the risks and benefits associated with exposure to biological and chemical components in the consumption of specific foods and the diet as a whole.

Deliverables
- Improved analytical methods for the detection and monitoring of food safety hazards that can be integrated into quantitative risk assessment routines (**2010**),

- Developed protocols for the integration of food quality and safety systems biology data into microbiological risk assessment (**2012**),
- Knowledge on risks and benefits associated with the consumption of specific foods, food categories including traditional foods, and based on consumption patterns (**2015**),
- Communication of this information in an appropriate form to the various stakeholders of the food chain (knowledge and skills) (**2020**).

Goal 4. Developing tools to ensure security of the food chain

The aim is to further improve the safety of competitive foods on the market by developing and making available tools for prevention, control, traceability, authenticity and food defence (adulteration and bioterrorism) at appropriate points in operational food chains. This will provide the technologies on which harmonised, focused and cost efficient management activities and safety policies can be implemented. The understanding and knowledge generated from the research needs identified in Goal 1, above, will be employed in the development of technologies presented here.

Detection and prediction of hazards in foods have also advanced considerably in recent years. This has permitted a more precise evaluation and validation of existing and novel technologies, speeding up both their development and 'time-to-market'. The success of the modelling approach to hazard behaviour demonstrates the wisdom of investing in tools which can take on the complexity of such questions.

New techniques for the detection of hazards or their controlling parameters are constantly being sought, an obvious and immediate reason being to improve food safety assurance. However successful new approaches frequently represent new opportunities for surveillance, tracing of sources of hazards and many other areas of research which have a direct impact on food safety at a societal level. Research on new or improved measurement of hazards will have a multiplier effect and these lines of study should always be advanced wherever they show genuine promise. Advanced technologies for safety interventions throughout the food chain will provide new options for control over the safety of raw materials, processes and finished products. Their development, validation and implementation must cover all aspects of food production.

Development and agreement on validation concepts and models is a crucial pre-requisite to successful acceptance of the outputs of this type of research and must be addressed in the drawing up of EU-wide initiatives. 'Validation' must not only include technical performance but also consider aspects of regulatory- and consumer acceptance.

<u>Major research challenges</u>

Monitoring and control

- Development of effective methodologies for culturing, tracking and tracing of microbes, natural toxins, toxic, carcinogenic and/or genotoxic contaminants and potential allergens along the food chain. This should include new plant varieties and novel foods; biosensors are expected to play a major role as are RFID and TTIs,
- Development of design tools based on models (see above), for the evaluation of the individual and combined effects at every stage of the integrated food chain. e.g. environmental and food matrix effects on the fate of microbial and chemical hazards.

Technologies - Sourcing and raw material
- Development of technologies for the reduction or the elimination of hazards at the level of primary production (bio-derived and bioengineered chemicals with enhanced spectrum of action and/or time limited life cycle; plants and animals with traits which contribute to the reduction of chemical and biological hazards; and strategies to prevent colonisation of farmed animals by food-borne pathogens (e.g. competitive exclusion, immunisation),
- Development of technologies for the screening, sorting, and developing safe raw materials, including the decontamination of 'contaminated' raw materials.

Technologies - Processing
- Development of novel technologies supporting flexible and safe manufacturing of foods incorporating for e.g. hygienic design and new contact materials,
- Advanced multi-hurdle concepts, combining different types of hurdles (e.g. preservatives, advanced preservation techniques, active packaging, etc.). This would include combination of hurdles (recipe and technology), development of new hurdles and modelling,
- Development and optimisation of alternative technologies to classical heat treatments: irradiation, ultra-high pressure, pulsed electric field, ohmic heating and sterilisation, nano-thermosonication, etc. Research needs include developing novel technologies and assessing the implementation of relevant existing ones.

Distribution and consumption
- Development of new logistic approaches for strengthening safe distribution of foods, including abuse detection,
- Development of effective approaches for the prevention of food adulteration and bioterrorism,
- Create novel solutions for the maintenance of low temperatures in the supply chain,
- Active and 'intelligent' packaging technologies, with safety enhancing properties; including monitoring and contamination reduction aspects,
- Development of 'intelligent' systems for optimal food preparation, guaranteeing microbiological safety and preventing formation of heat-induced contaminants, whilst maintaining key sensory and nutritional properties (part of development of alternative technologies above).

Regulations
Because of global sourcing of raw materials and ingredients, export of food products from Europe to all other continents, regulatory acceptance of novel processing technologies and analyses to provide evidence of food safety, it is imperative that food safety regulations should be harmonized between Europe and the rest of the world and be based on sound science. Proving safety of ingredients and novel processes is time-consuming and costly. It should therefore be needed once only and hence be done following internationally recognised and globally accepted protocols.

Deliverables
- Validated technologies for the optimal processing, distribution and use of foods with safety assured (from **2010**),
- Intelligent food contact surfaces to prevent microbial adhesion will be available (**2010**),
- Technologies for sourcing of intrinsically safe plants and animals for foods (from **2015**),
- Robust and flexible processing technologies that assure food safety (**2015**),
- Food safety indicators integrated within the entire food chain (**2015**),
- Food contact surfaces able to signal the presence of residues and microorganisms after cleaning (**2015**),

- Novel software and hardware for use in the supply chain to ensure the safe and efficient distribution and storage of foods (**2015**),
- Internationally accepted and recognised protocols to demonstrate the safety of food with new ingredients and/or processed with novel technologies (**2020**).

Goal 5. Understanding and addressing consumer concerns with food safety issues

Despite the fact that, in objective terms, food has probably never been safer before, consumers continue to express concerns with the safety of their food. This has at least partly to do with the fact that consumers do not have direct first-hand insight in the (un-)safety of food products and food production systems. For such assessment they have to rely on information provided by others and the trust / confidence that consumers have in actors and institutions is an important factor in their perceived confidence in the food provision system. Zero risk is an illusion and increasingly the focus shifts towards risk-benefit approaches, which in turn brings new challenges for risk communication practices. An understanding of the way in which consumers perceive risks, and also of the role of various stakeholders and the media in this context, is a prerequisite for successful risk communication.

Major research challenges

- Identifying and quantifying determinants of consumer trust and confidence in the food provision system (including trust in actors and institutions) for an understanding of consumer confidence and how it changes over time (monitoring),
- Understanding consumers' risk perception of products and lifestyles, particularly in the context of risk-benefit trade-offs and in the amplification of risk perceptions beyond the available scientific evidence,
- Understanding the role of public opinion formation for consumer risk perception,
- Development of effective consumer communication strategies and messages (e.g. use of layman's language) on risk related issues (including communication of risk-benefit and cost/benefit analysis and of uncertainties).

Deliverables

- Quantification of the determinants of consumer confidence in food provision systems and similarities and differences across Europe (**2010**),
- A better way of understanding how public perception of risk develops in interaction between consumers, media and stakeholders (**2010**),
- A tool to quantify consumer risk perception of products and lifestyle from a cost-benefit perspective (**2015**),
- A set of effective risk communication strategies to the public (**2020**).

Challenge 5.
Achieving sustainable food production

Consumers are increasingly motivated to purchase foods that conform to production criteria that are generally environmentally-friendly and conform to their ethical principles. In addition there are overall societal pressures for food production and supply to be more sustainable. To achieve these, synergies must be created between economic growth, environmental protection and fair social conditions. Three main factors contribute to the unsustainability of existing food production; these are:

- agricultural subsidies and trade barriers,
- the contribution of food production to environmental problems, and
- unfair distribution of revenues to the different actors in the food production system.

Over the past three generations, food production systems in Europe have developed with a focus on security of supply with low prices to the consumer, whilst at the same time seeking to reduce environmental impact and maintaining economic returns to rural communities. The recent expansion of the EU brings about an increasing diversity of food production systems, affording the opportunity to utilise this diversity for creating and supporting more sustainable food production systems.

Considerations of sustainability will guide future developments in European food production and must be an integral part of all developments - being considered as automatically as food safety and economic viability. Given the highly interlinked nature of food production and the many aspects of 'sustainability'[1] that need to be addressed, it is important to embrace a holistic view of European food production and supply systems. The transition towards more sustainable systems must go hand-in-hand with strengthening the competitiveness of the stakeholders in the European food system.

In developing the responses described below, close contacts will be developed with *ETP Plants for the Future*, which addresses sustainability issues throughout its SRA.

Goal 1. Understanding the sustainability of food production and supply in Europe

A system analysis perspective is essential in assessing the sustainability of food chains since their environmental impacts can occur in different places and different times. Several approaches are available. Life Cycle Assessment (LCA) has been developed to identify and quantify the environmental impacts of individual products and services. However, food production is a complex inter-linked system, so that the LCA approach must be extended into a more complete and realistic form of system analysis; it should not focus on single supply chains or products but should enable products to be examined in the context of the background system in which they are embedded. *Input/output analysis* is likely to be another useful approach and will need to show both the social- and environmental consequences of alternative food supply systems, and must also address fair working conditions, rural development and gender equality.

[1] Sustainability development as used within this ETP is defined as: "an environmentally sound, economically viable and socially acceptable development".

The system approach must be developed to show clear comparisons between different scenarios, including imports of foods into Europe, so as to reveal the consequences of different supply and consumption patterns. Models must be constructed to identify sustainability indicators, which can then be validated and used for comparing scenarios. A systematic programme is needed to measure these indicators so as to monitor progress towards sustainability. To support multi-criteria decision processes, models should be developed that can be optimised to show the effect that positive changes in one indicator might have on another.

Major research challenges

- Develop a methodology for describing the essential parameters of sustainability of the food supply system using sustainability- or extended LCA indicators,
- Develop dynamic modelling tools to determine and demonstrate the sustainability frontiers of different food production systems,
- Formulate models to describe food supply in Europe which can be disaggregated to 1) show the sustainability of regions and supply chains in the context of the whole European system, and 2) provide data for inclusion in public databases.

Deliverables

- LCAs performed for a range of regional and commodity food chains; appropriate sustainability indicators developed (**2010**),
- Sustainability indicators quantified for many food chains and applied to show the scope for improvement; (this information will have been used to guide development in the other goals of this theme) (**2015**),
- Dynamic modelling tools developed and used for rapid identification of more sustainable production and processing systems for a range of food products at different geographical levels in Europe (**2020**).

Goal 2. Developing scenarios of future European food production and supply

Scenarios are ‘possible futures’, intended to provide insight into the consequences of multi-factorial change, e.g. demographics, environment and world trade. Scenarios are a well-established way to structure “What if?” questions. While scenarios are widely used, there have been few applications to the European food production system. The need for such scenarios is become more evident as future changes in the European food consumption are expected to be more dynamic than previously. The following examples highlight how scenarios can elucidate ‘possible futures’:

Global climate change is projected to have multiple impacts on primary food production, populations and markets, including changes in the suitability of certain areas for particular crops. A comprehensive picture of the effects of climate change on the sustainability of the food production system is still elusive.

Dependency on fossil fuels. The European food production system depends heavily on fossil fuels, with both production and distribution sensitive to fuel prices. The effect of energy prices and fuel availability on the sustainability of the European food supply system needs to be explored.

Political boundary conditions such as the economic compensation to farmers through the European CAP (and similarly through the CFP) and global trade agreements also influence

the sustainability of the European food supply system. The consequences of alternative policies should be studied using scenario techniques.

Scenario studies will be carried out in close cooperation with those described under Challenge 6 (Managing the food chain).

Major research challenges

- Identify relevant factors for the sustainability of European food production systems, their projections into the future and use them to build scenarios, integrating demographics, economy, policy and trade, and environmental change,
- Build scenarios of global and 'top down' character where expert assessments are made based on existing knowledge and methods for analysis and prediction. Compare them with 'bottom up' scenarios based on participation and interviews with stakeholders,
- Use scenarios to study "What if?" alternatives, for a number of food production systems and policy options, using a 15 to 100 year perspective.

Deliverables

- Presentation of a number of scenarios illustrating the consequences of different futures, developed out of the present food production system (**2010**),
- Selection of relevant general scenarios to be used as a basis for future food production scenarios (**2010**),
- Presentation of a number of scenarios illustrating new and alternative highly sustainable food production systems (**2015**),
- Scenarios of radically novel food production systems, e.g. based on tissue culture (**2020**).

Goal 3. Developing sustainable processing, packaging and distribution

Industrial food production focuses on economic efficiency, reliability and consistency, and market demand. Current systems of manufacturing, preservation, storage, processing, packaging, transportation and distribution, and retail are not necessarily sustainable. The wasteful use of natural resources and food raw materials are wasted, policy or markets may favour unsustainable patterns of production and there is an inequitable remuneration of actors in the system.

Reduction in uses of energy, water and materials will require close links between raw material production, primary and secondary processing, packaging, waste management and reprocessing. Identification of improvement potentials from sustainability analysis will be an important driver for innovations that are directed towards new and novel technological solutions for food processing, packaging and transportation.

As food industries are highly complex and spatially-distributed, research into more sustainable food production systems must explicitly account for this complexity, as does, for example, the *'Industrial Ecology'* (IE) approach. This aims to restructure production systems into clusters of industrial firms with output-input connections as stocks and flow of materials, energy and information according to the principles of ecosystems. Such an approach will include analysis of complex and interlinked networks of primary food production, food processing, distribution and packaging. The necessary resources and services are provided by the 'natural' environment so that industrial and natural systems are linked.

Major research challenges

- Develop methods for value chain analysis explicitly incorporating assessment of environmental and social assets and factors,
- Viable approaches for innovation to reduce energy, water and matter use in food processing,
- Improve utilisation of food raw materials and reduce waste throughout the production chain. Reprocessing of valuable food waste to food or feed,
- Integrating different industrial systems, including food primary production and food industries in 'industrial ecology' relationships, exchanging matter, water and energy and economic value in inter-industrial networks.

Deliverables

- Methodologies for value chain analysis (**2010**),
- Identification of wasteful food processing, packaging and transportation operations with potential for substantial improvement (**2010**),
- Methodology for integrated assessment of sustainability of food production systems developed (**2010**),
- Scientific approaches underpinning sustainable management of food production systems and clearly-established sustainability measures (**2015**),
- Development and implementation of novel processing, manufacturing, packaging and distribution methods based on research on sustainable food production (**2020**),
- Development and implementation of highly integrated sustainable village systems, including food production (**2020**).

Goal 4. Developing and implementing sustainable primary food production

Within the next few decades, food production in Europe will experience major environmental, social and economic changes. These include climate change, changing international trade relations and regulations, large-scale shifts in global food production and demand, and stronger demands from society to reduce the environmental impact of food production. Primary food production must adapt to these changes to be sustainable. While additional research needs to expand further knowledge on the interactions of biological cycles to enhance traditional food production, radically different primary food production systems may provide additional sources of food to traditional food production. These should be analysed in terms of their sustainability in order to target effectively further research into the most promising approaches.

Biotechnology may, beyond its present role, be used to produce desired crop biomass in a targeted way, and to provide plants with better taste and nutrition besides intrinsically better production properties. Further *fine-tuning of production systems* through precision farming and other high-tech solutions could increase the efficiency of primary food production. Alternative systems for *animal husbandry* should be evaluated, including the dimension of animal welfare.

Fishery systems in Europe must be assessed for their sustainability and alternatives to traditional fishing must be explored. *Aquaculture* could not only encompass fish and marine animals, but also plants such as seaweeds and algae. This would diminish the use of fresh water for crop production and reduce pressure on land resources, while producing food of high dietary value.

Major research challenges
- Identify and analyse the major environmental, social and economic pressures that constrain the sustainability of primary food production (crop, livestock and fish),
- Investigate options for adapting to these pressures and analyse their implications for sustainability,
- Identify novel food production systems and evaluation of their sustainability.

Deliverables
- Establishment of the knowledge base required to optimise existing primary food production systems, further development of novel systems and assessment of their sustainability (**2010**),
- Scientific data underpinning the fully integrated management and assessment of sustainable primary food production systems (both established and novel) (**2015**),
- Scientific data on adaptive sustainable management of man-nature systems, including primary food production systems (**2020**).

Goal 5. Understanding consumers and their behaviour regarding sustainable food production

To succeed in the market, sustainable food production has to meet consumer expectations and preferences. Food supply systems have become global and agricultural production is increasingly striving for economic efficiency and reduction of pressure on resources such as biodiversity, land and water. European consumer behaviour and lifestyles show a growing demand for products delivering greater convenience.

Consumers appreciate products sourced from all over the world all year round. A diet with more meat exerts considerable pressure on resources, for animal husbandry uses disproportionate quantities of water, while almost half the world's grain harvest is presently fed to animals. *Consumer are concerned by how far their food is transported and under what conditions animals are kept or plants are cultivated*. There is also increasing consumer awareness about the ethical dimensions of food production and this is influencing purchase decisions amongst the more affluent sectors of society.

At the present time consumers probably regard health aspects as more important than environmental considerations in selecting purchases. However, all these issues interact in influencing purchasing decisions. In view of the increasing complexities of food choices, research is needed into value-related purchasing motives and into how sustainability can become a central part of consumer preferences; this will require qualitative social research inputs to better understand how preferences are formed and how they can be influenced

Therefore, multidisciplinary research into sustainable diets, in general, and animal and plant protein products, in particular, is a necessity, involving food technology, economic, environmental and socio-cultural research. Effectively harnessing such diverse expertise will in itself be innovative and will also provide a model for other areas of activity.

Major research challenges
- Analysis and monitoring of the sustainability of emerging lifestyles trends (including food waste generation, energy and water use) and food consumption patterns,
- Understanding how consumers are prepared to pay for, or deny themselves (e.g. in terms of convenience and taste), food products produced in a sustainable manner, and how responses differ between different consumer groups (according to gender, age, region,

socio-economic grouping),
- Analysis of purchasing motives related to ethical convictions of different consumer groups in different European regions,
- Analysis of dietary sustainability and development of multidisciplinary strategies, including studies of acceptability of sustainable diets by different consumer groups. Developing and validating measures for quantifying the level of sustainability of shopping baskets/food consumption patterns,
- Understanding consumer expectations, attitudes and responsiveness to sustainable products, production systems and corporate social responsibility,
- Developing appropriate materials for educating and informing stakeholders about sustainable food production (to maximise consumer preference for products derived from sustainable food production systems).

Deliverables
- Analysis of influence of lifestyle trends on sustainability of the food production system (**2010**),
- Analysis of future socio-economical policy options of sustainable food production (**2010**),
- A quantified model of how (groups of) consumers understand, value and behave in response to more sustainable food products and production systems (**2010**),
- Strategy to enhance consumer responsiveness to sustainability in food products and food production systems (**2015**),
- Analysis and recommendations of future sustainable protein supply systems in the European food production systems (**2015**),
- General public acceptance and preference for food from sustainable food production systems (**2020**).

Challenge 6.
Managing the food chain

The food sector builds on a complex infrastructure of food chains and networks involving suppliers, primary producers, processors and manufactures, and retailers, which have consumers as the final customers. The performance of this chain depends on the performance of individual enterprises, the quality and efficiency of interactions between the stakeholders in the chains and networks, the influence of natural, economic, competitive, legal, cultural, social, scientific, and technological environments, and the behaviour and expectations of consumers.

Food chain management deals with the organisation, management and coordination of the complex processes and interactions in production, trade, and logistics within and between enterprises throughout the agricultural and food value chain. While the consumer, as the final customer, is the 'driving force' in the food-industry, food chain management constitutes the 'integrative base' which integrates requirements and knowledge from other areas of the ETP into the reality of food chain operations.

In the existing and emerging global and highly competitive food markets, successful and sustainable food chain operations include three major elements, as follows:

- to gain and maintain ***competitiveness*** in a dynamic and global sector with increasing demands of consumers and customers in the chain on the quantity, variety, safety and quality of food,
- to gain and sustain *long-term* ***sustainability*** in competitiveness, business relationships, market acceptance, availability of resources, and the interaction with the cultural, social, legal, political, and natural environment, and
- to establish and *preserve* ***fairness*** in business and consumer relationships.

In the past, the provision and security of cheap food was the most important priority for food companies. Nowadays these requirements are replaced by concerns about the need for sustainable production, attention to ethical working practices, fair trade and balancing of interests of different parties in the chain. Furthermore, retailers and consumers increasingly demand concise information about the origin of the products they buy and for information about specific characteristics (social, environmental, technological) of processes in food chains.

New production designs, new product categories, new production processes, new quality efforts, all require an appropriate organisational and managerial integration into food chains and the adaptation of organisations and food chain management activities in order to turn new developments into successful food chain innovations.

Food chain management aims to integrate and balance the interests of all stakeholders into a sustainable chain management system that fits 'best' the cluster of requirements, or, in other words, to find the optimal balance in the consideration of requirements on economic efficiency, environmental control, process organisation, food safety, marketing or transaction rules, etc. The understanding of 'optimality' may differ between chains, regions or environmental scenarios. It may also change over time depending on the problem pressures that may exist or develop. Present increases in the complexity of requirements and the complexity of chain environments (as associated with globalisation) increase the complexity of food chain management and the design of successful food chain management systems.

Results are especially relevant for SMEs that lack the expertise necessary for successful food chain management in the emerging global, highly competitive and dynamic food markets, and, as a consequence, for engaging in successful and long-term sustainable food chain operations.

Among the many factors that determine the success of food chain operations in meeting the challenges in sector performance, the following stand out as key success factors:

- *Risk control and trust* in business-to-business and business-to-consumers relationships to sustain *food market stability*,
- *Innovation* in production, organisation (internal processes, logistics, and marketing), and management including the *flexibility* and speed to adapt to changing conditions and situations,
- *Integration of stakeholders* into the complex managerial and organisational food chain developments including the participation of *consumers* and of *small producers* especially in development regions and developing countries,
- *Coordination of policies* and standards (including social issues and market strategies) including a sustainable consideration of ethics, fair trade and a sustainable balancing of stakeholder interests.

In these key success factors, food chain management can directly build on support from other principle themes of the ETP (Figure 11).

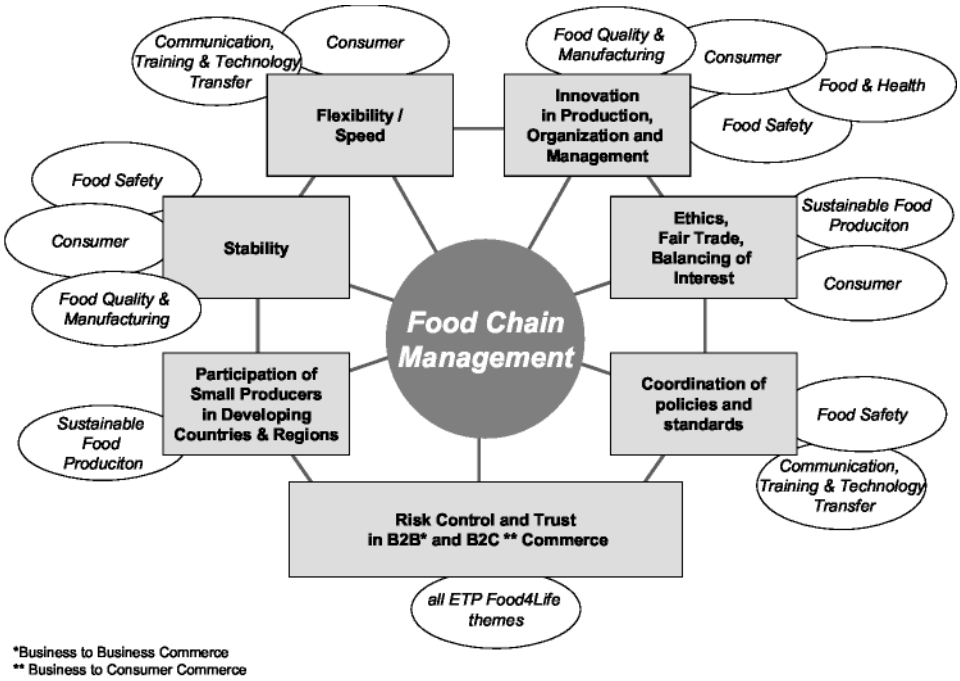

Figure 11. Key success factors in food markets and challenges for food chain management with main interfaces to other themes of the ETP Food for Life

The range of food chain management activities extends from value chains that concentrate on local and regional activities to chains that have global relevance. Furthermore, production and trade is rarely confined to well-structured chain organisations but is based on the activities of enterprises within a food (enterprise) network with dynamically-evolving

enterprise trade relationships that might, on different stages and at different times, involve individual enterprises, horizontal enterprise clusters, vertical contract relationships or any other cooperation construct. *The reduction of this complexity is one of food chain management's focus activities*.

For the successful strategic development of chains and the sector, one needs to know the future requirements, their relevance, the achievements in production technology, logistics or communication concepts and the opportunities of utilising knowledge from scientific research into the organisation and management of processes and chain activities. In this view, successful food chain management depends on research initiatives and results from other key inter-disciplinary challenges of this ETP and needs to complement them by research on the specification of economic and non-economic scenarios (*what to expect*), on the management of inter-organisational relationships, on 'best management practices' (*what do we know?*), and on food chain modelling for the identification of optimal chain management alternatives for newly evolving scenarios (*what could be done ?*).

In the complex food chains and food networks, research to cope with the challenges focuses primarily on the identification of 'best practices' through the analysis of past experiences as well as through modelling and simulation of food chain management strategies either for improvements of past experiences or for meeting the challenges of new scenario developments.

'Best practice' research is required for different levels of chain activities, e.g. for regional, national, European or international levels of activity. An analysis of 'best practice' experiences in different scenarios (e.g. different food policies in- and outside the EU, different climatic conditions) might allow to identify decisive variables for reaching best practice management results and, in turn, to determine best practice management opportunities for new scenarios.

Apart from the analysis of past experiences, research on management improvements and new management opportunities involves the following elements:

- Analysis of food management needs and limitations building on advanced analysis tools,
- Design and evaluation of management concepts through modelling approaches, especially simulation models,
- Design, development and evaluation of prototype management support tools and support systems including information and communication systems.

General deliverables are concepts, support tools and support systems. Examples of concepts of the past with major relevance include the concept of ECR (efficient consumer response), examples of support systems involve information systems for tracking, tracing and food quality control or communication systems for building consumer trust.

Goal 1. Identification of possible scenarios

Of major importance for all management activities is the anticipation of the *scenarios*, food chain management will have to deal with. They might be similar to today's, represent the results of ongoing developments or might be completely different from scenarios today's management is familiar with. This involves a *continuous never-ending need for research* that does not lead to concluding problem solving 'final results'. However, its continuous results constitute the basis on which all management activities do build. The research is especially needed for SMEs who are not in the position to do this analysis on their own and who

depend on recommendations and advise derived from external research and communicated by, amongst others, their representatives and associations.

Failures in the anticipation of scenarios make the difference between success and failures in food management and, in consequence, the success and competitiveness of the European food chains and networks. Examples of actual determinants for scenarios include climatic changes, competition between energy, food, and environmental protection in resource use, the use of novel foods, developments in food customs, developments in population growth and distribution in age, EU market liberalisation of agricultural products, food safety crisis, or the evolution of countervailing power due to firm concentration.

Major research challenge
In the dynamic and continuously changing food sector environment, it is of prime importance to have a *continuously* updated specification of possible scenarios assuming optimistic, pessimistic and most probable developments. To accomplish this it is recommended, to establish, at the European level, a scenario expert group involving all stakeholders in the value chain and experts from research that, together, provide assumptions on possible scenarios and specify preferences on sector developments.

Deliverable
- Assumptions on possible scenarios (**2010**) and on preferences for sector developments (**2010**) to support food chain management research in its task to identify management activities and organisational developments that would best *match identified scenarios* (reactive approach), and that would best support a sector's *developments towards preferred scenarios*, i.e., scenarios that had been given preferences by the group.

Goal 2. Stabilising markets and supporting food chain dynamics through the generation and preservation of trust

The generation and preservation of trust in business-to-business relationships as well as between food production and consumption is the key for market stabilisation and the creation of an innovative environment for dynamic chain and network developments. Trust between enterprises is the key for the acceptance of new technologies and organisational structures in trade, trust between enterprises and consumers is the key for market stability. It depends on appropriate managerial initiatives in risk control and communication.

Food industries face many *risks associated with uncertain outcomes of their activities*. They are related to *production* (product and process quality and safety, quantity, cost), *marketing* (prices, distributions channels), *financing* (interest rates, liquidity constraints, organisational structure), as well as to production or market *regulations* (legal uncertainties, time inconsistencies of policies). Consumers face risks of instable supplies, insufficient food safety, limited access to food for income and other reasons.

In *trading activities*, risk is closely associated with trust between trading partners or between enterprises and consumers as the last customers in the food chain. Success of food chains is highly dependent on *trust-generating inter-organisational arrangements*, such as contracts or relationships based on trading experience. Food chain stakeholders need to have a shared understanding of, and access to, the product-related information that they request. Systematic and trusted exchange of product, process and management data and trusted relationships assure customer trust in the quality and safety of food.

Major research challenges

- To analysis risks, their interdependencies and the identification of 'best' managerial initiatives in risk control and communication focused on production, financing and market activity,
- To design, develop and evaluate trust supporting 'inter-organisational arrangements' and 'information and communication infrastructures',
- Research on the design and organisation of a flexible *European communication infrastructure* that links enterprises with political infrastructure and consumer groups, supports the involvement of SMEs, provides an early warning system for new developments and innovations and assumes an educational role for different groups as, e.g., consumer groups. This structure should allow fast transmission of food sector issues between the various stakeholders in the food production, distribution and consumption network.

Deliverables

- Tested concepts for trust supporting inter-organisational arrangements (**2010**),
- Tested managerial concepts for specific risk control initiatives (weather risks, financial risks, etc.) (**2010**),
- Tested prototype solutions for information and communication infrastructures for different risk control and trust scenarios (e.g. food quality and safety, e-commerce, etc.) (**2015**),
- European communication infrastructure as described above (**2020**).

Goal 3. Improving the innovation potential of the food chain

A core strength of the European food system is its *diversity* and quality. The highly dynamic international food sector requires *system renewals* aiming at food chains and networks, covering inter-company quality systems and quality standards, risk management, inter-organisational information systems (such as those for chain management information and tracking and tracing), chain governance structures and regional and global logistics systems.

Changes in sourcing and marketing of food companies as a result of increased globalisation and shifts from bulk towards added value production as a response to increasing consumer demands, require new business-to-business relationships that must be highly responsive to dynamic consumer and market demands and at the same time be cost-effective. New types of efficient and responsive chain and distribution networks must emerge that can support these demands, taking into account varying quality parameters, organisational conditions and different requirements of market segments. Innovative consumer oriented food chain solutions, such as direct retailing, must become part of these designs.

Major research challenges

- Research on organisational/managerial initiatives for *promoting innovation* in high quality chains and networks with their regional and national diversity. This research builds on 'best practice' research and the general approaches discussed above.
- Design and identify appropriate instruments/approaches (guides) for integrating new technological developments (production, logistics, communication, etc.) into organisational infrastructures and managerial initiatives to reach innovation for the value chain and to speed up adoption of new technologies. This involves the identification of *activity clusters* and *institutional requirements* that need to be addressed simultaneously for successful adoption of different principal technological developments.

Deliverables

- (Tested) best practice innovation infrastructures (enterprise/institution cooperation models, networks, clusters) (**2015**),
- (Tested) best practice chain management and chain organisation structures (**2015**),
- European (digital) knowledge network infrastructures for innovation support (concept, prototype implementation of system, establishment of prototype support and maintenance organisation) (**2020**).

Goal 4. Supporting competitiveness through integration

In the emerging global and highly competitive food markets, organisational and managerial integration concepts are the key for reaching a high level of competitiveness in the complexity of today's and future food markets. Integration may involve a wide range of dimensions (including information, management, finance, trade relationships, market policy etc.) that link enterprises vertically or horizontally in food chain networks on a regional and global scale. It may build on any one or a magnitude of the dimensions and implement different levels of intensity. Examples for the support of *vertically integrated food chains and horizontally integrated clusters* (Figure 12) of enterprises include appropriate team infrastructures and collaborative planning systems, integrated information and communication systems or integrated distribution systems.

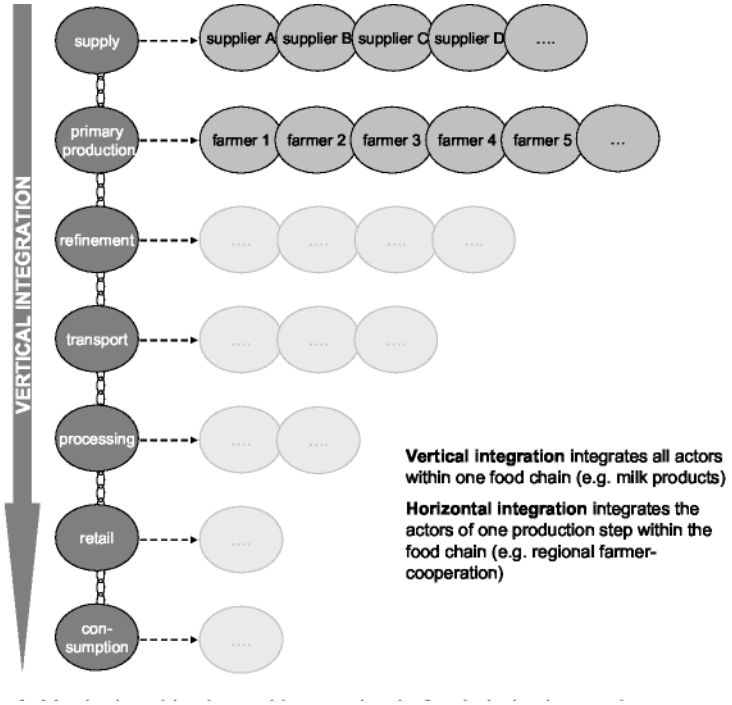

Figure 12. Vertical and horizontal integration in food chains/networks

Inter-organisational relationships are strongly embedded in an institutional environment that finds its expression in business norms, codes of practice, legislative frameworks and societal rules. Throughout the world, food safety and quality is delivered using different types of food quality and food safety management systems, representing the diversity of industries,

countries and people managing the production of food. Harmonisation of policies, systems and standards is a prerequisite for balanced development.

As the ability of enterprises, especially on the farm level, to cope with the issues of vertical integration may differ, the sector will develop different levels of integration, resulting in a *segmentation of markets* in different levels of excellence and regional activities (local, national, European or international). Especially farms with lower levels of management excellence might remain outside the emerging chain developments and remain restricted to very local small-scale markets. This will lead to new market infrastructures with a hierarchy of food chain clusters and networks.

Major research challenges

- To identify, analyse, and evaluate vertical and horizontal integration concepts and to facilitate their realisation, including the participation of SMEs in chains and networks with higher levels of excellence. This involves the optimisation and implementation of organisational systems and management concepts that are adapted to integrated infrastructures and support their efficiency and performance.
- In order to avoid development failures, research needs to identify *reference models* for integration initiatives. They build on research involving the *analysis and evaluation* of food chain organisation and management alternatives in the European and global food system and ask for research in the development of a *European database* of chain organisation and management alternatives. The analysis will have to address different perspectives, as e.g., quality management, distribution logistics, integration of SMEs.
- To develop *functional integration models* and *functional development paths* for integration to improve existing examples and the design of new innovative integration reference models. This involves many detailed issues as, e.g., information and communication systems in tracking, tracing, and quality control, the design of chain coordination models for improved logistics design, planning, and control or the design of risk management models and sector information infrastructures for improvements in chain risk control and management.

Deliverables

- A general frame work for market differentiation and consequences for institutional infrastructure (**2010**),
- Best practice reference models for horizontal and vertical integration for selected scenarios, including the appropriate supporting institutional infrastructure (see above) (**2015**),
- Best practice functional integration models (how to best integrate certain functions) (**2010**),
- Best practice paths towards functional integration (**2010**),
- Prototype solutions for integration support (information and communication systems for, e.g., quality control, disease management control, etc.) (**2020**),
- European database on chain organisation and management alternatives (**2020**).

Goal 5. Participation of small producers in complex food chain operations

The participation of small producers in development scenarios in Europe and in developing countries requires specific efforts to support them to adapt to the actual and future increasingly stringent quality and safety standards and regulations in Western markets. They must also gain better control over production, trade and distribution of their agricultural products in order to guarantee traceability of products and to operate in a cost-effective way in order to compete on the global market.

Major research challenge
Design and analysis concepts for the *integration of small producers* in developing regions into regional, national and global quality value chains without compromising in efficiency and competitiveness. It involves the design of supportive horizontal and vertical network infrastructures and infrastructure development paths.

Deliverables
- Design and evaluation of best practice organisational and managerial concepts (logistics etc.) for the integration of small producers in developing regions and developing countries in value chains (**2015**),
- Prototype management support systems (information and communication systems) for small producers in local/regional markets (**2015**).

Goal 6. Integrating food chain management and the consumer

The overall challenge is to make food chains more responsive to consumer demand. Since the food provisioning system is distributed across a range of actors, filling consumer demands will require not only a better consumer understanding, but also that this understanding is distributed across the food chain, that the chain has mechanisms for coordinating chain responses, that relevant consumer intelligence is channelled to where it is needed, and that the chains is organised in a way that facilitates flexible response to heterogeneous consumer needs.

Major research challenges
- Consumer knowledge, perceptions and trust in supply chains of different nature (e.g. high- *vs*. low technology input) and length (e.g. direct-selling vs. industrialised supply chains),
- Consumer needs and expectations regarding supply chains which are differentiated in terms of serving specific segments (e.g. disadvantaged consumers), personalising food supply (e.g. through personalised dietary advice and products), and providing specific and innovative retail assortments and/or formats,
- Consumer information needs and expectations regarding information that needs to be supplied by supply chains (transparency; tracking and tracing) RfID and other information carriers (labels, bar codes),
- Consumer perception and responsiveness to corporate social responsibility strategies in supply chains,
- Development of databases and consumer intelligence systems adapted to multiple chain users and integrated with flexible chain management systems.

Deliverables
- Consumer knowledge, perceptions and trust in different supply chains (e.g. high vs. low technology input, direct *vs*. industrialised chains) (**2010**),
- Consumer needs and expectations regarding supply chain differentiation (**2010**),
- Consumer information needs and expectations for information supplied from the supply chain (**2015**),
- A model for consumer perception and responsiveness to corporate social responsibility in the food chain (**2015**),
- Models for the integration of consumer intelligence in chain management (**2020**).

Challenge 7.
Communication, training and technology transfer

The results of research initiatives need to be communicated to the relevant stakeholders. Communication with enterprises, institutions and other stakeholders in the food chain will be through a variety of channels including workshops, representatives of stakeholders (such as enterprise associations), preparation of advisory material, support of implementation initiatives and support of pilot projects.

Reference models need to be widely advertised to reach an impact as has been achieved in the past with managerial developments in ECR (efficient consumer response) or with the Balanced Score Card Model of business development.

Communication, Training and Technology Transfer are crucial elements supporting an effective strategy for affirming the success of the ETP Food for Life. Transfer of technology to industry, in general, and to the SME sector, in particular, is the driver for innovation and represents a key focus for improvement.

SMEs are especially vulnerable to rapid and unexpected changes at the level of 1) diverse market conditions and requirements, and 2) fluctuating scenarios (cost reductions, new and improved manufacturing processes, definition of new products, compliance with norms for enhanced food safety). Few companies, with the exception of larger multinational firms, are in a position to react to these challenges; moreover, this lack of responsive is more often a psychological and cultural impediment than merely a matter of finance. Effective technical and organisational innovation requires a rapid response and detailed understanding of likely scenarios. The food sector, characterised by large turnover and small margins, has generally been slow to adopt and exploit cutting edge innovations (although food equipment manufacturers was be an exception), but technical developments and the results of scientific R&D are becoming a relevant part of product design. *An effective dialogue with consumers and society at large is an imperative since the industry is constantly under surveillance by all sections of society.*

Close links with other ETPs, especially those within the Knowledge-based Bio-economies (KBBE) sector, will ensure that best practices are identified, amended and introduced as rapidly as possible. In addition, the practices undertaken in countries with internationally recognised innovation records (such as New Zealand) will be examined with a view to adapting these to the European arena.

Goal 1. Effective communication

An effective communication strategy must build trust and confidence; this is not achieved in the short term and its ultimate impact will depend upon the ETP having, and being perceived to have, an independent position as beneficiary to all stakeholders. Real credibility for the platform will only be gained over the long term, but it is essential to establish a neutral and independent position from the start so that regular communication can be established, optimised and maintained. This trust is vital if training and technology transfer is to address the sustainability and competitiveness needs of industry.

Two lines of communication will be followed; 1) a general communication flow which will provide information to all interested parties and elicit necessary feedback, and 2) tightly-

focused information which addresses the needs of specialist groups. A number of countries are planning to establish 'national food platforms' as a consequence of the ongoing process of national consultation on the ETP and these platforms will be embedded in the overall communication plan.

The following structured set of actions will be pursued:

- promoting channels of communication and discussion among stakeholders in the whole food chain in the form of seminars, technology days, workgroups for technology evaluation,
- summarising and demonstrating the great challenges of the food and beverages sector,
- demonstrating the importance of R&D activities, technology transfer initiatives and increased training for the sector workforce as a means of reducing the vulnerability of the European food sector, especially SMEs, to competition,
- stimulating and exploiting new methods and formats for the effective diffusion of awareness.

Implementation plans will include the following:

- Active management of knowledge for all players,
- Attractive information flow from innovation deliverers,
- Use of traditional and modern communication tools,
- SME-oriented 'information filter',
- Specially-designed seminars and venues for discussions,
- Contact with companies *via* local trade associations and other institutions,
- Effective dialogue with the media.

<u>Key objectives</u>
- To establish an effective dialogue with society,
- To create a cultural desire to possess innovative goods and experience innovative services, which will associate 'Europe with innovation',
- To identify and transfer best practice at all levels,
- To establish new, simple methods for structuring existing fragmented information to SMEs and make it available, in an easily-understandable format, for factory personnel.

Deliverables
- Communication of the corporate identity of the ETP programme and philosophy (**2005-2015**),
- Communication management system for national communication partners of the SMEs (**2006-2010**),
- Communication of focussed and updated information to food companies about state-of-the-art in food research, in-depth food analysis at national level, country-specific information (from **2007**),
- ETP Communication Network for addressing strategic issues of the ETP (**2010-2015**),
- New communication formats for food-related issues (**2015-2020**),
- Continuous communication flow to and from consumers *via* associations and other sources (**2015-2020**).

Goal 2. Training

Training is a key ingredient for the extension and preservation of knowledge. Effective training may be envisaged as the 'energy' that powers the engine of technology transfer.

Transfer of knowledge is not only realised in development of products and processes, but also in training and education of food industry personnel.

The food industry generally invests little in training its workforce and this situation is even more apparent within SMEs. A reversal of this situation will significantly underpin the delivery of innovation. Paradoxically, training is nonetheless perceived by all actors in the food sector as crucial to sustain the competitiveness of companies and such activities are organised and promoted by trade associations and academia. However, training in the absence of a proper innovative environment is unlikely to deliver the innovation, and its benefits, that are sought.

Training must be made more attractive to food companies to enhance uptake and provide training opportunities for a significant proportion of the workforce who currently have inadequate access to training and education. This can be addressed using innovative forms of training developed over the last decade. Distance and *e*-learning are highly effective for delivering value-for-money training, are flexible enough for employees who are both time- and resource-poor, and impact directly on the needs of the company. Similarly, work-based learning makes the work environment the focus for enquiry and enhances the uptake of innovation and development. Adoption of such best practice will also enable employees who traditionally do not have the resources to allow this (e.g. single parents) to access training.

As an initial step an inventory will be made of best practices across Europe and a network of training centres established. The mobility of researchers towards industry has to be improved, so that competence and knowledge will be directly integrated on site. Mobility shall not be one way – a flow of researchers towards industry and *vice versa* will be enabled and supported by the technology platform. Activities proposed within FP7, particularly those within the People pillar will promote and encourage this process.

The network of national trainers established through the Advanced Foundation for Food Training, AFT, above, will be responsible for training national Techno Mediators at national level who represent the link between the needs of food companies and the deliverables from the research community. To manage the challenge of implementing an integrated technology transfer and training strategy over the next decade, a twofold approach is proposed:

- building up a centralised institution for creating and diffusing new formats for effective training linked to the innovation processes - this is the proposal of the Advanced Foundation for Food Training,
- developing groups of specialised personnel, so-called Techno-Mediators, to promote new training techniques closely associated with national programmes of technology transfer.

This process will be implemented in a step-wise manner:

- STEP 1: defining the curricula and prospectus of a European Advanced Foundation for food training. The resulting activity (‘training the trainers’) will be centralised and based upon the advanced expertise and skills of leading innovations laboratories and universities plus the ‘field’ experience of national agencies of technology transfer,
- STEP 2: creating a sustainable system of dissemination based on the proposals of AFT: *nationally* - through general organisational networks for adopting innovative training and stimulating the relative technology transfer; and *sectorally* - by ensuring the effective and timely dissemination of material to ‘sectoral-based communities’,
- STEP 3: progressive accumulation of data and libraries of best practice solutions built upon the current innovation technology transfer and training initiatives to be implemented.

Key objectives
- To establish and benchmark measures and mechanisms for training, including on-the-job options,
- To develop R&D and industrial 'partnerships' for training and technology transfer,
- To promote global knowledge management approach and associated technologies,
- To encourage personnel transfer and exchange at all levels of the food chain,
- To provide training and dissemination services to stakeholders in the agro-food sector.

Deliverables
- Establishment of the Advanced Foundation for Technology Transfer, AFT (**2010**),
- AFT fully operative (**2015**),
- National and sectoral bodies operating in 30 European countries (**2015-2020**),
- Training agreements taken at European level (European certification at high school/university level) (**2020**),
- Operable knowledge management system including a database of 25,000 European food SMEs and medium-sized firms above the SME threshold (**2020**).

Goal 3. Improved technology transfer

Technology transfer at its simplest is the conversion of existing knowledge into an appropriate format so that it can be used by the industry to develop new products, processing and services. Because the European food and drink industry has a clear need for innovation, a credible partner delivering innovation and its associated solutions should be THE driver for its future success.

Technology transfer, in its classical form, comprises *networks of expertise* that include both an analysis of needs and a search for solutions. Across Europe there are numerous networks, operating in the public and private sectors, which provide technical facilities for firms interested in developing R&D programmes and exploiting existing technologies. However, single firms, especially SMEs, are rarely aware of the value of a strategy for continuous implementation of technological improvements.

An especially rewarding approach is one of patience and 'listening to the company', since the purely technology push-based approach to the problem is generally counter-productive.

The importance of technology transfer in the agro-food sector is evident from the fact that 99.1% of food companies are SMEs, with very few of this number being high tech and only a minority being research-aware. However, whilst innovation requirements of large organisations and SMEs are generally addressed separately, data from EUREKA suggests that small enterprises may thrive in the 'slipstream' of larger companies. The industry sub-sector of medium-sized enterprises above the SME threshold has been considered to possess the greatest potential for growth in R&D investment and addressing its particular needs should be a priority.

To deal with this complex situation it will be necessary to explore and adapt existing models of best practice in technology transfer. Within Europe, such models are available in Norway, Austria, Denmark, the Netherlands, Sweden, France, Spain and UK; each possesses strengths and weaknesses and all are designed for operation within their own cultural context. An evaluation of existing best practice should be carried out and analysed with the aim of developing a generic model of practice capable of adaptation at national and regional level.

Evaluation of the effectiveness of these programmes is urgently required in order that best practice is captured and disseminated. One element of best practice already identified is the use of 'technology mediators' in all national programmes to date. These professional scientists, skilled in technology audit and communication, can 'mentor or coach' companies through their adaptation of technologies and innovation. One outcomes of the programme may be standardisation in the training of these mediators. This programme would also identify appropriate evaluation criteria for assessment of effective technology transfer.

A number of specific initiatives must be implemented, including:

- Creating a pan-European group of high-level specialists in food technology (process and product-oriented) to monitor, observe, filter and promote the most advanced progress in food technology. Such a 'Trustees Board' will link high level R&D in the food sector with ordinary industrial research activities carried out at firm or branch level. It will disseminate and champion the state-of-the-art of available technology and encourage early adopters to test new innovations,
- Establishing a European 'network of networks', complementing national networks and activities, to enlarge the processes of exchanging best practices, support the continuous exchange of personnel and active networking of groups facing common problems. These activities must be built on the basis of addressing the needs of the companies, not those of the agencies. Such collaboration will be supported by databases and knowledge-based initiatives open to all operators.

Identification of best practice in technology transfer within Europe and its possible adaptation to individual national and local market conditions will form the basis of implementing the strategy. Best practice will be disseminated at a national or regional level through training and education programmes which will contain training modules, adapted to national circumstances, for 'Techno-Scientific Mediators', TSMs, who will actively promote technology transfer in direct contact to food companies on national levels.

TSMs are an established part of a number of national programmes and are well recognised as being a particularly effective way to 'bridge the gap' between the technology/science providers and the companies seeking to apply the innovation. Their role is one of active meditation - supporting the company in recognising the need for innovation, identifying potential partners from technology providers, facilitating communication and managing the interaction between provider and company. Techno-Scientific Mediation is a new profession with high standards for entry. TSMs should be experienced within the food industry, educated to an appropriate level, and good communicators with demonstrable enthusiasm. The TSM network is needed both for communication and training and its impact in both areas will be continuously monitored.

These TSMs will work within the national network and, as part of their practice, they will gather information on both innovation needs from the industry and emerging technologies from research providers. Harnessing this information through a European wide database would provide valuable 'foresight' data for future R&D funding decisions. Alongside these activities, a biannual *Food Innovation Day* will be established to publicise best practice in innovation.

<u>Key objectives</u>

- Assist companies to improve competitiveness,
- Build a close relationship between the outputs of the ETP's communication, training and technology outputs and the activities and funding in public-private partnerships or

collaborative projects at national and regional level,
- Stimulate and promote entrepreneurial activities,
- Complement and support existing channels, identifying requirements common to other industry sectors and support cost-effective joint activities,
- Strengthen and improve schemes to support trans-sectoral mobility of R&D staff, with special attention on mobility involving new Member States, Candidate and European Neighbourhood Countries,
- Promote the benefits of collective research addressing the shared interests of SME sectors.

Deliverables
- Knowledge base and information structure (**2006-2010**), including databases on 'centres of excellence', food research activities, national technology transfer 'bottleneck' centres and legislative obstacles for innovation,
- Job description for Techno-Science Mediators (**2006-2008**),
- Inclusion of a high standard scientific committee for programme definition and selection of candidates financed by the European food industry (**2010**),
- 250 Techno Science Mediators established contacts between national bodies and the AFT for seminars and further activities (**2010**),
- AFT fully operative (**2010-2015**),
- Assessment report on Techno-Science Mediators in place and performance assessed by impact criteria (**2010-2015**),
- Evaluation of the effectiveness of SME partnership programmes and standardisation of such training (**2010-2015**).

Towards implementation

In addition to the SRA outlined above there are complementary activities that must be undertaken if the research is to deliver in an effective and timely way. The ETP Vision Document indicated the need for the development of an Implementation Plan as part of the SRA that would include the mobilisation of resources to support pan-European collaborative research, training and dissemination.

The European Commission have emphasised the importance they attach to such activities under the 'people' and 'capacities' elements of the proposed FP 7 RTD programme. They have emphasised the 'subsidiarity' principle where a prime function of the European research activity should be to more effectively co-ordinate the research resources spent by Member States to avoid duplication, and to obtain better 'added value' for the resource investment, as well as to improve the skill base, and provide an environment where innovation is embraced. This would enable the Commission to better catalyse trans-national research activities on those issues that will require substantial funds to deliver the necessary outputs in a timely way.

This present section concentrates on the stakeholders' views of the priorities that must form a part of the European research co-operation activities at the public level to achieve these goals. In the course of the development of the final SRA, attention will also be given to the issue of stimulating public-private partnerships in co-operative research and dissemination activities.

Three tasks are envisaged. These are:

A. Increasing the financial resources committed to innovation of the European food industry,
B. Improving education, skills and facilities in Europe,
C. Optimising stakeholder understanding and commitment.

In addition *a fourth activity is considered* important to inform and develop any future research agenda:

D. Initiating scenario studies.

Task A. Increasing the financial resources committed to innovation of the European food industry

The implementation of this ambitious research programme will need much more investment than is currently the case; indeed at present the European food sectors is investing only 0.28% in S&T, less than a third of its main competitors and very far from the target set at the Barcelona Council meeting. Whilst there is a strong case for an overall increase in the resources spent in the general field of 'food for life', there is no doubt that the better use of existing resources across the EU through closer coordination and cooperation needs to be given a higher priority. Such an activity will be one of the main objectives to be addressed by the ETP's Mirror Group. Another area that needs improvement is the area of public-private partnerships since ETPs, by definition, have this structure.

Research related to food for health crosses the responsibilities of many funding authorities in most EU Member States, and there is not always a close co-operation between them. It has

proved to be difficult to obtain data about the annual expenditure on food research within national authorities in part because expenditure falls into a number of other budgets such as agriculture, trade and health (nutrition) as well as food safety. However, this task will be continued within the ETP and will, hopefully, be facilitated by the composition of the Mirror Group.

It will also be of interest to establish to what extent these resources are able to be used flexibly to fund research, or if they are 'locked-in' to the support of specific research institutes and university food science departments in national administrations, and are therefore less likely to have innovation as their prime goal.

There still remains a need to co-ordinate national and regional programmes in the food for health area. The challenge is how to achieve this. The ERA-Net scheme developed under the 6th Framework Programme provides a basis for achieving this goal. The Nordic States have set up a Nordic Innovation Centre supported by the Nordic Council of Ministers. The Centre initiates and finances activities that enhance co-operation and enhancement of innovation capabilities. The scheme provides a model for other EU Member States. The active promotion of such models will be a key part of the ETP's activities during and beyond the immediate period of cross border consultation on this SSRA.

Deliverables

- An extended ERA-Net approach with emphasis on specific general areas of interest e.g. food microbiological safety, food contaminants, food phytochemicals, food preservation, seeking to involve as many EU Member States as possible in each activity (**2010**),
- New mini-ERA-Net activities involving relatively few national funding bodies that are ready to open up their research programmes, develop joint calls. These will also act as examples for other countries to join as thy see the benefits and opportunities (**2010**),
- A widening of the ERA-Net approach to cover national programmes focussed on support for innovation in order to encourage cross-border co-operation, with especial emphasis on new Member States, Candidate Countries and European Neighbourhood Countries in Eastern Europe, and thereby facilitate the potential to benefit from EU support for SME co-ordination programmes (**2010**).

Task B. Improving education, skills and facilities in Europe

The area of 'food for life' poses many research challenges; frequently these will be ones that will not be easy to resolve since they will require a concerted effort over the long term to deliver solid data. As will be evident from the specific research needs that have been identified, a striking feature of food and nutrition research is its multi-disciplinary nature. For a successful implementation and outcome there will need to be an effective interaction of the physical, biological and social sciences.

This poses unique challenges since the skills required cross-traditional academic boundaries; for this reason education of the young in the challenges, opportunities and excitement of a career in the food sector is seen as crucial. Perhaps for this same reason research in the area of food is not always given the resources necessary to ensure substantial progress.

A feature of the majority of the food research institutions in Europe is their focus on the characterisation of food materials and constituents, and their quantification. The vast majority of the facilities in Europe are unable to provide all of the skills necessary in a single institution. This is an excellent argument in support of trans-national co-operation and of the

European Research Area itself. There is a notable lack of skilled input from clinical scientists, molecular biologists, nutritionists, toxicologists, and consumer scientists in many of them. In the case of diet and health-related work their input is essential.

In line with this need it is essential to dedicate resources to public interaction and dissemination. Any institution or organisation that is able to easily access complementary skills, and has the flexibility to adapt to changes in consumer and market needs, will make a greater impact on the innovation process. Few have formed a strategic alliance between academia, government and industry and consumer representatives, in which all stakeholders have a role in determining the research agenda. Worldwide there are such alliances *and a study of best practice, in the organisation of effective innovation delivery in the food sector, should be undertaken to guide future developments*.

The challenges to the management of such national centres are manifold and a network of research directors of such publicly funded centres has been established. FOOD*force*, the forum for optimising research co-operation in Europe, has the possibility to identify and exchange best practice, to harmonise external evaluation processes and to exchange and train non-research personnel. This unique network which complements many other networks with a focus on research and training has been instrumental in the development of this ETP and there are clearly many opportunities for it to continue and expand its activities and operations under the umbrella of the Platform.

There is a need to invest more in health and nutrition research infrastructure and enabling technologies if the EU wants to ensure that Europe remains a world-centre of excellence for nutrition research. By sharing ideas, best practices and databanks, and by establishing structured processes to build trust and consensus, breakthroughs will be created, which will allow the development of more effective nutritional interventions and dietary recommendations.

- **Establish European Nutrition Research Council** or European Nutritional Institute (comparable to the already established: EMBL, European Molecular Biology Laboratory in Heidelberg).
- **Foster cross-disciplinary research centres: need for integration and collaboration (public-private partnerships), multidisciplinary approach, dietary surveys across Europe.**
- **Develop libraries, databases, biobanks, standardised protocols, networks of facilities.**
- **Foster prospective cohort studies** (example: EPIC study) and building them into public nutritional databases; The EU and national government support for the European Prospective Investigation of Cancer (EPIC) involves collecting data on food consumption data and as well blood samples and physical data on over half a million people in ten European countries. By studying very many people in different countries with differing diets, using carefully designed and tested questionnaires, EPIC should produce much more specific information about the effect of diet on long-term health than was previously possible. This ‘virtual’ centre of food epidemiology needs to be expanded in various ways and it should be renamed to reflect an interest in all issues in relation to diet and health, not just cancer. Links with the European Clinical Research Infrastructure Network (ECRIN), could be beneficial especially if a network emerged on which to build a specialist focus on diet and health issues. Such a facility would need long-term financial support if it were to be successful. Developments in the field of personalised nutrition could require collaboration with a European Centre on Genotyping, which does not exist at the present time.
- **European stable isotope standard repository for metabolic nutrition studies**.

- **Standardised European food tables**: initiatives already taken must be continued.
- **Interacting closely with the European Bioinformatics Institute** (EBI) to apply the 'omics' tools that will be required to study the biological effects of food components, and to understand their optimal levels of intake.
- **Training initiatives** focussed around the skill areas that are judged to be weak in Europe. A particular priority in this regard is the need to train scientists to be effective communicators with other stakeholders, including industry and consumers. In addition there is a dearth of properly trained and equipped young people to take advantage of the opportunities for project management within FP7. Finally, Europe needs to train, identify and support young entrepreneurs who will be key to Europe's vision of innovation.
- **Support for food research institutions in the new Member States and Candidate Countries to become truly multidisciplinary**, of a critical size to be effective, and to ensure a major input into their management structures from stakeholders. This latter might be addressed by co-operation and twinning initiatives through the FOOD*force* network mentioned above.
- The requirement that **effective dissemination to, and interaction with consumers forms part of any research programme** designed to improve the quality of the food chain.

The Capacities and People pillars that form part of the EU 7th Framework Programme provide the enabling opportunity to achieve these infrastructure reform objectives, but further analysis of the problems that have been raised should be undertaken as part of the proposed study in best practice (Design Studies).

Marie Curie industry-academic interchanges

The focus in FP6 on exchanges between industry and academia has brought about interactions between the sectors, facilitating transfer of technology and knowledge, improving innovation and helping to foster an entrepreneurial culture. However, the opportunity should be taken to create and fund specific *Marie Curie Entrepreneurial Fellowships*, to include a communication element to engage, enthuse and support other young researchers. At the other end of the professional career, Europe has many people recently-retired from industry who have a wealth of experience and knowledge that could be transferred, especially to new EU MS and smaller countries. In general such people are unable to spend prolonged periods abroad and so represent an untapped potential for stimulating entrepreneurial activity and enhancing industry/academic interactions. If the concept of Marie Curie Fellowships were extended to include multi-short term visits by a Fellow to an organisation or country, this would go a long way to opening up this potential.

Task C. Optimising stakeholder understanding and commitment

This will be achieved through a series of national, regional and web-consultations, completed by January 2007 that will lead to publication of the *Strategic Research Agenda* and *Implementation Plan* in March 2007. Thereafter, commitment and support will be achieved through communication, meetings and consultations, and – where appropriate - from inputs channelled through national food platforms that many countries are proposing to set up as a direct result of establishing this ETP. These ongoing activities which will address both dissemination and feedback will be driven by the *Horizontal Activities* Working Group and the *Communication, Training and Technology Transfer* Working Group.

Establishing a Mirror Group
The Mirror Group will include representation of national funding agencies, ERA-Nets, COST, EUREKA and other bodies funding agro-food research, training activities and innovation. The ETP and the Mirror Group will work together to:

- Establish the level and targets of national publicly funded food research programmes across Europe (**2007-2008**),
- Exchange best practice in calls, evaluation and administration of research programmes (**2007-2008**),
- Align research priorities and agendas so as to minimise overlap and identify opportunities to add-value to national research through use of common protocols (**2010**),
- Open up national research programmes to European competition (**2015-2020**).

Linking with national and regional organisations and projects:
A database of national and European (FP6) projects and contacts will be established to provide a pool of experts, speakers. This will provide a basis for speakers and presenters.

Exchanging and exploiting knowledge across the food/pharma spectrum
A workshop will be established bring leading stakeholders in the food and pharma sectors together to discuss common opportunities, exchange knowledge and best practice and, where necessary, develop common projects to most cost-effectively address common issues.

FP7 links
Following discussions with stakeholders in Brussels, Kiev, Sliac (Slovakia), Bucharest and Warsaw some additional measures are proposed that will need to be encouraged and adopted widely if Central/Eastern Europe is to compete successfully in the production of value-added food products and the European Research Area is to become truly European and transform the potential and enthusiasm of C/E countries into a reality.

Networking FP5 Centres of Excellence
Centres of Excellence in (then) Candidate Countries under FP5 have generally delivered a high level of training, linkage with industry (especially SMEs), networking with old and new EU Member States and contact with society. The decision not to extend this scheme was taken in FP6. These Centres have established a considerable research presence, participated in FP6 and, in some countries such as Poland, have been absorbed into the fabric of national excellence centres. Many of the FP5 Centres of Excellence are clustered in the health and food chain sector; however, there is little evidence of value-addition by their networking across the primary production-, food- and health chain. A SSA call for specific networking of FP5 Centres of Excellence would be a cost-effective means of ensuring the durability of these centres; optimising their involvement in FP7 and ETPs; contributing to 'levelling up' within the ERA and promoting the fork-to-farm philosophy within Theme 2. This ETP would be ready to actively support such activities which would impinge positively on European Neighbourhood States.

Project Management
Fewer Networks of Excellence and Collaborative Projects (replacing the FP6 distinction between IPs and STREPs) are at the heart of the proposed FP7 Co-operation pillar. However, the multidisciplinary and trans-sectoral challenges that will be contained in the calls will still require a very considerable level of management and administration if they are to deliver maximum impact and afford optimal benefit to society and industry. Given the pool of European researchers and organisations able and willing to co-ordinate such activities is small and that many of the most able will already be co-ordinating FP6 IPs and NoEs it is

crucial that the European Commission takes positive steps to increase the number of proficient research managers and to ensure that these numbers are not just confined to the larger (and north-western) EU Member States. This could be done by including project management as a topic within the Marie Curie Intra-European Fellowship scheme, by allowing researchers to 'shadow' managers and administrators of FP6 IPs and NoEs or by taking active steps to capture and disseminate best practice in trans-national research management.

Development of trust and confidence between SMEs and academia
This is necessarily a complex process, especially if durable links are sought. Many brokerage activities, representing a single meeting or event, do little to foster the conditions for long-term co-operation. Opportunities should be provided for networking of SMEs and academics that take account of the initial 'lag phase', which is essential to develop mutual 'trust and confidence'. This is especially important for SMEs in new EU Member States.

Deliverables
- SRA and IP (**March 2007**),
- A Mirror Group (**2006-2007**),
- Improved methodologies for risk/benefit assessment, toxicological evaluation, exploitation of 'omic' technologies (**2010**),
- Horizontal actions and measures in support of international co-operation (**2007-2013, FP7**),
- Coherent development of research policies,
- Networking FP5 Centres of Excellence,
- Improved project management and administration in FP7,
- Development of trust and confidence between SMEs and academia.

Task D. Initiating scenario studies

These studies, also referred to as foresight studies, aim to provide challenging visions of the future to ensure effective research strategies by providing evidence to inform actions by Government, business and academia. They focus around key issues where scientific research is expected to provide solutions to a problem and ask feasible 'what if' questions. In addition they often consider the policy framework that will be needed for a successful outcome.

The Horizontal Activities Working Group has considered *four topics* that are felt to be of crucial relevance to the future competitiveness of the European agro-food industry. They are:

1. Obesity,
2. Novel approaches to determining the risk versus benefit of consuming specific food products,
3. Obstacles to local food production and distribution,
4. Nutrition and healthy ageing.

Study 3 closely links with the broader issues of sustainability (challenge 5). Under the EU´s 6th Framework Programme the ForSociety ERA-Net was commissioned to co-ordinate the national foresight programmes of 15 countries, with a view to increase their national and European impact and to implement joint programmes. A close liaison will be maintained with this activity since they have registered an interest in the field of nutrition. The Office of Science and Technology in the UK, who are participants in ForSociety, have completed a scoping exercise on the topic of obesity and will develop this into a full foresight project by

the autumn of 2007. Depending on the international context of the conclusions it is proposed that any decision on whether additional work is required should be deferred until they have reported.

Scenario studies are also included within Challenges 5 and 6, and all will be developed in a concerted action so as to optimise value-for-money and relevance to the wider remit of this ETP. It is proposed to work closely in this area with the JRC Institute for Prospective Technological Studies (IPTS), Seville, although support and encouragement from DG Research and others is likely to be needed to initiate this cooperation.

Deliverable

- Foresight studies on the last three topics (**not later than 2010**).

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Glossary

A&I	Active and Intelligent (packaging)
AFT	Advanced Foundation for Food Training
CAP	Common Agricultural Policy
CFP	Common Fisheries Policy
CIAA	Confederation of the Food and Drink Industries of the EU
DALY	Disability-Adjusted Life Year
ECR	Efficient Consumer Response
ERA	European Research Area
ETP	European Technology Platform
ERA	European Research Area
FP	Framework Programme
HTC	High-throughput computing
IE	Industrial ecology
IP	Implementation Plan
KBBE	Knowledge-Based Bio-Economies
LCA	Life Cycle Assessment
PAN	Preference, Acceptance and Needs of consumers
RFID	Radio Frequency Identification
R&D	Research & Development
SFP	Structure/formulation-property functions
SME	Small and Medium-sized Enterprise
SPC	Structure-ProCess functions
SRA	Strategic Research Agenda
SSRA	Stakeholders Strategic Research Agenda
TM	Techno Mediator
TSM	Techno-Scientific Mediator
TTI	Travel Technology Initiative

Agro-food industry:	agriculture and food related industries.
Agro-food sector:	the sector of the economy that produces agricultural and food products.
Bio-economy:	all industries and economic sectors that produce, manage and otherwise exploit biological resources (and related services, supply or consumer industries), such as agriculture, food, fisheries, forestry, etc.
Biotechnology:	technologies for cultivating, modifying or deriving products from living organisms.
Sustainability:	an environmentally sound, economically viable and socially acceptable development.

For a more detailed glossary please refer to
http://europa.eu.int/comm/research/biosociety/library/glossaryfind_en.cfm