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FORWARD LOOK

European Food Systems in a Changing World

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This ESF-COST Forward Look final report has been prepared under the responsibility of:
the ESF Standing Committees for Life, Earth and Environmental Sciences (LESC), European Medical Research Councils (EMRC), Social Sciences (SCSS), Humanities (SCH) and of the COST Domain Committees for Food and Agriculture (EFA), Earth System Science and Environmental Management (ESSEM), Individuals, Societies, Cultures and Health (ISCH).

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Foreword 1

Food is essential to human wellbeing. For millennia, food has been produced, traded and consumed locally, and, while in some regions farmers, pastoralists and fisherfolk generally still sell their products in local markets, the overall picture of local production and consumption has changed radically over the last few decades. This is especially so in Europe and in other parts of the Western world where society has increased food availability by employing industrial production approaches combined with regional and worldwide exchange of food. These changes in producing, in processing, in packaging and distributing, and in exchanging and consuming food (in short, the "food chain"), have already left their mark on the environment with altered landscapes, water cycling and biodiversity, and also contributing to climate change. They have also affected consumer behaviour and increasingly the consequent changes in consumption patterns are having negative and positive effects on health.

Food safety is a major issue nowadays and is a challenge for the production chain. For example, the epidemic of bovine spongiform encephalopathy (BSE) in the 1990's affected seriously Europe's beef production. Likewise the recent production and consumption of tainted milk-powder in China has had serious consequences locally and raised concern elsewhere due to its global export of the product.

Changes in climate, population growth, energy production and economy closely interact with these food chain activities and hence food security at large. The dynamic interactions between these components can have dramatic effects as witnessed by the recent sharp increase in food prices, which led to food riots in many countries. The increase in food prices is a complex matter of a global nature but one principle contributor is the change in the demand for food. The per capita consumption of food in major emerging economies such as India and China continues to rise in particular due to a more meat-based diet. This is paralleled by the Western world's increasing demand for biofuels, which both compete for land and other resources and/or are derived from food crops themselves. Volatile fossil fuel prices also contribute to food price inflation since many stages of the food chain are highly oil-dependent, with the situation being complicated further by export quotas and trade restrictions on internationally-exchanged food. Underlying all is the need to satisfy the increased food demand of a population which is estimated to grow to 9 billion people by 2050 while minimising environmental degradation. New technologies, management methods, policies and institutional arrangements will all be needed to increase both the availability of food – and access by all sections of societies to food – while reducing the environmental impact of the food chain.

Europe's Food Security: Priorities for Science Policy

The rapidly-growing awareness of major global issues such as climate change and shifts in energy policy are raising fundamental concerns about Europe's food security in relation to other needs of society ("competing claims"). This needs the urgent upgrading, renewal and strengthening both of the complementary parts of Europe's food systems, and of the system as a whole. The ESF/COST Forward Look on "European Food Systems in a Changing World" identified critical areas of research to address this need.

These examples illustrate the dynamic nature and complexity of food systems. It is against this background that ESF and COST joined forces to tackle the issue of European Food Systems in a Changing World through a Forward Look. The objective of the Forward Look was to develop medium- to long-term views of future research need around the thematic focus of food security. It was multidisciplinary in nature, involving the ESF Standing Committees for Life, Earth and Environmental Sciences, Medical Research, Humanities, the Social Sciences and the COST Domain Committees for Food and Agriculture, Earth System Science and Environmental Management and Individuals, Societies, Cultures and Health. Both the Science Policy Briefing and Final Report have been internationally peer-reviewed, and have been approved by the relevant ESF Standing Committees and COST Domain Committees.

This final report describes a research agenda and actions to be taken in Europe for this highly timely and important topic. Its major recommendations were published in March 2009 in the corresponding Science Policy Briefing (see pages 147-152). The action plan addresses the complex challenges ahead and aims to contribute to shaping European food policy.

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Foreword 2

The past few decades have seen dramatic changes in European food systems. The next few decades may be as radical but the direction that future developments take can be initiated, influenced or mitigated when the right decisions by policy makers are made. The role of science in this interesting field may be best characterised as that of an honest broker. Scientists and science may help to explore various options to clarify particular developments, to help generate closer insights and knowledge, and to expand scientific contributions to food production, processing, packaging and distribution to meet a strong changing demand from consumers and retail organisations. ESF/COST took the decision to develop a Forward Look on European food systems where the different components of food systems are considered in an integrated way.

Production, processing, packaging and distribution, and retail and consumption are taken together in one forward look. The individual components are reflected upon and their interactions are studied. The food system as a whole is more than the sum of the parts and that is considered. In each of the comprising fields the state of affairs of the system is considered, and the trends that determine the present situation are evaluated and used in combination with scenario approaches to explore possible future developments. The interaction between the various components may hinder some developments but also stimulate particular challenges and chances. This is demonstrated in this report.

Chapter 2 lays out the background of European food systems and the way they may be characterised. It also covers how various components of food systems can be distinguished, and how their interaction takes place and may be used to strengthen the coherence of the system and to serve social goals better.

In Chapter 3, scenarios are described as a means to explore possible futures, and various methodologies that lead to such scenarios are reviewed. It also explains what scenario exercises are used for in this ESF/COST Forward Look, and how.

Chapter 4 gives a state of the art of the various activities involved in European food systems with in-depth analyses of the current trends and developments, and a look forward in relation to the questions raised from the scenarios in Chapter 3.

Chapter 5 covers conclusions and recommendations, based on the results of the earlier parts.

Chapter 6, finally, presents the research agenda, in which especially the need for better, more integrated explorative scenario studies is highlighted.

The research issues highlighted by this ESF/COST Forward Look will help deliver the new knowledge needed to lead to a stronger and more fitting European food system for all stakeholders involved.

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1. Introduction

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1. Introduction

Changes in agriculture, food production and food systems during the last five decades may be characterised by five megatrends that influence the way agriculture takes place and how it is integrated in society. These megatrends affect the development of food systems and their performance in the near future. They are:

1. *Productivity increase* per ha, per man-hour and per kg of input has created an agriculture that is productive, environmentally-friendly and saves land for nature and other purposes. There is still ample opportunity for further productivity increases, as is demonstrated in the paper on primary production.
2. The *nature of agricultural production* has changed considerably. It is no longer a skill for those with green fingers but an industrial way of producing, where efficiency and efficacy not only count in economic terms but more and more in environmental and social terms.
3. There is an increasing *vertical integration* in the food chains, where the slogan "from farm to fork" or "from soil to shelf" is fully adopted. The feedback and feed forward in these food systems are more and more common. That requires a strong and well-coordinated effort over the whole production chain.
4. The *objectives for primary production* are much wider than before. Next to productivity, other aims have become important, such as environmental goals, water saving, nutrient use. Efficiency and landscape count. The broadened objectives do not necessarily mean that everything should be done anywhere but that there is ample opportunity to develop a variety of production systems. Heterogeneity and multiformity are becoming more common than homogeneity and uniformity.
5. *Food, nutrition and health* are closely connected. The better understanding of nutrition and the specifics for a better diet are coupled back to primary production. Fine-tuning to the specific needs of individuals dictated by their genetic make-up is not yet possible but may be an ultimate aim. At present, harvests with specific attention for some product characteristics are already possible.

Two additional megatrends are also apparent but probably less important for the development of food systems.

1. The traditional linear knowledge model is being replaced by a *participatory interactive knowledge model* where co-innovation and a more direct relation with the ultimate uses of knowledge and insights exist.
2. Food systems are affected by the increasing use of *biofuels* promoted by government policies and regulations.

The latter trend is not based on regular market development but on an active policy of various governments that stimulate the production and use of biofuel for mandatory regulation such as a minimum fraction of biofuel in transport fuel.

A combined effort is needed to achieve one overruling societal aim. It requires a holistic approach as the premise in this food systems study is that the whole is more than the sum of the parts. The combination of detailed traditional reductionistic research that analyses parts of the system with holistic research at systems level will lead to a better understanding and may also lead to some predictions. The detailed analysis may also pave the way for more explorative studies. Such studies could be used to explore the possibilities for various production systems, but also demonstrate how various societal goals may be reached. Explorative studies that quantify the possibilities and limitations are likely to be very helpful for policy makers and more useful than qualitative storylines that describe possible developments in abstract and often very general terms.

During the last decades, some explorative studies have been conducted in individual components of food systems. For example, in 1992 the Netherlands Scientific Council for Government Policy did a study with four scenarios for land-based agriculture and forestry in the European Community up to 2015. The scenarios in this study are not forecasts, but technical surveys, which define the limitations and opportunities of alternatives for future development. The scenarios indicate how land can best be used in rural areas, depending on the choices which ensue from a number of different philosophies for the future. Four strategic philosophies, based on the main positions in the debate on European agricultural policy, were used to construct four scenarios:

- scenario A: free market and free trade;
- scenario B: regional development;
- scenario C: nature and landscape;
- scenario D: environmental protection.

The outcomes of the four scenarios differ by a factor of 2 to 7 in terms of the amount of land required, costs, employment, and use of fertilisers and pesticides. They also differ greatly from the current situation.

The Netherlands Scientific Council regards this study and the ensuing differences as significant for policy in two ways. Firstly, the differences between the scenarios are important for policy making, particularly on European agriculture. Widely varying policy decisions lead to widely varying results. This means that policy makers must constantly take account of the goals they want to achieve, also when it comes to choosing instruments. Thus, the changes recently agreed upon in Brussels – a reduction in price supports and an increase in land-related and income subsidies – will, in the view of the Council, have little effect on long-term developments. They will not solve the basic problems and offer little scope for exploiting new opportunities.

Secondly, the four scenarios unmistakably point to a number of structural developments in land-based agriculture and forestry, which will have to be catered for in future policy. According to the Council, these developments are:

- a continuing rise in productivity in the agricultural sector, which will eventually reach objectively-defined ceilings;
- increasing land surpluses, irrespective of policy;
- a further loss of jobs in agriculture;
- good possibilities for more environmentally-friendly agricultural production;
- sufficient land available to achieve a tentative ecological main structure at the level of the 12 EU Member States of 1992 (EU-12) as the "backbone" of nature.

In all cases, policy that is not geared to reducing the amount of land under cultivation would appear to be counterproductive. Opting to keep land in production artificially, partly in an attempt to preserve jobs, would hinder the creation of new structures in the sector, thereby also frustrating environmental and technical improvements, which have been made possible thanks to technological progress.

Highly productive agriculture as currently practised in a number of areas is associated with severely adverse environmental effects. This need not be so. Nitrogen and pesticide emissions can be reduced without adverse economic consequences. In all the above scenarios, agriculture is highly productive but also environmentally safe and compatible with other forms of land use. The concept of integrated agriculture is compatible with each of the scenarios and fits in with widely differing distributions of land use, depending on the kind of future envisaged for rural areas.

The realisation of various views concerning the future for land-based agriculture and forestry in the European Community centres around land policy. The aim of bringing European agriculture more closely into line with market forces does not detract from the need for active governmental policies broadly determining which land should be reserved for which activities, and helping to promote developments in that direction. If government policy remains passive and scope is simply created for greater market forces, new structures will certainly evolve in many regions in due course, but this will be associated with the pauperisation and bankruptcy of elements of the rural community. Land-based agriculture would then undergo the purgation of (excessive) market discipline. The result need not even be optimal efficiency; the fact that short-term economic factors will always be the decisive consideration in such policies, rather than the physical characteristics of the area in question, means that marked impoverishment can also take place on agriculturally good soils. This is another reason in favour of an active government policy.

However, more is possible. Working from the firm foundation of technical scenarios, it is possible to look to a more distant future. The findings in the report of the Netherlands Scientific Council provide a frame of reference for the future shape of agriculture as it might develop in the European Community under a two-fold model. The first element would consist of highly productive agriculture meeting the lion's share of the demand for food on a small area using the best technical means. Such agriculture would make use of the most advanced eco-technological principles and of maximum biological self-help (i.e., by means of persistent strains, the high uptake of plant nutrients, biological pest control, good crop rotations, crops designed to minimise mineral losses, and mixed farms on a larger scale than now). The area required for such agriculture would be limited, as would the employment. Alternatives will therefore need to be created, which can vary widely.

Possibly the biggest threat for the future for land-based agriculture and forestry in the European Community is the failure to make choices and to keep in place a policy by adapting its instruments without taking stock of what its goals are or should be. In this way, with a bit of patching here and there and some minor modifications, the great bastion of the CAP remains intact at ever-increasing cost to the Community. By denying the structural nature of surplus of agricultural land and indeed compulsorily maintaining such land for agricultural purposes by means of temporary set-aside schemes, other possibilities with attractive features to them remain blocked. Particularly in the densely populated areas of Western Europe, land is a scarce commodity. The over-allocation of land to agriculture means that other forms of land use go begging.

The scenarios of the study performed in 1992 and their outcomes have been discussed over the last 15 years, but the afterword as given by the Council is still valid. Surveys of the future help to identify threats and opportunities. In doing so, they can provide a framework for the strategic choices that need to be made, and form a basis for a fruitful discussion about the direction to take in policy making. In spite of all the merits of the above study, it also has an apparent limitation in the fact that it only covers one set of activities in the European food systems, namely land-based agriculture and forestry. Therefore, a similar approach, based on explorative scenarios that yield quantitative data, is urgently required to design policy and a research agenda for the future of

European food systems. Although studies like the one described above have been done in other components of European food systems (see Chapter 3), no comprehensive study comprising the four domains of the food system has yet been undertaken. That approach is now needed, also in the light of the new CAP that is to be formulated in 2013. This ESF/COST Forward Look paves the way for such approaches.

2. Food system concepts*

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* Paper derived from Ericksen and Ingram, (2004); and from Ericksen (2008).

2. Food system concepts

The ESF/COST Forward Look on European Food Systems in a Changing World is based on an integrated and holistic approach to "food systems" to aid a comprehensive analysis of the interactions between European food systems and major drivers.

Food systems can be described as comprising four sets of *activities*: (i) producing food; (ii) processing food; (iii) packaging and distributing food; and (iv) retailing and consuming food. These activities lead to a number of *outcomes*, many of which contribute to food security, and others which relate to environmental and other social welfare concerns (see Figure 2.1; and Box). Including the outcomes as part of the food system concept provides an explicit analytical lens for understanding food security, the principal objective of the food system[1].

Food security is achieved when *all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life* (FAO, 1996). Food security outcomes are described in terms of three components and their sub-components: food availability (production, distribution and exchange); food access (affordability, allocation and preference); and food utilisation (nutritional and social values, and food safety) (see Figure 2.2).

Because of the interest in both the interactions between drivers of change and food systems, and the trade-offs among food security and environmental goals, the ESF/COST Forward Look also needs to consider the determinants (or drivers) within its food system concept. The determinants comprise the interactions between and within biogeophysical and human environments which both determine how food system activities are carried out, and the nature of the outcomes. Further, although the food system activities have a large influence on food security outcomes, these outcomes are also directly determined by socio-political and environmental drivers.

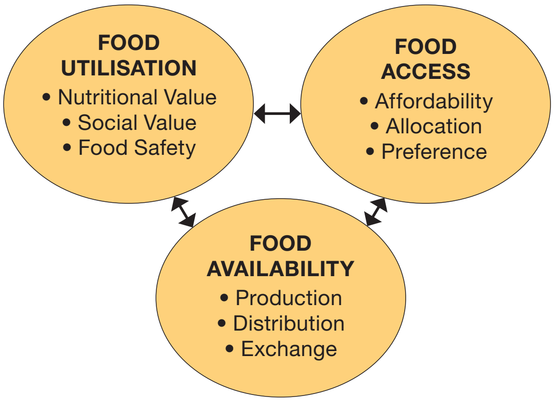

Figure 2.2. The three components of food security outcomes

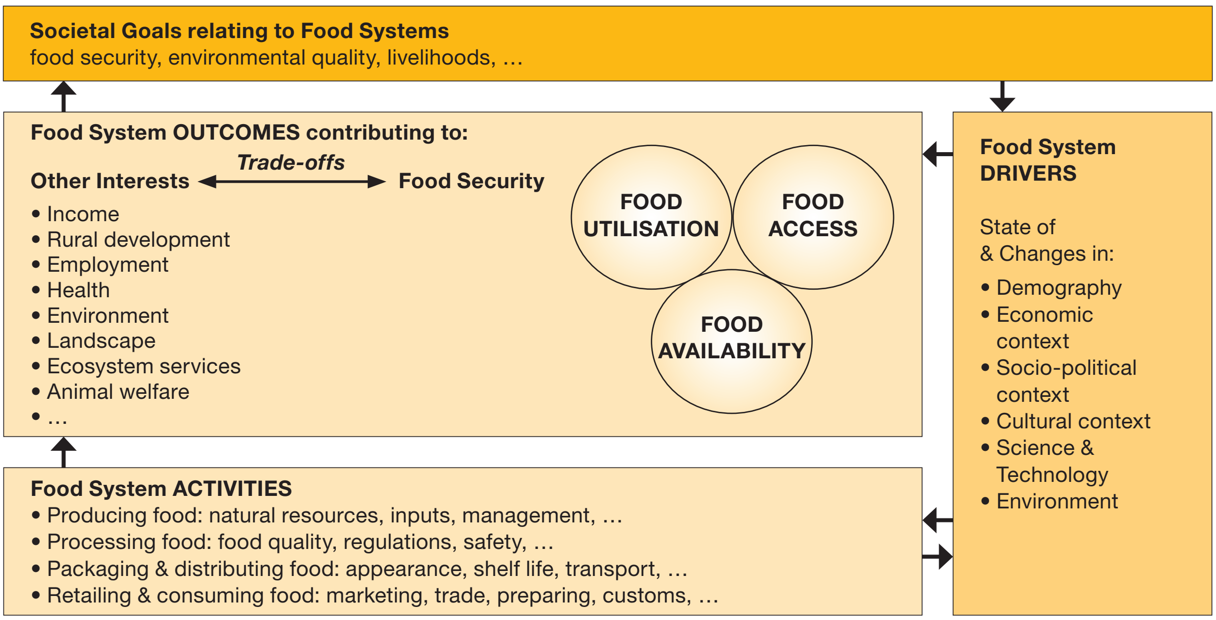

Figure 2.1. Key Food System Drivers, Activities, Outcomes and Feedbacks. [Derived from Ericksen, P.J. and Ingram, J.S.I. (2005) *IHDP Annual Report 2004-5*, pp. 45-46; and from Ericksen, P.J. (2008) Conceptualizing food systems for global environmental change research. *Global Environmental Change* 18, 234-245.]

Food Chain and Food System concepts in the context of Food Security

One of our principal societal goals is to achieve and maintain food security. In 1996 the World Food Summit (held at the UN Food and Agriculture Organization of the United Nations) defined food security as: *when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life.*

We, as a society, actively engage in a number of different *activities* to help ensure our food security. These include: (i) producing food; (ii) processing food; (iii) packaging and distributing food; and (iv) retailing and consuming food. These *activities* are often referred to as the "food chain", and are considered to be a continuum from primary production (including the production of animal feed) to the consumption of food by the consumer.

A more holistic approach is to specifically link these *activities* to a number of *outcomes*, many of which contribute to food security (i.e., to those aspects relating to availability of food, access to food and food utilisation). These activities also contribute to many other outcomes which relate to other social welfare and environmental concerns (e.g., income, rural development, animal welfare, employment, health, environment, landscape and a range of ecosystem services such as provision of clean water).

The food system concept includes both the activities and the outcomes, and as such provides a more holistic approach; including the outcomes as part of the food system concept provides an explicit analytical lens for understanding both food security (the principal objective of the food system) and the trade-offs with other societal goals. By specifically linking activities + outcomes, the food system approach helps understand both linear and non-linear links between activities as part of the outcome analysis. The food system concept is especially useful for analyses of the interaction of changes in and stresses brought from, for example, changes in CAP, international trade, and/or climate, as it:

(i) identifies interactions of stresses and/or issues of concern within the food system, e.g.:
  a. multiple vulnerabilities within the food system
  b. embodied water and carbon in food

(ii) allows analysis of multiple food system outcomes, e.g.:
  a. food security
  b. ecosystem services
  c. social welfare

(iii) identifies possible intervention points for improving any desired outcome, e.g.:
  a. improved nutrition
  b. reduced GHG emissions
  c. higher income from agriculture

(iv) can be used to help analyse trade-offs between outcomes of different management options for achieving desired outcome, e.g.:
  a. *Fair-trade* food consumption vs. embodied carbon
  b. fisheries biodiversity vs. runoff from intensive agriculture
  c. issues regarding multiple trade-offs

By specifically linking activities + outcomes, the Food System approach helps understand both linear and non-linear links between activities as part of the outcome analysis.

In order to capture these concepts holistically and to allow the analysis of driver impacts, adaptations, and feedbacks, the Forward Look analysis of food systems must therefore include:

- interactions between and within biogeophysical and human environments which determine a set of activities;
- the activities themselves;
- outcomes of the activities (contributions to food security, environmental security, and other securities); and
- other determinants of food security (stemming in part from the interactions in bullet one).

1. Note: Food systems may or may not result in food security for the unit of analysis of concern (household, community, district). Determinants/drivers can "disrupt" or "distort" the food system so that it does not deliver food security.

The food system activities

Food system activities are grouped into four categories:

Producing food includes all activities involved in the production of the raw food materials. These range from the process of obtaining inputs such as land and labour, preparing land, breeding animals, planting crops or obtaining young animal stock, caring for the growing food material (including weeding, thinning, fattening, vaccinating, etc.), and then harvesting or slaughtering it. A variety of social, economic, physical and biological factors determine these activities, from land tenure to input prices to agricultural or harvest technology to government subsidy provisions intended to protect or promote production. Key actors include farmers, hunters, fishermen, the multiple suppliers of production inputs including agricultural labourers, and land owners.

Processing food includes the various transformations that the raw food material (e.g., grain, vegetable, fruit, animal) undergoes before it is sent to the retail market for sale. All of these activities "add value" to the raw material in an economic sense, but these activities may also significantly alter the appearance, nutritional value, content and storage life of the raw materials. For example, wheat undergoes extensive processing and packaging before it is sold as bread, and increasingly the dairy industry involves much more processing and packaging of raw milk. The determinants of these activities are quite different from those pertaining to producing food, and involve a different set of actors and motives, although most actors in the food supply chain are to some extent motivated by the desire to capture more of the final market price for themselves. The main exception to this is the regulatory bodies established to control quality and safety. However, many of the standards set in this sector are privately determined, raising concerns about safety and health outcomes. The key actors are the middlemen who buy from producers and sell to processors; the owners and managers of processing and packaging plants; and trade organisations that set standards.

Packaging and distributing food is heavily influenced by a range of factors including, for instance, the appearance of the final product and other demands of the retailer, the shelf life needed, transportation infrastructure, trade regulations and storage facilities. Location of the market vis à vis the producing and/or processing site is crucial and migration and changes in demand are having a major influence. Consumer preference and the need to reduce waste are also key factors. As with processing, the determinants of these activities are quite different from those involved in producing food, and involve a different set of actors and motives, although – again – most actors in packaging and distributing activities are keen to capture more of the final market price.

Retailing and consuming food is increasingly influenced by how markets are organised, where they are located, and what sort of niche or premium category the product may fit in to. Advertising is a significant activity under retailing. It also involves everything from deciding what to purchase, through to preparing, eating and digesting food. Prices are very influential, as are income levels, cultural traditions or preferences, social values, education and health status. As diets and the food system globalise, the influence of advertising and the structure of the food supply chain also have a large influence on what people choose to eat. Key actors in retail are supermarket owners, the transportation sector, government ministries that regulate markets, a range of middlemen who go between the processors, packagers and the final markets, and consumers themselves.

The food system outcomes and their determinants

The food security outcomes are highlighted in detail in the framework in Figure 2.2. The three major categories of food security determinants are access, availability and utilisation. Food **availability** refers to the amount, type and quality of food that a unit (individual, household, community, region or nation, depending upon the scale of analysis) has at its disposal to consume. It may be produced locally, imported, or reflect a change in stocks. Availability may vary seasonally or by geographic location, as well as a host of other biogeophysical and socioeconomic factors. **Access** to food refers to ability of units to obtain access to the type, quality, and quantity of food they require. Food **utilisation** refers to the unit's capacity (including strategies) to consume and benefit from food. This includes how it is prepared (for consumption) and utilised by the body. Each of these can be further broken down as follows.

Food availability

Three categories of determinants – production, distribution and exchange – contribute to food availability. Although familiar to many food security analysts, they have been modified slightly to fit the agenda of describing a food system holistically.

- **Production** = how much and which types of food consumed (by a given unit) are available through local production. The determinants of availability from local production include seed varieties, land-holding sizes, resource tenancy arrangements, irrigation availability, cropping cycle, labour availability, human capital, energy sources, input and output prices, available and adopted technologies, and the control local producers have over their own products.
- **Distribution** = how food for consumption is made available (physically moved), in what form, when and to whom. The determinants of distribution include transportation and infrastructure, public safety nets, storage facilities, availability of post-harvest processing, governance (power distribution, corruption, whether food has worth beyond consumption), security, and the enforcement of trade barriers and borders (regional and international).
- **Exchange** = how much of the available food is obtained through exchange mechanisms such as barter, trade, purchase, or loans. Determinants of exchange include income levels and purchasing power, informal social arrangements for barter, local customs for giving and receiving gifts, migration, gender and age structure, markets, terms of trade, currency value, and subsidies.

Access to food

Three groups of determinants contribute to accessibility of food: affordability, allocation, and preference.

- **Affordability** = the purchasing power of households or communities relative to the price of food. The determinants of affordability include pricing policies and mechanisms, seasonal and geographical variations in price, local prices relative to external prices, the form in which households are paid, income and wealth levels.
- **Allocation** = the mechanisms governing when, where and how food can be accessed by consumers. Markets are a key determinant of food allocation; government policies are often designed to correct market failures by allocating food to remote areas or at lower prices. Social capital (as a function of age, class, gender) influences informal allocation processes (e.g., within households), while at a broader scale social/political capital in urban areas influences where supermarkets are located. Both social and political capital influence rules for fishing, hunting and gathering in rural communities.
- **Preference** = social or cultural norms and values that influence consumer demand for certain types of food. Determinants may be religion, season, advertising, preparation requirements, human capital, tastes, customs and female labour force participation.

Food utilisation

The three elements of food utilisation are nutritional value, social value, and food safety.

- **Nutritional value** = how much of the daily requirements of calories, vitamins, protein, and micronutrients are provided by the food people consume. Both over- and under-nutrition are issues. Determinants of nutritional value include diversity of food consumed, type of primary protein (animal or vegetable), disease incidence (which affects food absorption), education, facilities for cooking and preparing food, access to clean water, and hygiene practices.
- **Social value** = all of the social and cultural aspects of consumption, for example, eating meals together may be an important part of kinship, or it may be very important to always have food for guests, or special foods may be an integral part of important holidays. In some places eating locally- or organically-produced food is highly valued. Understanding the determinants of social value requires insight into the community and household relations, as well as cultural customs.
- **Food safety** = this refers to the dangers introduced from the addition of chemicals during production, processing and packaging, and food-borne diseases such as salmonella and Creutzfeldt-Jakob disease (CJD). The main determinants of this are the procedures and standards and regulations (or lack of) for food production, processing and packaging.

References

Ericksen, P. J. (2008). Conceptualising food systems for global environmental change (GEC) research. *Global Environmental Change* 18(1): 234-245.

Ericksen, P. J. and J. S. I. Ingram (2005). *Global Environmental Change and Food Systems (GECAFS)*. IHDP Annual Report 2004-5. pp. 45-46.

FAO (1996). *Report of the World Food Summit*. FAO, Rome.

3. Analysing the future of European food systems in a changing world

Using scenario-based approaches to support research of European food systems

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3. Analysing the future of European food systems in a changing world

3.1 Introduction

Changes in European food systems not only depend on the choices that relate directly to food system activities, but are also bound to be affected – both directly and indirectly – by wider ("global") societal developments such as global and regional economic and political developments, globalisation, consumer preferences, life-style changes, or global environmental change. Thus any forward-looking assessment aimed at discussing possible options to strengthen future food security needs to take into account the myriad of possible paths future development of European food systems may take. However, while a number of global and European-level exercises have explored different plausible futures from an environmental or agricultural perspective, none of these past assessments has – to our knowledge – focused on or addressed comprehensively the challenges European food systems face.

Thus, in this ESF/COST Forward Look on European Food Systems, a scenario-based forward-looking exercise set out to frame some of the uncertainties that the future holds. However, the scenario work did not attempt to develop a robust set of scenarios, but rather aimed to enable an exploration of the merits of, and possible challenges in, adopting a scenario-based approach in a fuller exercise. To this end, a set of proto-scenarios were developed. The aim in building and using these proto-scenarios was to give an initial impetus and, even in this exploratory phase, to start outlining the research agenda. The scenario process enabled discussions between scholars and key stakeholders of European food systems.

The proto-scenarios provided a means to reflect on: (a) the wider global context(s) that will shape future developments of European food system(s) – and thus identify key questions arising in this respect; (b) the definition of European food systems, i.e., further labelling/framing of critical concepts such as "food security outcomes" and "food system activities" – and thus identify key questions arising in this respect; and (c) provide those involved with an experience about what such an approach involves and the potential added-value a full exercise can deliver. The outcome of this preliminary exercise has highlighted the need to, and value of, undertaking a full scenario exercise in the years ahead.

In Section 3.2, the concept of European food systems as complex adaptive systems and the challenges this raises for strategic decision making and policy implementation are highlighted. In Section 3.3, some basic concepts of scenarios are introduced, and the strengths and limits of scenario-based approaches are discussed. In Section 3.4, a selected number of recent scenario-based assessments are summarised and gaps with regard to analysing the future of European food systems are discussed. In Section 3.5, there is a condensed description of the proto-scenarios developed in this Forward Look. Section 3.6, finally, offers some further considerations that are relevant in the design and initiation of a fuller exercise.

3.2 Analysing European food systems

Food systems encompass all activities related to the production, processing, packaging, distribution, retailing, preparation and consumption of food: this set of activities spans from "plough to plate" or "farm to fork". In addition, the notion of food systems also includes the outcomes of food-related activities, such as food availability, access and utilisation. Figure 3.1 provides a conceptual framework of food systems, and the various elements that define it (see Chapter 2 for a more detailed description of the food system concept).

The European food system is a complex, adaptive system[2] and, as such, food security outcomes cannot be predicted or managed through traditional command-and-control approaches. Instead, the future evolution of European food systems and food security outcomes depend on:

1. A collective ability to understand and manage such complex, open and adaptive systems, coupled with a common vocabulary for conceptualising such systems and food security challenges and goals.
2. An effective and shared appreciation of the wider causal (i.e. global) context in which such systems are embedded – a similarly complex interplay of wider socioeconomic, environmental, technological, and global political factors.

In other words, the European food systems are embedded in a wider ("*global*"), continuously evolving and causal landscape and, as such, will be affected — both directly and indirectly — by wider developments, such as global economic competition and geopolitics, local-

2. A Complex Adaptive System is characterised by interactive, interdependent, multiple and diverse *agents*. Unlike mechanical and engineered systems, for example a car, we cannot understand how a complex adaptive system works by breaking the system down into smaller and smaller parts (e.g., an engine, the wheels, etc.) and then studying each part in detail. Instead, we must look at the interaction of the agents to understand what happens to the whole system. Whilst the individual behaviours of the agents often follow simple rules, their interactions result in non-linear dynamics. Furthermore, the agents are *adaptive* in that they have the capacity to change and learn from experience.

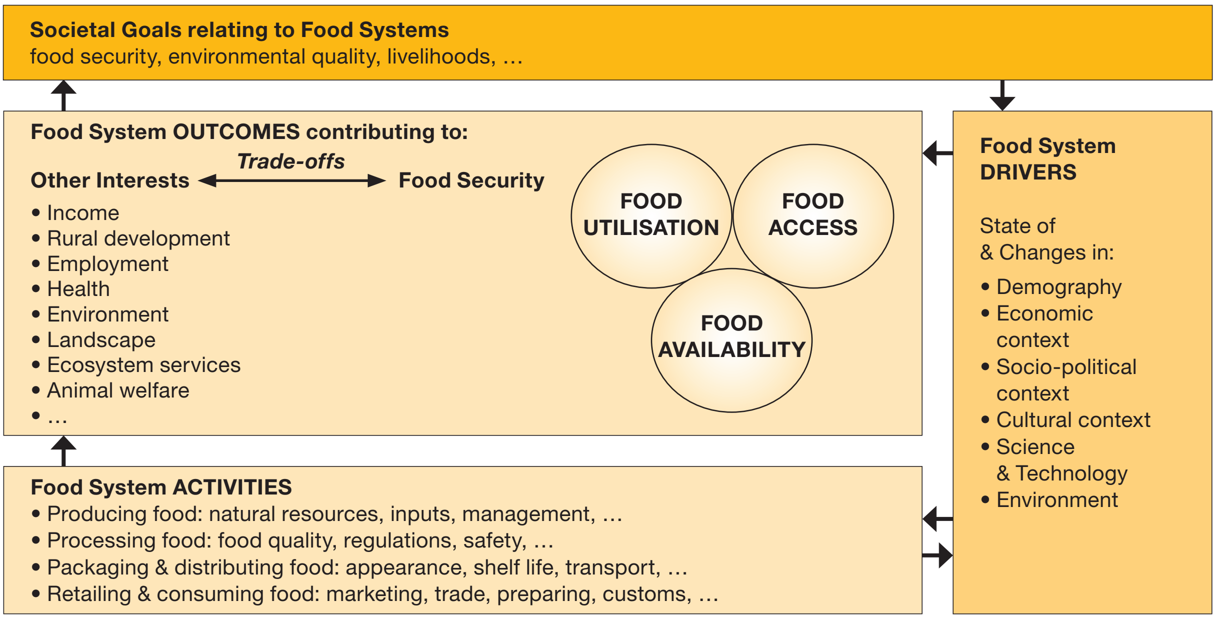


Figure 3.1. Key Food System Drivers, Activities, Outcomes and Feedbacks. [Derived from Ericksen, P.J. and Ingram, J.S.I. (2005) *IHDP Annual Report 2004-5*, pp. 45-46; and from Ericksen, P.J. (2008) Conceptualizing food systems for global environmental change research. *Global Environmental Change* 18, 234-245.]

to-global consumer preferences, population growth, life-style changes, and global environmental change. It is thus imperative for any forward-looking assessment of European food systems to take into account the myriad of future possibilities associated with the developments in the wider context of European food systems, as well as to forge a common vocabulary and shared understanding of such systems and how to manage them more effectively.

3.3 Scenario-based assessment and planning

The assessment of possible long-term food security outcomes is complicated by scientific uncertainty about today's European food system, by the heterogeneity and interdependence of the multitude of actors comprising this system, by the complexity of future dynamics that will unfold within the system and by the similarly complex and causal influences of changes in the wider global context on this system.

By definition, forward-looking assessments aimed at catalysing and informing strategic decision making must not only be informed by learning "with" the future — a future that is inherently uncertain — but must also enable common ground (i.e., a shared understanding) to be forged between the various policy makers and key stakeholders involved, as well as deliver practical wisdom, i.e., actionable knowledge needed to effectively navigate under conditions of complex and causal environments and potentially turbulent changes (Emery and Trist, 1965). This calls for more systemic approaches that can deal with the construction of (future-related) knowledge, at the same time addressing the challenges of institutional filtering, i.e., the social construction of ignorance, and help make uncertainties and key strategic assumptions about the future more explicit.

Scenario-based assessments have evolved to be an approach to enable a systemic exploration of inevitable changes [i.e. so-called "predetermined elements" (Wack, 1985)] as well as to highlight critical uncertainties about future developments – particularly when analysing complex systems. Whilst there is no single agreed definition, scenarios have been described as "plausible and often simplified descriptions of how the future may develop, based on a coherent and internally consistent set of assumptions about key driving forces and relationships" (MA, 2005). Consequently, a set of scenarios comprises alternative stories about the future, and how it came about. In contrast to predictions and many forecasting practices, scenarios – recognising the inherent indeterminism of complex systems – are based on the idea of exploring different, often contrasting, sets of possible future developments (see Figure 3.2).

3. Analysing the future of European food systems in a changing world

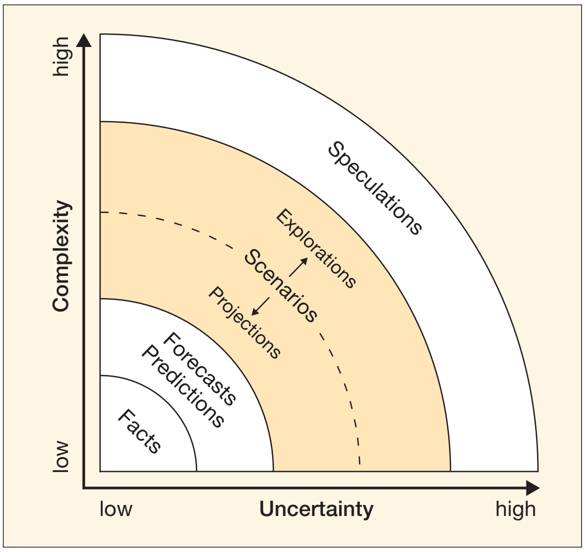


Figure 3.2. Dealing with uncertainty and complexity (from Zurek and Henrichs, 2007)

Indeed, scenarios encourage us to anticipate "breaks" with the past, that is, the idea the future is unlikely to remain within today's boundary conditions, that we face a "changing world". At the heart of scenario-based approaches is the belief that, though we cannot predict the future, we can at least create a coherent picture of a number of alternative futures. In effect, to engage with scenarios is to hold two or more stories in mind at the same time – and therefore, hold the future not as a belief, but as a fiction.

There are many scenario-building methods: ranging from more quantitative-led analysis, computer-based modelling and an emphasis on formal expertise, to more qualitative-led and intuitive logics-based systems building, involving a multitude of key stakeholders. Scenario sets and storylines are often rendered through a combination of qualitative (e.g., words, pictures, systems maps, theatre) and quantitative (e.g., numerical estimates, graphs, charts) analysis. Scenario planning, i.e., building and using scenarios to inform action (policy making, strategising, for example), requires that any scenario process is focused (i.e., relevant to the challenges facing, and assumptions of, key decision makers), has traction with the decision-making system and is legitimate to the predominant decision-making culture of the organisations that will use the scenarios.

There are also different ways of using a set of scenarios, but common steps are first to derive implications and then explore options, drawing conclusions from the set of scenarios, rather than focusing analysis and strategic conversation on any one scenario.

Strengths and limits of scenario-based approaches

There has been a proliferation of different approaches to future-orientated studies in the past four decades and there is no definitive listing of methods and a lack of well-ground theory to explain what works, when, why – and when/why not. The use of alternative, equally possible future contexts helps to resist the temptation to try and predict the future and instead opens the space for consideration of many more options for policy and action.

However, in situations in which there is confidence that future developments are known and knowable (e.g., stable trends, steady-state systems, short-term time horizon), forecasting and computer-based simulations, coupled with appropriate sensitivity analysis, may provide a satisfactory basis for decision making. In these cases, future implications are derived from the extrapolation of historical trends.

Conversely, in situations characterised by uncertainty, high decision stakes (Funtowicz and Ravetz, 1990), turbulent change and/or involving contradictory certitudes (i.e., positions underpinned by different worldviews and belief systems), there is often ambiguity or contestation about how to define the current reality, and making detailed predictions, or even projections, is meaningless, can catalyse political conflict and undermine the effectiveness of policy implementation.

In such situations, scenario-based approaches can help to map and navigate complexity and establish common ground, whilst respecting a diversity of worldviews. Furthermore, the scenarios can be used to identify a wider set of strategic options and create shared understanding about what needs to be done, and by whom, not by forging a more precise understanding of the future but by enabling a more inclusive and iterative exploration of the problem, from the perspective of the future and the discussion of the implications of a wider range of options. Indeed there are many different typologies of scenarios (Börjeson et al., 2006; Van Notten et al., 2003).

A noteworthy distinction can be made to differentiate so-called "projection-based" and "exploration-based" scenario exercises (see Figure 3.2). While recognising the inherent uncertainties with which forward-looking assessments are faced, projection-based scenario studies set out to present one (or several) probable projections of future developments (often as a reference scenario with variants). This type of approach is particularly valuable when the impact of a defined set of options is discussed. Conversely, explorative studies aim to widen the scope of discussion about future developments, and to identify emerging issues. This feature allows exploration-based scenarios to be most useful when strategic goals are discussed and reflected against a range of plausible futures.

It is worth noting that in many practical instances the choice of futures method and scenario design is often not made explicit and under-attends to the purpose, and/or nature of, change/system. Instead, methodological competences tend to determine the type of scenario process and analysis deployed by organisations and projects alike: for example, organisations with competency in forecasting tend to forecast, organisations with a bias towards numerical calculation and computer-based simulation modelling tend to reject qualitative-led scenario processes.

3.4 Review of existing scenarios related to European food systems

Over the past years, a number of global and European-level exercises have explored different aspects of global change, and have developed and analysed a range of alternative futures, that is, scenarios describing a range of alternative outcomes and the developments that these would bring about. Yet, to our knowledge, none of these past assessments has focused on the specific challenges associated with defining and managing European food systems. Nevertheless, some of the recent scenario-based assessments have either addressed several components of the European food systems (focusing, for example, on agricultural production and consumption) or have proposed plausible, global contexts in which the European food systems might be situated in the future.

Also, a variety of forward assessments have focused on individual food system activities (i.e., only limited sub-sets of the whole European food system), which have been developed using projection-based analyses. Indeed, both at national and international level, such assessments have been published. Prominent examples are the food production-oriented projections presented in the FAO Agricultural Outlook (FAO, 2002, for example) or the recent Environment Outlooks (EEA, 2005, for example) – however, these are not included in this review as the focus is on assessments that look across a range of food system activities.

Instead, this section reviews only a selected number of scenario-based and explorative assessments, those suited to a forward-looking assessment of European food systems in a changing world – that is, suited to deal with complex issues (food systems) in a context of high uncertainty (i.e., a changing world, with a perspective of 20 years and more), and relevant to strategic discussions about future policy and research priorities in the realm of long-term food security. Assessments were included in this review if they:

- portray multiple future scenarios AND
- address the European dimension, and explicitly explore the implications of a changing world AND
- EITHER develop and analyse scenarios focusing on a range of food system activities and outcomes
- OR develop and analyse scenarios with considerable detail across a variety of driving forces directly relevant to food system assessments.

The forward-looking assessments reviewed here in more detail include:

- Ground for Choices (WRR, 1992)
- UNEP – Global Environment Outlook (UNEP, 2002; RIVM, 2004)
- ATEAM – ATEAM assessment (PIK, 2004)
- MA – Millennium Ecosystem Assessment (MA, 2006)
- EUruralis – EUruralis assessment (EUruralis, 2006 and Westhoek et al., 2006)
- PRELUDE – EEA's land use scenarios (EEA, 2006 and EEA, 2007)
- SCAR – EU RTD's Standing Committee on Agricultural Research (EU, 2007)

Ground for Choices

The Ground for Choices study was presented in 1992 and assessed the viability of different possible future developments of Europe's rural areas. Four explorative scenarios of land use changes at both the European (i.e., EU-12 of 1992) and regional level are developed and analysed, in particular in view of the achievement of policy goals for rural areas (focusing on the agriculture and the forestry sectors).

The Ground for Choices study uses modelling approaches (the GOAL model), augmented by some qualitative spatial evaluation techniques. The study provides policy-relevant insights into the interrelations between (a) various agricultural and technological developments, (b) societal goals related to socioeconomic developments and environmental protection, (c) the consequences of these interactions for rural areas in Europe.

The four scenarios highlight a range of options related primarily to different societal priorities regarding free market and free trade, regional development, and the protection of nature and environment. They also include some assumptions on the type and level of future food consumption, and for each scenario quantitative estimates show a comparison of effects of diets on land use ("current diet" versus "luxury diet").

3. Analysing the future of European food systems in a changing world

Policy goals addressed in Ground for Choices

Economic
- Employment (in agriculture)
- Self-provision/protection
- Regional economic development
- Productivity development

Social
- Income
- Regional development

Environment
- Emissions

Nature and Landscape
- Nature values

Four Scenarios (Ground for Choices)

***Scenario 1:* Free Market & Free Trade**
In this scenario agriculture is treated primarily as an economic activity: economic criteria determine where agricultural production takes place.

***Scenario 2:* Regional Development**
In this scenario, the maintaining of agricultural employment is a key driver. Market forces, including import and export, are assumed to be heavily regulated.

***Scenario 3*: Nature and Landscape**
In this scenario, a large focus is put on the reduction of agricultural pressure on nature in Europe. This leads to an assumption of reduced agricultural area in Europe.

***Scenario 4*: Environmental Protection**
In this scenario, environmental criteria restrict agricultural production — regardless of where it takes place. Also here, import and export are assumed to be heavily regulated.

Box based on WRR, 1992

UNEP – Global Environment Outlook 3

The UNEP Global Environmental Outlook 3 (GEO-3) emphasises that the next 30 years will be as important as the past 30 for shaping the future of our environment. It develops and analyses four scenarios to explore what the future could be, depending on principally different approaches to policy making. The scenarios span developments in many overlapping and interlinked areas, including population, economics, technology and governance.

UNEP's Outlook is based on narrative descriptions of possible futures, which are supported by quantitative scenario analysis. A set of four main modelling tools is employed to provide detailed output for Europe per scenario for demographic and economic development, cropland degradation, built environment (the PoleStar model), infrastructure expansion (the GLOBIO model), water stress (the WaterGAP model), greenhouse gas emissions, climate change, land and biodiversity (the IMAGE model).

Environmental implications addressed globally

- Climate trends
- Ecosystem pressure (built-up area, infrastructure)
- Water stress (area, population)
- Population living with hunger

Results that focus on Europe:
- Emissions and land use
- Energy- related carbon dioxide emissions
- Extent of built-up areas
- Land area impacted by infrastructure expansion
- Natural Capital Index
- Population living in area with severe water stress
- Thought experiment: "Imagine a food scare in Europe"

Four Scenarios (UNEP GEO)

The ***Markets First*** scenario envisages a world in which market-driven developments converge on the values and expectations that prevail in industrialised countries;

In a ***Policy First*** world, strong actions are undertaken by governments in an attempt to reach specific social and environmental goals;

The ***Security First*** scenario assumes a world of great disparities, where inequality and conflict prevail, brought about by socioeconomic and environmental stresses;

and

Sustainability First pictures a world in which a new development paradigm emerges in response to the challenge of sustainability, supported by new, more equitable values.

Box based on UNEP, 2002 and RIVM, 2004; images from UNEP, 2002

For Europe, the GEO analysis emphasises that agricultural policy is critical for the future state of the environment, but does not reflect in great detail its implications on the food system. Some modelling results for hunger incidences are presented — based largely on assumptions on income distribution. In addition, the implications under each scenario of a major food scare in Europe brought on by a combination of factors are explored in a short, qualitative "what-if" reflection (see, for example, UNEP, 2002, p. 373).

ATEAM – Advanced Terrestrial Ecosystem Analysis and Modelling

The ATEAM project assesses ecosystem-related vulnerabilities in an integrative assessment approach. This includes a comprehensive modelling framework for predicting major European terrestrial ecosystem changes, macro-scale indicators of society's adaptive capacity, a range of relevant scenarios, maintenance of a continuous dialogue with stakeholders, and a series of maps depicting regions and sectors that are especially vulnerable to global change.

The ATEAM assessment is based on the four emission and climate change scenarios developed by the IPCC-SRES. However, the original scenarios and the underlying assumptions were adapted and down-scaled to frame the European analysis. The project's modelling framework then focused on bringing together different ecosystem models, including land use change models, forestry models, a carbon storage model, water model, as well as statistical niche modelling to assess biodiversity change.

While food systems are not addressed in much detail, the ATEAM scenarios address future developments of food and fibre production (both in general terms and for 20 individual crops) as a key driver of land use changes. Particular attention is given to the competition of land use for food production and for energy crops.

MA – Millennium Ecosystem Assessment

The Millennium Ecosystem Assessment (MA) considered the possible evolution of ecosystem services during the 21st century by developing four global scenarios, which explore plausible future changes in drivers, ecosystem services, and human well-being — incorporating both ecosystem dynamics and feedbacks.

The approach used for scenario development combines qualitative storyline development and quantitative modelling. The storylines cover many complex aspects of society and ecosystems that are difficult to quantify, while the models helped to ensure the consistency of the storylines and provided numerical input. The main models employed include the IMPACT model (food supply, demand, trade), WaterGAP (water stress), and IMAGE (climate change and land use).

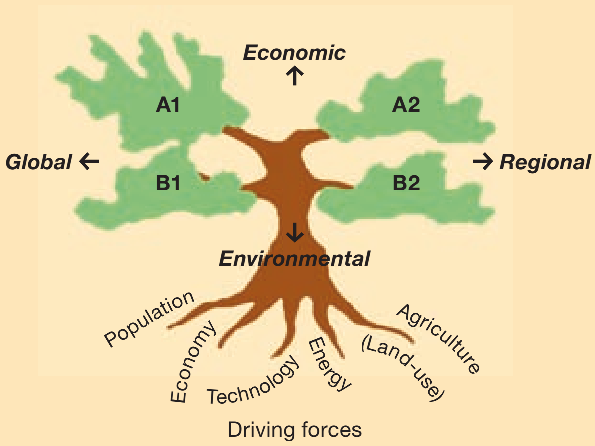
The MA focuses on a range of ecosystem services, and does not address food systems as such. Nevertheless, the four scenarios address food-related ecosystem services, such as food provisioning (including indicators on food production) and food security (including indicators on calorie availability, food prices, and share of malnourished children). Results for Europe, however, are only presented at an aggregate level.

Cross-cutting driving forces detailed in ATEAM

- Economy
- Population
- Technology
- Institutions and government
- Rural development
- Recreation, tourism
- Spatial planning
- EU enlargement
- Climate change

Note: *The scenarios developed and analysed in ATEAM were constructed to be consistent with the IPCC's SRES scenarios.*

Four Scenarios (IPCC SRES Scenarios)



Box based on PIK, 2004 and IPCC, 2000; image from IPCC, 2000

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Main assumptions/driving forces addressed	**Four Scenarios (Millennium Ecosystem Assessment)**
• Demographics • Average income growth // GDP growth rates • Income distribution • Investments into produced assets // human capital • Overall trend in technology advances • International cooperation • Attitude towards environmental policies • Energy demand and lifestyles • Energy supply • Climate policy • Approach to sustainability • Land use change • GHG emissions by 2050 • Air pollution emissions • Climate change • Nutrient loading	The ***Global Orchestration*** scenario is based on a socially conscious globalisation, reacting to ecosystem problems when they reach critical stages. The ***Order from Strength*** scenario represents a regionalised approach, in which emphasis is on security and economic growth, reacting to ecosystem problems only as they arise. The ***Adapting Mosaic*** scenario is also a regionalised approach, but one that empha-sises proactive management of ecosystems, local adaptation, and flexible governance. The ***TechnoGarden*** scenario sees a globalised approach with an emphasis on green technology and a proactive approach to managing ecosystems.

Box based on MA, 2006

EUruralis – European Land Use Scenarios

The EUruralis project highlights current policy issues in European rural areas. It depicts land use changes under a set of different future developments for the three domains of sustainable development: ecology, economy, socio-cultural aspects. Four contrasting scenarios, based on the IPCC-SRES scenarios, are analysed, focusing on those driving forces that shape land use and agriculture in Europe.

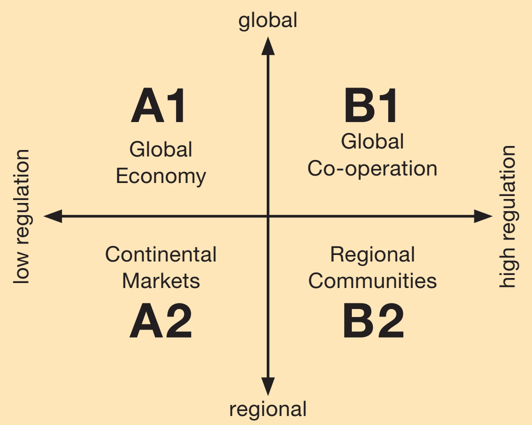
A suite of three linked models is used to assess effects assuming changes in driving forces: The Global Trade Analysis Project (GTAP) model simulates world trade for all economic sectors (agriculture including processing industry, services); the IMAGE model (Integrated Model to Assess the Global Environment) assesses effects of global change on the environment; and the CLUE model (the Conversion of Land Use and its Effects) is used to allocate the predicted changes in land use at a 1 km^2 resolution.

EUruralis scenarios focus on land use changes, and thus address food systems only from the food production and food trade perspective. Assumptions on agricultural developments are presented, and food availability (i.e.,

Key drivers addressed in EUruralis

- Demographic changes, i.e., growth, decline of populations, major migration flows, and the ageing of people in case of declining population growth.
- World economy is a powerful determinant of changes in agriculture and other sectors (industry, services). Supply and demand determine trade.
- Technology, but completely new inventions are hard to predict; once their relevance has been shown, dissemination of technologies can be assumed.
- Climate change and sea-level rise
- Geopolitical change, i.e., EU enlargement, international agreements (WTO or other).
- EU Common Agricultural Policy.
- Consumption patterns: all kinds of human preferences, diets, attitude towards animal welfare.

Four Scenarios (EUruralis)



Box based on www.eururalis.nl

crop and livestock production) is addressed in some detail at EU-25 level. Alongside this, changes in consumption and dietary patterns are acknowledged to be important drivers, but are not detailed.

PRELUDE – EEA's Land Use Scenarios

The PRELUDE project explores what European landscapes may look like 30 years from now. Instead of making predictions, it tackles the vast uncertainties of the distant future by analysing a range of plausible developments. As a result, five contrasting futures are depicted in a set of coherent scenarios, built on different assumptions about changes in our society.

The scenarios take the form of qualitative stories, which are supplemented by quantitative modelling of land use change, both at the European level and for selected regions (Northern Italy, Estonia, the Netherlands). The five scenarios presented include both linear developments based on shifting paradigms (as do most other exercises — see above) and disruption scenarios (based on sudden events, or shocks).

As the focus of the scenario discussion is on the interplay between societal future and land use changes, much of the food system related discussion is on agriculture and food production. Nevertheless, the qualitative storylines depicted elaborate on a range of issues directly relevant to consumption patterns and distribution of food stuffs in Europe.

SCAR – Standing Committee on Agricultural Research Foresight Report

The Standing Committee on Agricultural Research (SCAR) of the EU's DG Research tasked a Foresight expert group to formulate possible scenarios for European agriculture in a twenty-year perspective. The aim of this foresight exercise was to identify long-term research priorities. The study resulted in short descriptions of a set of major driving forces for agriculture in Europe. Based on this, five scenarios were developed, i.e., a "baseline-like" scenario plus four disruption scenarios.

The SCAR Foresight Report does not make use of dedicated modelling approaches to quantify any of the impacts of the disruptions discussed. Instead, the expert group describes for each scenario the implications of the assumed disruption on society in general, and agriculture in particular, in short qualitative assessments. However, the scenarios do not describe the interaction of drivers in great detail.

Where the scenario discussion addresses food systems, it focuses primarily on food production issues — although some other aspects of food systems are hinted upon throughout all five scenarios. An exception to this is the "Food Crisis" scenario, which highlights in more detail some implications of changed food processing, packaging and consumption as well as related health concerns on all other parts of food systems.

20 driving forces addressed in PRELUDE

Environment	Climate change; environmental awareness; renewable energy
Solidarity & Equity	Social equity; quality of life; human behaviour; health concerns
Governance	Policy intervention; subsidiarity
Agriculture	Agricultural optimisation; international trade; self-sufficiency
Population & Economics	Population growth; ageing; settlement density; internal migration; immigration; daily mobility; economic growth
Technology	Technological growth

Five Scenarios (PRELUDE)

Great Escape Scenario – A Europe of Contrasts
- international trade (globalisation)
- decreasing solidarity
- reduced policy intervention

Evolved Society Scenario – A Europe of Harmony
- energy scarcity (and shift to renewable energy sources)
- growing environmental awareness
- policy intervention (rural development)

Clustered Networks Scenario – A Europe of Structure
- population dynamics (ageing)
- international trade (marginalisation of agriculture)
- policy intervention (spatial planning)

Lettuce Surprise U Scenario – A Europe of Innovation
- technological innovation (including surprises)
- growing environmental awareness
- reduced policy intervention (decentralisation)

Big Crises Scenario – A Europe of Cohesion
- growing environmental awareness (after crises)
- growing solidarity
- policy intervention (centralisation)

Box based on www.eea.europa.eu/prelude

Key drivers addressed in the SCAR Foresight Report	Five Scenarios (SCAR Foresight Report)
• Societal and demographic changes • Economy and trade • Climate change/Global warming • Environment • Energy • Science and technology • Health	***A "baseline-like"*** Scenario: Identifies an emerging trend towards competitiveness, disruption in agriculture, largely due to globalisation. ***Disruption Scenario:*** Climate Shock Focus on climate change and the acceleration of related environmental impacts as the key drivers. ***Disruption Scenario:*** Energy Crisis Focus on energy and "industry-manipulated" acceleration of related economic and societal impacts as key drivers. ***Disruption Scenario:*** Food Crisis Focus on food, health, and society as key driving forces jointly determining a more consumer-oriented research. ***Disruption Scenario:*** Cooperation with Nature This scenario focuses on society and science as key joint drivers evolving in a beneficially symbiotic relationship.

Box based on EU, 2007

The overview presented here highlights that none of the scenario-based assessments focus on food systems as such; rather food supply and demand have been treated as either a driving force of other developments or as one issue among many that may be affected by other developments. Nevertheless, the existing scenario studies do provide assumptions on a wide range of driving forces that are relevant to discussing food systems at a European scale. All of the studies presented here are based on explicit assumptions on demographic changes and socioeconomic development and to a lesser degree on general technological progress and world market futures.

To what extent each of the above sets of scenarios may be suited to serve as a platform upon which food systems can be further addressed depends not only on whether and how food systems are addressed, but also on a number of other characteristics of the respective scenarios. Important characteristics include: (a) what type scenarios have been developed (forward-looking, back-casting, explorative, normative); (b) whether the scenarios are underpinned by results from simulation models; (c) what spatial and temporal resolution do the scenarios address; (d) by whom and how the scenarios have been developed; and (e) how food system related factors have been addressed.

What types of scenarios have been developed?

All seven forward-looking studies discussed in this paper explore the implications of a changing world in an integrative manner and depict sets of alternative scenarios. All except one of these assessments build on forward-looking, explorative scenarios ("what-if" scenarios). Ground for Choices differs somewhat from this, as its scenarios are developed to assess whether a number of normative policy goals are feasible, and what their implications for land use and food consumption are.

The forward-looking assessments presented by UNEP, ATEAM, EUruralis, and MA each explore the implications of four contrasting, but more or less linear pathways into the future: thus these scenarios might be labelled as "alternative projections". Commonly the alternative projections developed in these studies are based around assumptions on the level of globalisation of the market for commodities on the one hand, and the degree of political intervention or prevailing cultural values on the other. It should be noted that both the ATEAM and EUruralis scenarios are based on the scenarios originally developed by the Intergovernmental Panel on Climate Change (IPCC, 2000).

SCAR presents a very different type of scenario set: besides detailing a "baseline-like scenario", it addresses the implications of a selected number of possible disruption factors (climate shock, energy crisis, food crisis), as well as one "utopian" scenario. PRELUDE, finally, combines the two types of scenarios, and includes alternative forecasts and disruption scenarios side by side.

Have the scenarios been underpinned by simulation models?

Forward-looking assessments can build upon quantitative scenarios, qualitative scenarios, or combinations of both. Recently, scenarios that address cross-cutting issues such as environmental or socioeconomic change bring together both scenario narratives (*viz.* to develop and illustrate a range of alternative futures) and simulation models (*viz.* to underpin and analyse the assumptions made and conclusions reached in each of the alternative futures depicted) – see also EEA, 2002.

Most of the forward-looking assessments discussed here (with the exception of the SCAR scenarios, which are developed around narratives only) have applied a suite of models to quantify and analyse selected scenario aspects. The Ground for Choices study used a linear programming model (augmented by qualitative evaluation techniques) to calculate the optimal allocation of land use under given sets of economic, social and environmental policy goals (i.e., the GOAL model).

Both UNEP and MA employ a similar set of global level models within their cross-cutting environmental assessments to quantify a set of socioeconomic drivers (the PoleStar model, in UNEP only), climate change and land use change (the IMAGE model), water stress (the WaterGAP model) or agricultural commodities and trade using a partial equilibrium model (the IMPACT model, in MA only).

Also the European-scale land use change studies presented in EUruralis, ATEAM and PRELUDE base their assessments partly on simulation models. ATEAM and PRELUDE both make use of the same land cover model (the Louvain-la-Neuve Land Cover Model; in the ATEAM project this is based on European agricultural demand figures from the IMAGE model). EUruralis links three different models to compute changes in agricultural land: a general equilibrium model (GTAP), an integrated environmental assessment model (IMAGE), and a high-resolution land use model (CLUE-S).

What spatial and temporal resolution do the scenarios address?

All seven scenario exercises presented here address either the global or the European dimension (see selection criteria for including assessments in this review). The scenarios presented by UNEP and MA primarily look at European developments in a global context, and address Europe as one among several aggregate world regions. As a consequence, the spatial resolution, at which European aspects are described, is coarse for most outcomes: UNEP distinguishes only between Western, Central and Eastern Europe, while MA often presents projections only for the entire OECD region.

The other five scenario exercises have greater emphasis on developments within Europe. PRELUDE, EUruralis and ATEAM focus on the European Union as a whole (i.e., the 25 pre-2007 Member States), and present land use futures for all of Europe at high spatial resolutions (PRELUDE and ATEAM show land use changes on a 10-minute grid, EUruralis even on a 1 km grid). Also the SCAR scenarios centre on the European Union. However, here expected future developments are described at coarse resolution only (and only within the text of the scenario narratives). Finally, the coverage of the Ground for Choices exercise is limited to the 12 EU Member States of 1992 (EU-12).

The time horizon and temporal resolution of all seven scenario exercises is similar: all reflect on developments over the next 20 to 50 years. The shortest time horizon (the year 2015) is presented in Ground for Choices. The longest perspective is presented in the scenarios of ATEAM (2080s) and the MA (2100), but both exercises also present some results for intermediate time steps (primarily 2020s and 2050s). By comparison, PRELUDE, EUruralis, and UNEP address a shorter time horizon (2030s). The end year of the SCAR narratives varies, but all include at least a 20-year perspective.

By whom and how have the scenarios been developed?

As noted above, most of the forward-looking assessments discussed here (with the exception of the SCAR scenarios) have applied a suite of models to quantify and analyse selected aspects of scenario storylines. The scenarios themselves, and especially their respective narratives, were arrived at using rather different methodologies.

The ATEAM and EUruralis studies based their assessment on scenarios developed by the Intergovernmental Panel on Climate Change. The 5th EU Framework Programme project ATEAM used both stakeholder consultation and expert input to downscale them to the European level. In the EUruralis project, the European-level scenarios were downscaled by a group of experts from the cooperating research institutes. The project was commissioned by the Dutch Ministry of Agriculture. Ground for Choices was also originally a Dutch initiative – nevertheless, it received considerable attention at the European level. Here the scenarios were detailed by a group of experts based on main streams in the social discussion on the future of agriculture.

Both in UNEP and MA the scenario narratives and underpinning modelling evolved in an iterative process (see EEA, 2002). A scenario panel, in both cases composed primarily of a group of experts, developed initial scenario storylines. Modelling teams then quantified key elements of the scenarios, which allowed for a revision and further elaboration of the original storylines. A similar approach was applied to construct the PRELUDE scenarios presented by the European Environment Agency. However, here the scenario narratives were developed by a varied group of 20 stakeholders. The SCAR scenarios, finally, were developed by a group of experts who reviewed and analysed foresight information relating to European agriculture under the coordination of DG RTD.

How have food systems been addressed by the scenarios?

Where the forward-looking studies presented here have addressed food-related issues, they have primarily centred on issues relating to food availability, food production or food supply. Indeed, most of the scenarios introduced here focus either on land use changes or agricultural futures (i.e., Ground for Choices, PRELUDE, EUruralis and SCAR). Alternatively, food provisioning is addressed in the context of ecosystem changes (MA, ATEAM) or in the wider context of environmental change (UNEP).

To some degree all of the studies also include (at least implicitly) some assumptions on future consumption or food demand and address food market trends. In particular those assessments that make use of general/partial equilibrium models to calculate food demand (such as MA and EUruralis) necessarily calculate food consumption. Here the Ground for Choices study offers some additional detail by looking into the impact of different levels of food consumption, contrasting, for example, the impacts of a preference for a protein-rich "luxury diet" versus "current diet".

Neither food system activities related to the issues of food processing and packaging nor the retailing and distributing of food have been discussed in much detail in any of the scenarios. The only exception to this is provided by the SCAR study, which mentions issues related to packaging and processing in some of its scenarios (for example, in the "food crisis" scenario).

Need for a scenario-based assessment of European food systems

This review highlights that there is a lack of scenarios that focus on food systems in a changing world at the European level. Individual food system activities, especially those related to food production, are addressed in the studies featured here, but also in other projection-based agricultural assessments. Yet, none of these assessments seems to look at European food security in the wider context.

However, a range of questions related to the future of food systems and food security in Europe remain, which can only be answered if implications and feedback of different food system activities are included. Examples of this kind of question have been reiterated within this ESF/COST Forward Look; see Chapter 2 for more details. Thus, to answer these and other questions, a need emerges for a crosscutting and integrated scenario-based assessment of European food systems and European food policies.

3.5 Proto-scenarios to support food system analysis

In looking to the future, the aim was to create two further opportunities to learn about the present European food systems and the implications for policy intervention. The first opportunity is to look at the future to perceive the system itself, for example, the component parts of the system (production, processing, packaging, distribution, retailing and consumption) and how they are linked with one another. The second opportunity is to re-perceive the system by looking from the "outside in". How might developments in the wider context reshape our understanding, as well as the reality, of the European food system? In the ESF/COST Forward Look this has been realised by building proto-scenarios, i.e., alternative, but crude, impressions of possible future contexts.

Time permitted only two of the four proto-scenarios to be used to inform the ESF/COST Forward Look search for research questions, i.e., what are the questions we need to ask ourselves today if we are to design future research in a way to formulate policy interventions that are effective, purposeful and robust in the face of an imperfect understanding of the system itself and of the influence of future developments of the wider context in which the system is situated?

In building a set of proto-scenarios, the ESF/COST Forward Look has avoided treating the future as continuity from the present, i.e., an extrapolation of trends from the past that we pay attention to today. Instead the proto-scenario building process commenced its search in recognition of the discontinuities and surprises that might characterise the wider context and reshape the European food system.

The starting point for developing these proto-scenarios was to utilise an existing set of scenarios – the four surprise/disruption scenarios developed by DG Research for SCAR, namely Climate Shock, Energy Crisis, Food

Crisis, Cooperation with Nature (see: http://ec.europa.eu/research/agriculture/scar/index_en.cfm?p=3_foresight). The SCAR scenarios by themselves, however, could not provide a pre-existing, clear and logical scenario framework, or set of storylines, that are relevant to the consideration of European food systems – see Section 3.4 for a fuller reflection.

Nevertheless, key factors that were identified as external and potentially significant in shaping the evolution of European food systems included: the degree of climate change; policy responses to non-food system concerns — such as energy security, health; globalisation of food supply; and, innovation in food technology (production, processing and packaging).

The four proto-scenarios

Based on an understanding of these key factors, a proto-scenario framework was developed and used as a basis for further discussions in the ESF/COST Forward Look (Figure 3.3). Next, the proto-scenarios were developed by a diverse group of 20 researchers and stakeholders under the guidance of Angela Wilkinson and Pam Hurley at a two-day ESF/COST Forward Look workshop in Preddvor, Slovenia in May 2007.

Only two of the proto-scenarios were explored in any further detail and, even then, only in slightly more depth. There now follows a description of the four proto-scenarios:

- **FAST FORWARD** – *More global markets with a low incentive to act*
  A future shaped by the combination of continued economic globalisation, the expansion of global food markets and decreasing public concerns about climate change, energy security and food safety scares.
- **PAUSE** – *Globalising markets and higher perception of risk*
  The stop-start dynamic that was unfolding at the start of the millennium between the twin engines of global economic growth and climate and ecological sustainability moves up a gear. A series of events, crises and scandals unfolds. Despite early warnings, the lessons are late: a number of countries simultaneously experience public health crises, stemming from globally extended food supply and processing chains coupled with supply side disruptions from extended droughts and/or flooding. In a world of food-related fears and panics, people seek a comfort zone in traditional foods. Market actors, in collaboration with regulators, respond with a plethora of food verification and accreditation services. As mass-produced food gets safer and holds its par nutritionally with organically-farmed products, the economic and social

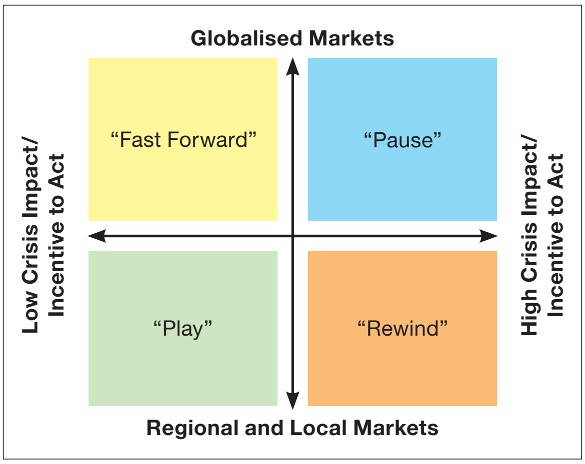


Figure 3.3. The framework of the proto-scenarios

value of ordinary food increases. The combination of increased global productivity and lower global food prices (on average), however, sees some producers further marginalised from a possible share of benefits in exporting to and importing from global markets. In response, Chinese consumers launch "Food Aid" to help African and Brazilian farms enhance traceability and food processing safety. In the process, this campaign helps to reduce some of the implicit trade barriers facing developing economies as they seek to increase and diversify food exports. As the diversity of food suppliers and supplies increases in the global market, China further increases its dependency on foreign imports. As global market integration increases, European food production goes down but global production goes up. Consumers relish the very wide variety of safe food available to them from all around the world, although in some cases prices are high. These reflect in part the high costs of shipping food all around the world and this feeds concerns about energy shortages. The threat of reducing land availability for food in order to grow biofuels to meet the fuel crisis finally makes even the food lobby take notice and there is a concerted movement to provide better storage facilities and enhance product shelf life so that "food miles" can be reduced.

- **REWIND** – *Higher awareness of impact and incentive to act with regionalised focus*
  The *laissez-faire* approaches of governments in the early years of the 21st century have provided consumers with a wide range of foods, albeit at relatively high prices. However, problems in the Middle East, which seem intractable even to the so-called "Quartet of Global Powers", along with the increasingly unpredictable behaviour of Russia, ensure focus on global energy

security concerns over the longer term. Alternative fuels really must be developed, and fast, and fuel supplies conserved. The impacts of climate change create opportunities as well as downsides. The daily use of the North West passage is a boon to commercial shipping but the frequent flooding and unusual weather patterns have made agriculture in Europe a much riskier livelihood and the pressure is on to find adaptation and palliative measures. Collaboration across Europe, both of national governments and in R&D, enables the most efficient utilisation of natural resources to suit the specific circumstances. Water limitations change the cultural landscape of the EU and there is a shift in traditional agricultural zones to better fit the new climate conditions. Following the redefinition of the Treaty of Rome, governments at a regional and national level together legislate to impose heavy tax penalties on foodstuffs that have to travel halfway around the world. These penalties appeal to the eco-lobby, which has a deep mistrust of unusual foods whose traceability is limited. Resistance to the overweening power of the ever-decreasing number of ever-larger supermarkets becomes very vocal and consumer boycotts are no longer a rarity. An unusual Europe-level alliance of consumer bodies, NGOs and governments together preach the message of safe, fresh foods, locally grown and appropriate for the season. Initially reluctant to abandon their global supply chains, the big retailers soon learn that this movement to localise food production is unstoppable and move to make the best deals they can with the cooperatives that are springing up everywhere. You can now tell what country you are in and the time of the year simply by walking around the local supermarket. You may not be able to tell from the label exactly what is in every product and therefore how healthy it is, but at least you can be confident that it was not produced thousands of miles away using processes unknown to you. This focus on local, seasonal food breathes new life into food tourism and regions increasingly identify themselves by the food they have on offer, holding festivals in celebration of the first crop of their special fruit or vegetable. There is renewed pride in reinvigorating particular varieties, some of which had almost become obsolete in the first decade of the new millennium, and those who are able to do so achieve a new status in their community.

- **PLAY** – *Regionalised markets and low perception of risk*
  Confidence in European agriculture is high. The movement towards sustainable production of organic foods has now moved from peripheral to mainstream and Europe is uniquely well placed to deliver that. The drive towards sustainability applies to wildlife, flora and fauna just as it does to foodstuffs. But not everyone can benefit from this fragmented world epitomised by "Tuscany Agriculture." Many parts of Eastern Europe are more focused on developing their economies than on sustaining agriculture. There is a distinct polarisation between those who can afford to enjoy the individualised products available from specialised shops that are supplied by small-scale, local farmers and those who mourn the increasing loss of the wide variety of cheap products imported by the large supermarkets.

Comparison of the different characteristics of each scenario

A full scenario exercise would enable attention to different dimensions of changes in the wider context of the European food system. For example, and for illustrative purposes only, the key characteristics vary between the four proto-scenarios, as shown in Table 3.1.

Deriving implications using the proto-scenarios

A full scenario process would reveal clear and different implications for different parts, as well as the "whole" of the European food system. For illustrative purposes only, an initial set of implications is provided in Table 3.2.

Using the proto-scenarios to inform a research agenda

Two of the proto-scenarios were presented for discussion at the ESF/COST workshop in Budapest, Hungary in November 2007, involving wider stakeholders in European food systems. The workshop provided a further opportunity to:

- Explore the initial implications for the different parts (production, processing, packaging and distribution, retailing and consumption) and the "whole" European food system under two proto-scenarios, as an illustration of the potential added value of a full scenario exercise in the years ahead.
- Help identify any additional contextual factors (driving forces) and research questions that should be taken into account.

Participants were divided in two parallel break-out groups, of which one group discussed the proto-scenario "Pause" and the other group the proto-scenario "Rewind". Special focus was on the implications of these scenarios on the four sets of activities – producing, processing, packaging and distributing, and retailing and consuming – and on research questions that result from these implications. Each parallel break-out group was divided in smaller groups of 6-8 persons.

Table 3.1. An initial comparison of proto-scenarios (illustrative purposes only)

Key characteristics	Scenario			
	Fast Forward	Pause	Rewind	Play
Prices	Low	Low on average + global / – regional	High	Polarised
Social value	Genetically tailored	Choice safety	Seasonal/local	Social differentiation
Whole system	High energy use	Disruptions	Collaboration	Local adaptation

Table 3.2. Illustrative example of different implications derived using the proto-scenarios

Food system component	Scenario			
	Fast Forward	Pause	Rewind	Play
Production				
Pattern	globalised	globalised	regionalised	localised
Resource-use efficiency	market/price incentives	approached from multiple angles	protectionism prevails	multifunctional types flourish
Land use	lots of agric. land freed up for other uses	some land freed up from agric. uses	greater land take by agric.	greatest land take by agric.
Biodiversity	vulnerable to large-scale epidemics	global benefits	locally addressed	localised benefits
Retailing and Consumption				
Labelling and traceability	high	high	less diversity	more organic and sustainably produced
Regulation and steering	low	moderate (state-led)	high (multiple local authorities)	high (regional level)
Locality, freshness and authenticity	low	low	high	high

After the proto-scenarios were discussed, both groups came together and mixed with each other into new small groups. These newly-formed groups discussed general research needs/questions on food systems in appreciation of both proto-scenarios (and any other future context – as the two proto-scenarios were only used to help guide thinking about possible futures).

Examples of research questions for European food systems

- How to ensure flexibility/adaptive capacity of food systems in an efficient manner: local vs. global back-up systems?
- How could/would crises (e.g., energy crisis, health crisis, water stress, terror threats) affect food systems?
- What dynamics govern risk perception and consumer response? How does society respond to food scares?
- Can local references, production methods, product variety, feed supply, etc. be maintained in a globalised market and what is the role of SMEs in this? If so, how?
- Would a continued move towards globalised markets clash with local preferences ➔ is there a risk of a "cultural back flash" to globalisation of food systems?
- Can we better substantiate the strengths/weaknesses of European agriculture?

- Can we have better integration of European food policy?
- Is continued concentration of retailers making the system more volatile or stable? What are the implications for consumer welfare?
- What are trade-offs and implications for developing countries (less exports) vs. price vs. health?

3.6 Further considerations

Scenario processes encourage the elicitation of ideas and perspectives that would have been highly unlikely to appear otherwise. When people are able to indulge safely in thinking outside their own professional box, or beyond the timeframe of their imminent decision-making responsibilities, all sorts of new realisations can emerge. Scenario-based processes explicitly encourage the consideration of new developments from many different, relevant perspectives in order to identify what really matters and why. By respecting differences in perspectives — rather than seeking to force consensus — a scenario-based process can avoid polarisation and foster new insights.

By invoking alternative, equally possible futures the aim in building this set of proto-scenarios has been to enhance the collective ability to “see” the present European food system more clearly, and establish a shared research agenda that anticipates possible changes in the wider context of the system.

Rather than offering policy prescriptions, the proto-scenarios developed in the ESF/COST Forward Look on European Food Systems have helped to forge a wider appreciation of the need to consider food systems, as well as starting to apply the new vocabulary required for strategic conversation and policy planning on a more adaptive and systemic basis.

Meanwhile, the process of developing and working with this set of proto-scenarios has brought attention to a number of key considerations that need to be borne in mind for any subsequent and fuller scenario-based analysis of European food systems. These include:

- Who will build and use the scenarios?
- What balance is needed between *senso stricto* and *senso lato*, i.e.:
  – *senso stricto*, in the strict sense ➔ looking at food systems in depth
  – *senso lato*, in the broad sense ➔ looking at the context of food systems?
- What types of futures are digestible/can be consumed by different scenario users – predictable, probable, plausible, possible and/or preferable futures?
- What is the key purpose of the scenarios: exploration, sense-making, strategising and/or community building?
- What balance is needed between expert-led and quantitative analysis methods and more stakeholder-inclusive and qualitative techniques to ensure effective communication, engagement and deployment in decision making?

It is the view of the authors that the review presented in this paper, as well as the preliminary exercise described above, have helped to highlight an immediate research need: the need to, and value of, undertaking a more comprehensive scenario exercise focusing on the future of European food systems in the years ahead.

References

Börjeson, L., M. Höjer, K. Dreborg, T. Ekvall and G. Finnveden (2006). Scenario types and techniques: Towards a user’s guide. *Futures* 38(7): 723-739.

EEA – European Environment Agency (2002). *Scenarios as tools for international environmental assessments*. Environmental issues series No. 24, EEA, Copenhagen.

EEA – European Environment Agency (2005). *European Environment Outlook*. EEA Report 2/2005, EEA, Copenhagen.

EEA – European Environment Agency (2006). *PRELUDE – Prospective Environmental Analysis of Land Use Developments in Europe* – project web site – www.eea.europa.eu/prelude.

EEA – European Environment Agency (2007). *Land-use scenarios for Europe: qualitative and quantitative analysis on a European scale*. EEA Technical report No. 9/2007.

Emery, F. and E. Trist (1965). The causal texture of organisational environments. *Human Relations* 18: 21-32.

Ericksen, P.J. (2008). Conceptualising food systems for global environmental change research. *Global Environmental Change*.18(1): 234-245.

Ericksen, P.J. and J.S.I. Ingram (2005). *Global Environmental Change and Food Systems (GECAFS)*. IHDP Annual Report 2004-5. pp. 45-46.

EUruralis (2006). *EUruralis* project web site – www.eururalis.nl.

EU (2007). FFRAF report: Foresighting food, rural and agri-futures. Available at http://ec.europa.eu/research/agriculture/scar/pdf/foresighting_food_rural_and_agri_futures.pdf.

FAO – United Nations Food and Agriculture Organization (2002). *World Agriculture: towards 2015/2030*. Earthscan.

Funtowicz, S.O. and R.I. Ravetz (1990). *Uncertainty and quality in science for policy*. Vol.15. Kluwer Academic Publishers.
IPCC – Intergovernmental Panel on Climate Change (2000). *Special report on emission scenarios*. Oxford University Press, Oxford, 2000.
MA – Millennium Ecosystem Assessment (2006). *Ecosystems and human well-being: Scenarios* – Findings of the Scenarios Working Group, Millennium Ecosystem Assessment. Island Press. Washington DC.
Notten, P.W.F. van, J. Rotmans, M.B.A. van Asselt and D.S. Rothman (2003). An updated scenario typology. *Futures* 35(5): 423-443.
PIK– Potsdam Institut für Klimafolgenforschung: Schroeter, D., W. Cramer (and 57 others) (2004). *ATEAM – Advanced Terrestrial Ecosystem Analysis and Modelling.* Final report 2004 (Contract EVK2-2000-00075).
Available at www.pik-potsdam.de/ateam.
RIVM (Dutch National Institute for Public Health and Environment) (2004). *The GEO-3 Scenarios 2002-2032 Quantification and Analysis of Environmental Impacts*. RIVM Rapport 402001022, Bilthoven. 230 pp.
UNEP – United Nations Environment Programme (2002). *Global Environment Outlook 3: Past, present, and future perspectives*. (http://www.unep.org/geo/geo3).
Wack, P. (1985). *Scenarios: Uncharted Waters Ahead.* Harvard Business Review.
Westhoek, H.J., M. van den Berg and J.A. Bakkes (2006). Scenario development to explore the future of Europe's rural areas. *Agricultural Ecosystems & Environment* 114: 7-20.
WRR (1992). *Ground for choices: four perspectives for the rural areas in the European Community*. Sdu Uitgevers, The Hague, The Netherlands.
Zurek, M.B. and T. Henrichs (2007). Linking scenarios across geographical scales in international environmental assessments. *Technological Forecasting and Social Change* 74(8): 1282-1295.

4. Food system activities

4.1 Current systems and future scenarios for food production activities

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4.2 Current systems and future scenarios in food processing

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4.3 Current trends in distribution and packaging

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4.4 Current trends in food retailing and consumption and key choices facing society

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4.1 Current systems and future scenarios for food production activities

4.1.1 Introduction

Food systems consist of the following subsequent activities: production, processing, packaging and distributing, retailing and consumption. This paper describes the key current food production activities in the European Union, the main drivers with respect to evolution of those systems in the coming decades and finishes off with an initial outlook on how those systems might evolve under different scenarios. The latter is crucial to identify a research agenda taking into account uncertainties with respect to drivers and factors which are largely exogenous to the food production part of the system.

Three questions have been identified in the course of the process of the ESF/COST Forward Look that frame the analysis and outlook of food production systems:

- Will there be substantial changes in agricultural resource use in Europe as a consequence of intensified production systems and policies on energy security/diversity?
- Will changes in global food markets (resulting e.g. from industrialisation in China, India and South America, energy security policies in the USA, and climate change in sub-Saharan Africa) result in changed production systems in Europe?
- Will new technologies be adopted in Europe or elsewhere that result in "best" methods of food production, enhance environmental management and healthy foods?

In the following sections these questions are not addressed one by one. Instead, we provide information about present systems that forms a basis for answers to the three questions. The information is structured according to the three questions, but the information provided allows analysis of a broader set of questions. We preferred this set-up as there is overlap in information needed to answer the three questions, and we also think the selection of the three questions is somewhat subjective and arbitrary. We hope the information provided in this paper is somewhat robust and useful also for addressing slightly different questions. In Section 4.1.5 we make a start in trying to address the questions, though answering them is beyond the scope of this paper and would be speculative by definition, given the uncertainties surrounding the exogenous drivers.

The paper starts with a short account of the methodology followed to describe current production systems in Europe. Section 4.1.3 presents empirical and experimental information about key attributes and indicators of agricultural production systems which are necessary to address the three questions listed above. Section 4.1.4 provides an overview of important drivers which are largely exogenous to agricultural production systems, but affect their evolution in the decades to come. Section 4.1.5 makes an initial attempt to relate the information on agricultural production provided in Section 4.1.3 to the drivers presented in Section 4.1.4, using the three questions. Section 4.1.6 presents possible implications, from a production perspective, of four scenarios which have been developed in the ESF/COST Forward Look and which underpin the process, to come to a robust research agenda, of which a first version is presented in the final Section 4.1.7.

4.1.2 Methodology for describing and analysing food production systems in the European Union

4.1.2.1 Indicators

The analysis of the three questions listed in the Introduction, or related questions, requires information on a range of characteristics of agricultural systems. For this purpose we will use so-called "indicators" of agricultural systems, of their sustainability and their contribution to sustainable development at large. Indicators are defined as "parameters, or values derived from parameters, which provide information about the state of a phenomenon/environment/area with significance extending beyond that directly associated with a parameter value" (OECD, 1993). Indicators can be used to help monitor and assess policies and programmes (including R&D) and to provide contextual information, to identify new agri-environmental issues, to assist in targeting programmes addressing such issues and to understand linkages between agricultural systems and other economic sectors and ecosystems (after EC, 2000).

For the analysis of the three questions above, in the light of the purpose of this Outlook exercise, we need indicators reflecting the economic, environmental and social aspects of sustainability of agricultural production systems and of the contributions of such systems to sustainable development of society at large. We propose that only this broad perspective allows a sufficient holistic analysis of the three questions and, importantly, provides flexibility as to the questions to be addressed. The analysis keeps relevance (i.e., the indicators can still be used) when the precise questions at stake change.

Indicators reflecting the status and performance of agricultural systems and their relationship with the environment are increasingly used in the policy domain and agro-industries. Analyses using established indicators will benefit from "recognition" and "a common ground". For us this was a reason to make use of existing indicators, if possible and relevant, in particular those of the European Commission and the recently-established list of agri-environmental indicators by the European Environmental Agency (EEA, 2005). Obviously, these lists of indicators were developed for a particular purpose, with limitations for our aim. In particular, we argue that the degree of agronomic detail in the indicators, allowing analysis of agricultural management and resource-use efficiency, is inadequate. We have therefore extended our analysis to include indicators reflecting resource-use efficiency and identification of limitations and shortcomings of current production systems and technologies. These indicators also provide a handle to identify new systems and technologies in the ESF/COST Forward Look phase.

The EEA listed criteria used to evaluate the usefulness of individual indicators. These criteria include: political relevance, responsiveness to actions, analytical soundness, data availability and measurability, ease of interpretation and cost effectiveness in relation to information derived from the indicator (EEA, 2005).

In our assessment of the performance of agricultural systems and how this evolves, we need to consider some (indicators for) external factors that are subject to change and may affect agricultural systems, especially those reflecting economic growth, technological development, climate change, energy prices, international agreements and policy development.

4.1.2.2 Spatial and temporal detail

Indicators used for policy evaluation (ex-post) or assessment (ex-ante) in the European Union generally use a spatial detail at NUTS2 (administrative) level or at member state level. Indicators derived from the so-called Farm Accountancy Data Network (FADN) of DG Agriculture can be presented only at a slightly coarser scale, i.e. HARM level, which is a level between NUTS2 and NUTS1. Pan-EU information on agricultural management is scarce and will not allow greater spatial detail than HARM regions for two reasons: (1) data may not be available; and (2) if available, disclosure rules do not allow their presentation. For the purpose of this paper, we however need some more location- and case-specific information on agricultural production options. We therefore provide indicators at three different spatial levels: (1) member state level; (2) NUTS2 level within EU-27; (3) examples of specific location production systems reflecting the different biophysical and socioeconomic conditions in the EU. If possible, we use so-called existing typologies, such that specific examples have some statistical representation. Typologies for farms are based on those developed within the EU project SEAMLESS (Van Ittersum et al., 2008).

Data availability allows a fairly complete picture for the former EU-15, but less for the 10 countries which joined the EC in 2005 and even less so for Bulgaria and Romania which entered the EU in 2007. In this paper, EU-15 refers to member states of the EU until 2005; EU-10 to the ten new member states as per 2005. In a few cases data of Norway and Switzerland are part of the analysis. In some instances we cluster European countries following the zonation used by Olesen and Bindi (2002) (Figure 4.1).

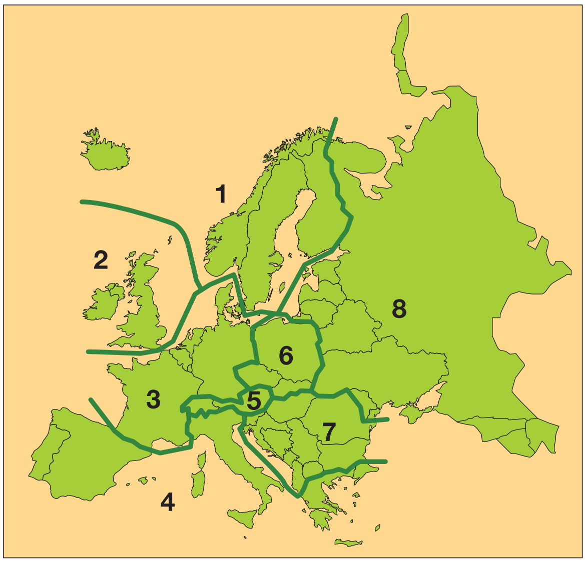


Figure 4.1. Agricultural regions in Europe. For names, see Table 4.2; for countries see Appendix 1. (Source: Olesen and Bindi, 2002)

In Section 4.1.3.2 indicators are presented, mainly to reflect the current situation, implying indicators with the most recently available information (generally dated 2003-2005 or older). Wherever useful and available, we also provide some information on trends, and an indication of what may be achieved with already available ("on-the-shelf") knowledge, systems, technologies and information which is currently not in widespread use. The indicators relate to the three questions, as presented in Table 4.1 (next page). In Section 4.1.5 we try to tentatively answer the three questions.

4.1.2.3 Comprehensiveness

It is by no means possible to provide a full picture of the EU's agricultural systems for two reasons: (1) information is largely lacking; (2) the paper would become a bulky report with lots of information and cumbersome analysis. The choice of indicators and information presented reflects the information available and includes subjectivity of the authors to get to an analysis, and a basis for an outlook of EU's agricultural systems.

4.1 Current systems and future scenarios for food production activities

Table 4.1. Relation between indicators presented in Section 4.1.3.2 and the three questions related to future food production

	Question 1	Question 2	Question 3
Resource use (per ha) • land • energy • nutrients • water	×	×	
Resource-use efficiency (per kg or € product)	×	×	
Intensity of production • output intensity • input intensity	×	×	
Yield gap	×	×	
Competitiveness • farm structure • labour productivity • cost price		×	×
Climate change • climate change • adaptability		×	
Use of GM crops			×

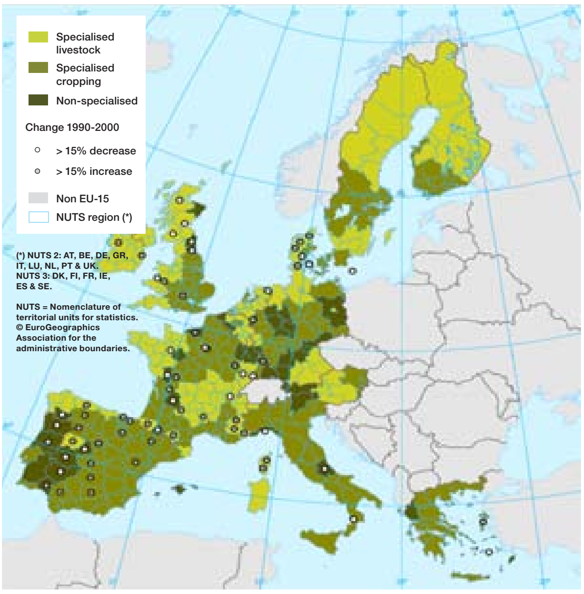


Figure 4.2. Regional distribution of dominant farm types by specialisation and the trend 1990-2000. "Non-specialised" includes non-specialised livestock, non-specialised cropping and non-specialised cropping/livestock. Information on trends in the regions of Finland, Sweden, Austria and Germany is not available. (Source: EEA, 2005; Eurostat)

Table 4.2. Land use and output per region in Europe based on EU statistics till 2005. For country-level data, see Appendix 1. UAA = Utilised Agricultural Area. (Source: Eurostat, 2007)

Region		Agricultural area (2004)		% of agricultural area (different years/period)						Output (2004)		
Number	Name	Agricultural area (1000 Ha)	Agricultural area of total (%)	Arable land[1] (2005)	Permanent crops[1] (2005)	Permanent pasture[1] (2005)	Horti-culture[2] (2001-2004)	Irrigable area[3] (2005)	Organic farming (2003)	Agricultural industry Mio euro	% of the EU-27 (%)	Euro per ha UAA
1	Nordic	5 407	7	93	0	7	0.5	4.4	10.5	4 233	2.6	1 710
2	British Isles	21 377	68	38	0	62	0.7	1.0	3.4	6 169	8.9	1 621
3	Western	52 765	52	66	3	31	1.6	10.0	2.9	6 858	41.7	2 748
4	Mediterranean	46 355	45	51	21	27	10.9	21.6	4.6	595	31.5	2 280
5	Alpine	3 254	39	42	2	56	0.7	3.7	10.1	5 804	1.7	1 779
6	North Eastern	21 867	50	75	2	22	2.9	1.6	1.6	3 623	5.7	927
7	South Eastern	26 008	56	72	3	24	3.6	4.1	0.7	3 464	7.1	953
8	Baltic	5 017	29	66	1	32	2.0	0.1	1.8	473	0.7	474
	EU-27	182 048	42	61	7	32	4.3		3.4	347 573	100.0	1 916

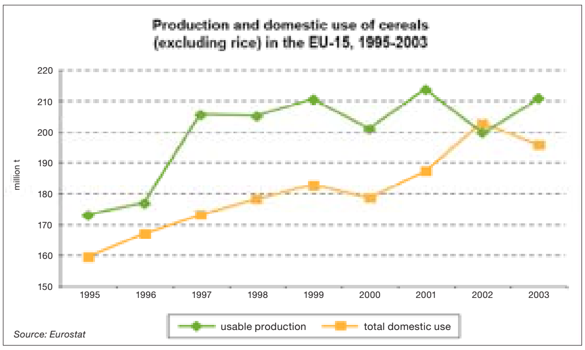
[1] Cyprus, Bulgaria, Romania: 2003 data — [2] 3 to 4 year average — [3] some countries: no data

4.1.3 Current agricultural production systems in the EU

4.1.3.1 Initial characterisation of agricultural production in the EU

The EU-27 uses 182 of its 433 million ha for agriculture, which amounts to 42% (Table 4.2). On this area 348 billion € gross value is produced. The EU-25 counts close to 10 million farms (ca. 5% of the total employment, varying from 1.2% in the UK to 18.7% in Lithuania); Bulgaria and Romania add another ca. 5 million farms. For the EU-25 the gross production per farm is ca. 31 k€. The EU-15 was already the largest exporting trade block globally with respect to agricultural products (2004), taking ca. 24% of the global agricultural exports; the EU-10 added another ca. 4% to this share. The EU is also the largest importer of agricultural goods (the EU-15 takes 23% of the global imports). The share of agricultural production in GDP is 1.6%.

Table 4.2 provides some values of the regional distribution of agriculture, in terms of area and output. Of the agricultural area 61% is in use for arable farming, 32% for permanent grassland and 7% for perennials. Some spatial differentiation between arable and livestock farming can be observed in the EU-15 (Figure 4.2). Dominant crops are wheat, barley, maize, potato and sugar beet (Table 4.3). Horticulture under glass amounts to 113.6 kha (EU-25), of which Spain, Italy and the Netherlands take 84.8 kha (LEI, 2005). Evidently, agriculture is a very important sector in the EU, policy-wise. An annual 43 billion €, ca. 34% of the budget of the EU, are spent on agricultural policies; in addition, part of the 12.4 billion € for rural development is used directly or indirectly for the agricultural sector. Partly due to decreases in price subsidies, production of cereals now almost matches total use in the EU; for meat, production is still much higher than internal consumption (Figure 4.3).



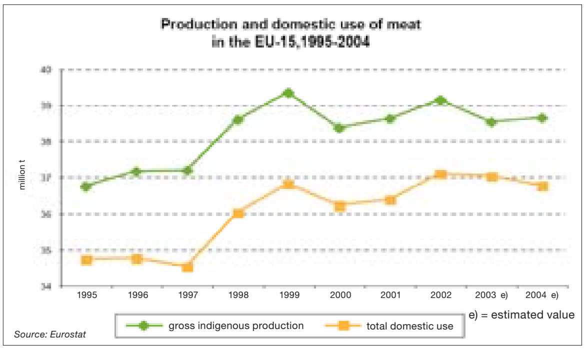


Figure 4.3. Production and domestic use of cereals (excluding rice) in the EU-15, 1995-2003 (top) and of meat in the EU-15, 1995-2004 (bottom) (Source: Eurostat 2007)

Agriculture is associated with a range of environmental externalities, including water use and water pollution with nutrients and pesticides, soil degradation, greenhouse gas emissions, air quality and effects on landscape quality and biodiversity.

Table 4.3. Area under arable crops (1 000 ha), by crop, 2004.
For country-level data, see Appendix 2. (Source: Eurostat, 2007; Eurostat, 2006a; Eurostat, 2006c)

	Region	Wheat	Rye	Barley	Oats	Corn	Potatoes	Sugar beet	Silage maize
1	Nordic	629	51	925	552	0	58	78	5
2	British Isles	2 097	4	1 189	142	0	160	184	117
3	Western	9 371	691	4 403	416	2 324	724	1 059	3 274
4	Mediterranian	5 523	133	3 580	724	2 060	263	361	471
5	Alpine, Austria	290	46	191	30	179	22	45	76
6	North Eastern	3 543	1 642	1 707	604	647	773	398	598
7	South Eastern	4 541	77	1 100	322	4 902	335	89	194
8	Baltic	597	107	559	141	1	138	37	17
	EU-27	26 591	2 750	13 652	2 930	10 116	2 472	2 252	4 751

Data for oats: Estonia, UK and Cyprus — potatoes: France and Cyprus — sugar beet: Latvia are from previous year

4.1 Current systems and future scenarios for food production activities

4.1.3.2 Analysis of agricultural production systems in the EU

(a) Resource use and resource-use efficiency of agricultural production

Land

Agriculture uses more than 40% of the land area and is the prime user of land (Table 4.2). In terms of land use, arable crops and permanent grassland are the dominant types of agriculture. Analysing land use efficiency is equivalent to assessing productivity (yields per hectare). Figure 4.4 and Table 4.4 show the dramatic increase in agricultural productivity for several crops; note that yields in Figure 4.4a are expressed on a fresh weight basis, which gives the impression that yields of cereals, having a high dry matter content, have increased relatively little. However, expressed on a dry matter basis this would not be the case. Figure 4.4b shows that increases vary substantially across countries. In Figure 4.5 wheat yields are used as an indicator for productivity of arable farming. Evidently there is an enormous variation across the EU in terms of land productivity. The highest productivity is found in NW Europe and the lowest in Mediterranean regions. Variation is also high within relatively homogeneous biophysical conditions. For example, yield variation across different farms in NE Italy was 13-122 GJ per ha of rape and 14-124 GJ per ha for sunflower (Venturi and Venturi, 2003). Table 4.5 provides an overview of productivity of wheat and milk across the EU-27. Milk productivity seems to vary less than wheat productivity, but it is likely that when milk productivity is expressed on a hectare basis, the variation would be quite similar.

Intensity of agriculture

Intensity of farming can be expressed in the amount of inputs per hectare or the amount of output per hectare. The two indicators do not lead to the same conclusions with respect to intensity of a region, though relationships are evident (compare Figures 4.6 and 4.7). High output intensities are associated with high fertiliser and crop protection use, low share of fallow, high stocking density and high milk yields per livestock unit (Tables 4.6 and 4.7).

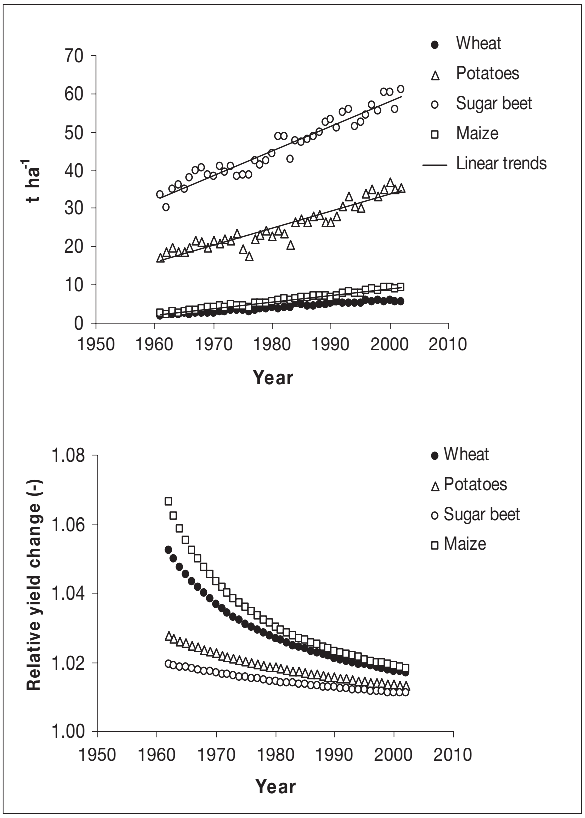


Figure 4.4a. Observed (FAO, 2003) (a) yields and (b) relative yield changes for selected crops in EU-15 + Norway and Switzerland (Source: Ewert et al., 2005)

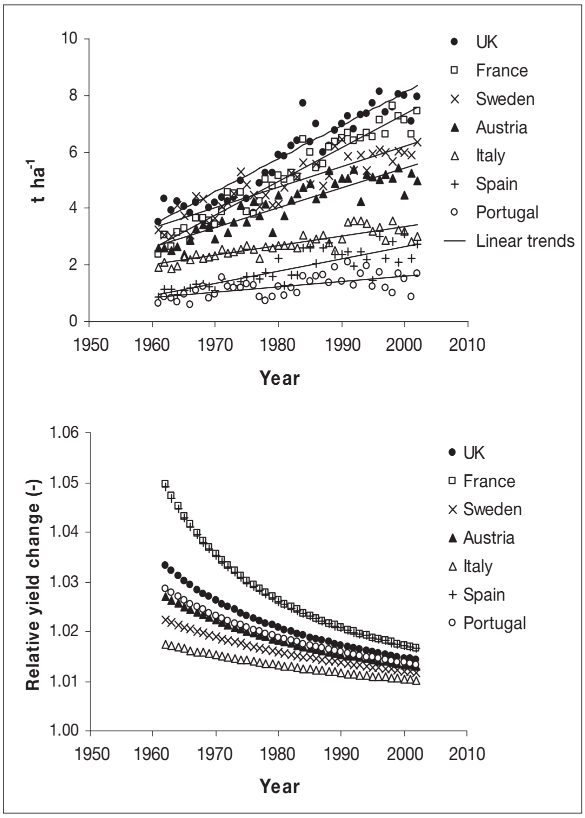


Figure 4.4b. Observed (FAO, 2003) (a) grain yields and (b) relative yield changes of wheat in selected countries in Europe (Source: Ewert et al., 2005)

Table 4.4. Land use and selected yield statistics for major European crops. Rates of yield change are in 0.1t ha^{-1} yr^{-1} (Source: Ewert et al., 2005)

Crop	Harvested area		Yield average (t ha^{-1})		Rate of yield change[a] (t ha^{-1} $year^{-1}$)	Relative yield change[b] (%)
	ha (×10^6)	% of arable area	1961-1970	1991-2000		
Cereals (all)	37.8	51	2.6	5.27	0.88	1.6
Wheat	18	24	2.4	5.54	1.02	1.74
Barley	10.7	15	2.9	4.29	0.47	1.06
Oats	1.9	3	2.37	3.28	0.29	0.84
Rye	1.2	2	n.a.	4.17	0.96[c]	2.05
Triticale	1.0	1	n.a.	4.87	1.45[d]	2.56
Maize	4.2	6	3.19	8.32	1.69	1.89
Potatoes	1.3	2	19.65	32.64	4.4	134
Sugar beets	1.9	3	36.53	55.31	6.43	1.1
Rapeseed	3.0	4	1.92	2.88	0.34	1.1
Sunf ower	1.9	3	1.17	1.54	0.18	0.9
Sum/average	45.9	53	–	–	–	1.51[e]

Scientific name of selected crops are *Trilicum aeslivum* (wheat), *Hordeum vulgare* (harley), *Avelia Saliva* (oats), *Secak cereak* (rye), X *Trilicosecale* (triticale), *Zea mays* (maize), *Solanum tuberosum* (potatoes), *Bera vulgaris* (sugar beets), *Brassica napus* (rapeseed), *Helianthus annuus* (sunflower). n.a.: not available.

[a] Calculated from measured yields between 1961 and 2002.
[b] Calculated from estimated yields for 1999 and 2000 (see Eqs. [1] and [2]).
[c] Based on available data from 1979 to 2002.
[d] Based on available data from 1986 to 2002.
[e] Value refers to area weighted average.

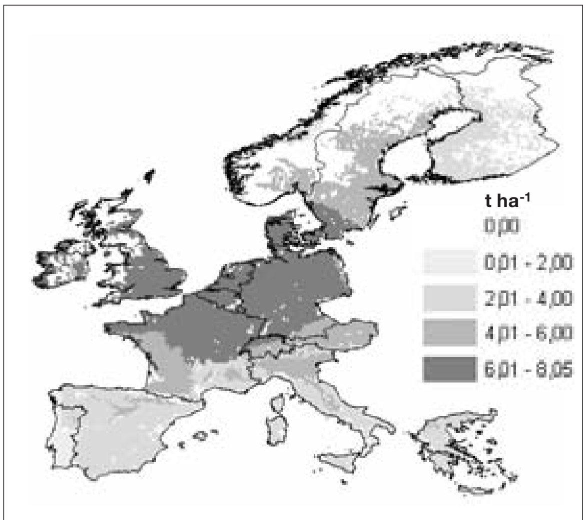


Figure 4.5. Wheat yields in EU-15 in 2000, based on Eurostat (Source: Ewert et al., 2005)

Region		Wheat productivity (2004-2006)	Cows' milk collected (2004-2005)
		ton per ha per region	ton milk per cow per year
1	Nordic	5.02	7.93
2	British Isles	8.03	6.15
3	Western	7.15	6.60
4	Mediterranean	3.23	5.92
5	Alpine	5.17	5.82
6	North Eastern	4.19	4.61
7	South Eastern	3.53	3.79
8	Baltic	3.20	4.45
	EU-27	5.26	5.88
	EU-15	5.98	6.43

Table 4.5. Agricultural output in different regions of Europe based on EU statistics. (Source: Eurostat)

Table 4.6. Selected farm management indicators for field crops farms (EU farm typology types 1 and 6) and for different combinations of the land use and intensity dimensions with which the EU farm typology has been extended. UAA = Utilised Agricultural Area. (Source: Andersen et al. 2007)

	Share of UAA (%)	Share of farms (%)	Wheat Yield (kilo/ha)	Barley Yield (kilo/ha)	Fertiliser use (Euro/ha)	Crop protection use (Euro/ha)	Set aside & Fallow/ UAA (%)
All field crop farms	100	100	6218	4312	99	92	10
Intensity							
Low-intensity	25	18	3455	3048	50	22	18
Medium-intensity	69	66	6701	5168	108	103	7
High-intensity	5	16	7181	5252	216	275	4
Land Use							
Arable/Cereal	50	44	6403	4815	107	96	6
Arable/Fallow	24	16	4972	3324	65	45	25
Arable/Specialised crops	10	18	7689	5690	149	180	4
Arable/Others	16	22	6308	4543	94	90	5
Intensity and land use							
Low-intensity cereals	8	7	3343	3123	64	30	7
Medium-intensity cereals	41	35	6697	5337	113	107	6
High-intensity cereals	1	2	7141	5470	162	180	5

Table 4.7. Selected farm management indicators for dairy cattle farms (EU farm typology type 41) and for different combinations of the land use and intensity dimensions with which the EU farm typology has been extended. UAA = Utilised Agricultural Area; LU = Livestock Unit. (Source: Andersen et al. 2007)

	Share of UAA (%)	Share of farms (%)	Stocking density (LU/ha)	Fertiliser use (Euro/ha)	Crop protection use (Euro/ha)	Milk yield (kilo/LU)	Permanent grass/ UAA (%)	Rough grass/ UAA (%)
All dairy cattle farms	100	100	1.7	82	24	6408	45	2
Intensity								
Low-intensity	2	1	0.4	13	1	3491	40	28
Medium-intensity	73	64	1.3	78	21	5952	46	2
High-intensity	25	36	2.9	98	32	6939	44	0
Land use								
Dairy cattle/ Land independent	1	3	7.7	133	63	6327	15	1
Dairy cattle/ Permanent grass	41	37	1.6	77	14	6229	74	5
Dairy cattle/ Temporary grass	16	15	1.4	76	19	6483	9	1
Dairy cattle/Others	42	45	1.7	87	34	6555	32	1
Intensity and land use								
Low-intensity permanent grassland	1	1	0.5	15	1	3815	50	39
Medium-intensity permanent grassland	31	26	1.4	74	13	5667	74	5
High-intensity permanent grassland	9	11	2.5	99	19	7176	77	1

Source: FADN-CCE-2003 DG Agriculture/A-3; SEAMLESS adaptation.

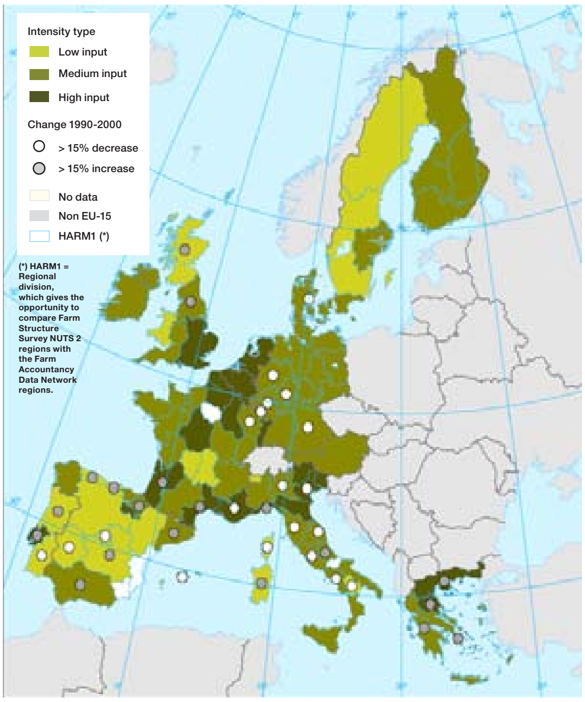


Figure 4.6. Regional importance of low-input, medium-input farming and the trend 1990-2000 (Source: EEA, FADN, Eurostat, LEI)

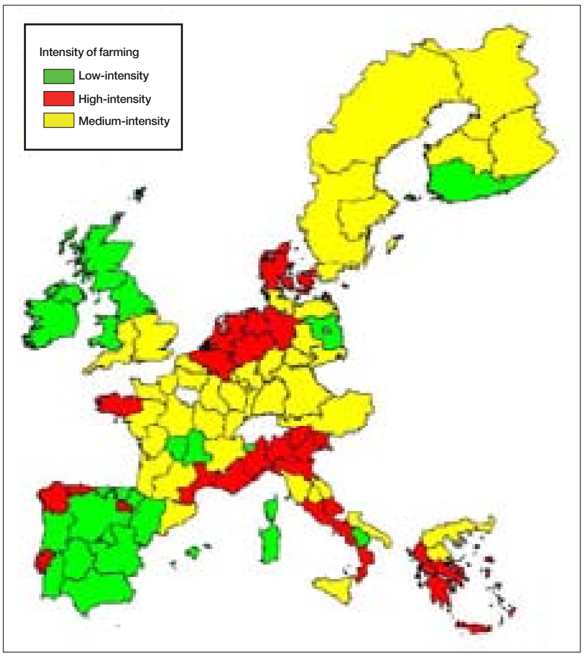


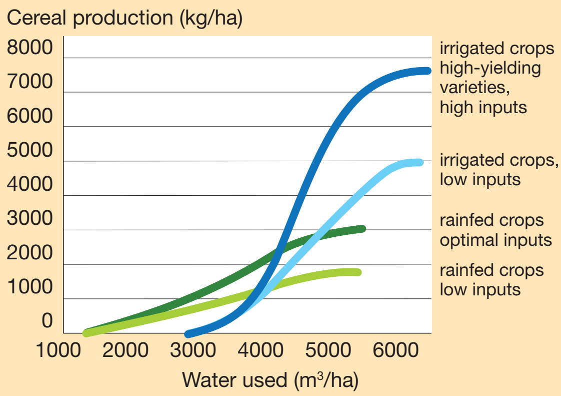
Figure 4.7. Regions where low- or high-intensity (based on outputs) farms manage more than 25% of the agricultural area (the highest shown if overlap) and with the remaining regions indicated as medium-intensity (Source: FADN-CCE-2003 DG Agriculture/A-3; SEAMLESS adaptation, Andersen et al. 2007)

At regional level there is a positive relation between the intensity of farming and the number of livestock units in a region (compare Figures 4.6 and 4.7). There are indications that input use per hectare has decreased somewhat since 1990, probably mostly on the intensive farms (i.e., lower nutrient and pesticide input), which points to increased use efficiencies of inputs.

Organic agriculture is a specific form of extensive agriculture. Its area has increased substantially over the past decade; in the EU-15 it increased from 1.8% in 1998 to 4.0% in 2003, totalling 5.3 million ha (EEA, 2005; EC, 2005), which is in relative terms still fairly small. At EU-25 level the share was 3.6% in 2003. Another category of agricultural land which is usually managed in an extensive way is "high nature value" (HNV) farmland; these are more extensive than organic agriculture. These are the farmland areas which contain the most biodiversity – rich areas of farmland. The estimated share of HNV farmland is 15-25% of the total agricultural area in the EU-15 (EEA, 2004; EEA, 2005).

When analysing intensity levels of farming, it is relevant to consider synergies between inputs. Figure 4.8 illustrates this principle for water and other inputs: irrigation is much more effective (also per drop of water) when other input levels have been optimised (De Wit, 1992).

Yields and water requirements of irrigated and rainfed agriculture



Irrigation has the potential to provide higher yields than rainfed agriculture but water requirements are also much higher

Figure 4.8. Synergy between inputs: well-managed crops use water more efficiently (Source: FAO, 2007)

Energy

In terms of energy use, agriculture is only a small economic sector: both in Europe and the USA it accounts for only ca. 2.4 and 1.1%, respectively, of the total energy use (Schenkel, 2006; Schnepf, 2004). This refers to the direct use only, and excludes consumption through fertiliser and pesticide production (and production of machinery and building). Inclusion of these energy sources increases energy use by about 50% (EEA, 2005); this still does not make agriculture a prime energy consumer. Energy use of agriculture in the EU-15 ranges between 0.5 and 6.5% of total energy use (OECD, 2007; EEA, 2005). Major sources of direct energy use are the use of oil products and electricity for heating and fuel for farm machinery. As a result of this, agricultural sectors differ a lot in energy consumption. Protected horticulture in countries such as the Netherlands is the dominant energy user, followed by intensive livestock sectors. Even though greenhouse horticulture in the Netherlands uses just a small fraction of the total area (0.5%), it accounts for 76% of the direct energy use in agriculture. Evidently, this shows the scope for energy-saving or efficiency-increasing measures in different agricultural sectors. Developments in, for instance, the Dutch horticultural sector demonstrate that much has been and can be gained; despite the fact that the area of horticulture under glass grew by 4% in the period 1995-2003, the energy use decreased by 10% (LEI, 2005). Figure 4.9 shows an even more drastic increase in efficiency in the 1980s.

Apart from great differences in energy use across sectors, energy use and energy-use efficiency differs between different production methods within a sector (e.g., intensive versus extensive systems; Table 4.8) and within a population of farms using similar types of systems. A study comparing sugar beet systems in the UK (Tzilivakis et al., 2005b) showed that different production systems (differing in soil type, production intensity and conventional versus organic) vary in energy use between 15.6 and 26.8 GJ/ha, and 0.26 and 0.54 GJ/ton of sugar beet. Generally, organic production systems use much less energy per hectare, but per ton of product the figures of organic and conventional systems are much closer, though organic still slightly outperforms conventional systems in most cases (Bailey et al., 2003; Tzilivakis et al., 2005b; Tzilivakis et al., 2005a; Gronroos et al., 2006). This is mostly due to the fact that organic systems do not use chemical fertiliser, which requires a lot of energy for its manufacturing (40-50 MJ/kg N – Tzilivakis et al., 2005a; Meul et al., 2007).

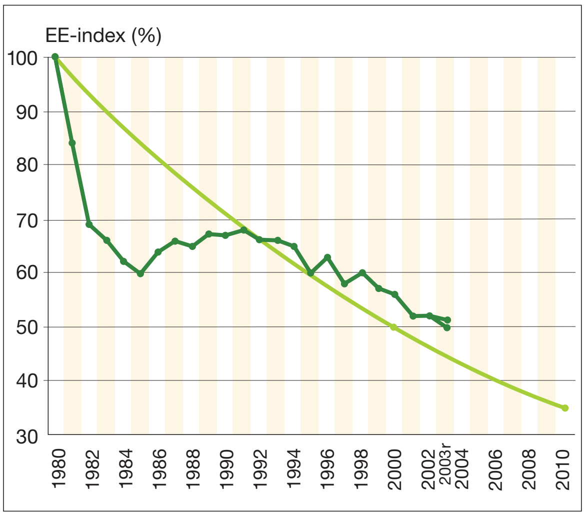


Figure 4.9. The Energy Efficiency (EE) index in Dutch greenhouse horticulture (corrected for temperature) in the period 1980-2003. The EE-index is defined as the primary fuel use per unit of product, using the 1980 value as 100%. The smooth line indicates the EE-index policy targets for the EE-index.
(Source: LEI and Van der Knijff et al. 2004)

Variation in energy use (and efficiency) across farms within similar systems is very high. For instance, the top

Table 4.8. Examples of energy use in different agricultural sectors and production methods

Type of farming	Unit of Energy use	Conventional	Integrated	Organic	Source
Arable: rotation	GJ/ha	21.0			(Meul et al., 2007)
Arable: rotation	GJ/ha	14.7	13.4		(Bailey et al., 2003)
Arable: rotation	GJ/ton	Ca. 2.0	Ca. 2.0		(Bailey et al., 2003)
Arable: sugar beet	GJ/ha	23.8		19.0	(Tzilivakis et al., 2005b)
Arable: sugar beet	GJ/ton	0.48		0.42	(Tzilivakis et al., 2005b)
Pigs	GJ/FPE*	3.6			(Meul et al., 2007)
Dairy-milk	GJ/ha	36.4			(Meul et al., 2007)
	GJ/1 000 l	3.7			(Meul et al., 2007)
	GJ/1 000 l	6.4		4.4	(Gronroos et al., 2006)

* FPE = Fattening Pig Equivalent

Table 4.9. Crop water productivity (CWP) benchmark values per unit of water depletion according to "FAO33" (Doorenbos and Kassam, 1979), CWP ranges according to the literature study by Zwart and Bastiaanssen (2004) of the data sets by crop (Source: Zwart and Bastiaanssen, 2004)

Crop	CWP-range ("FAO33" kg m^{-3})	CWP-range* (this research kg m^{-3})	*n*	Minimum	Maximum	Mean	Median	S.D.	CV
Wheat	0.8-1.0	0.6-1.7	412	0.11	2.67	1.09	1.02	0.44	0.40
Rice	0.7-1.1	0.6-1.6	105	0.46	2.20	1.09	1.02	0.40	0.36
Cottonseed	0.4-0.6	0.41-0.95	126	0.38	1.70	0.65	0.58	0.23	0.35
Cottonlint	Not given	0.14-0.33	66	0.10	0.37	0.23	0.23	0.064	0.28
Maize	0.8-1.6	1.1-2.7	233	0.22	3.99	1.80	1.60	0.69	0.39

*Defined as the 5 and 95 percentiles of the entire range.

performing farms in Flanders reached a 170% and 163% higher energy productivity for dairy and pig production, respectively, than average farms (Meul et al., 2007). For arable farming this figure was even higher (205%), but this was partly due to differences in crop rotations, i.e., some crops are more energy efficient than others: winter wheat, for example, has an output/input ratio of 14.4 versus potato 4.3 (Hulsbergen et al., 2001).

In summary, historical trends and variation across farms within a sector show that energy use and energy-use efficiency have improved and can still be improved further. In absolute terms, the largest gains can be achieved in horticulture and intensive livestock systems. However, given the large number of arable and dairy farms, scope for improving energy use in these sectors is also significant. This should be assessed jointly with issues such as the role of agricultural systems in carbon sequestration and biofuel production. This will be further discussed in the Outlook part of the paper.

Water

Irrigation is the main source of water use in agriculture, and it causes agriculture to be a major user of water, i.e., between 7 and 60% of our total water use in Northern and Southern Europe, respectively (EEA, 2005). Table 4.2 (page 36) provides the irrigable area per member state and region; across the EU-15 the irrigable area amounts to 9% and across the EU-27 to 7%. In the EU-15, 85% of irrigated land is in the Mediterranean area (France, Spain, Italy, Portugal, Greece; Appendix 3). In the acceding and new member states, Romania and Turkey are the major users (93%). The water use in the EU-15 for agricultural purposes has been fairly stable (EEA, 2005); this is the net result of an increase in irrigable area (France, Greece and Spain) and a decrease in application rates per hectare. Figures on annual water allocation rates point to a likely reduction in water use per ha of irrigated land, while yields have not decreased but rather increased (between 1990 and 2000, the mean water allocation rates in France, Greece, Italy, Portugal and Spain decreased from 6578 to 5500 m^3/ha/year (EEA, 2005). This points to an increase in water-use efficiency.

Zwart and Bastiaanssen (2004) reviewed the recent literature (the past 25 years) and summarised the crop water productivity (in kg/m^3), defined as the actual marketable crop yield divided by the actual seasonal crop water consumption by evapotranspiration. Few of the 84 references are from Europe, but there is little reason to assume that variation in Europe is much less than in other parts of the world. Table 4.9 shows this variation for wheat, rice, cotton and maize. The main reasons for the variation in crop water productivity are climate, irrigation-water management and soil-nutrient management. The data underpin the scope for improving water-use efficiency through irrigation, optimising irrigation-water management and other crop management, including fertilisation.

Nutrients

Nutrient use is another indicator of agricultural production and its intensity, as well an indicator for environmental effects. The amount of mineral nitrogen fertiliser consumption in the EU-15 has decreased by ca. 15% between 1995 and 2005 (Eurostat); trends differed significantly across countries, to some extent depending on their level of fertiliser use. In the Netherlands the use of fertiliser-N decreased by ca. 25% over the past 10 years. In countries such as Italy and Portugal, fertiliser inputs tended to increase rather than decrease. For phosphate mineral fertiliser, consumption in the EU-15 decreased by 35% in the 1990-2001 period.

Nutrient balances are a much better indicator for possible environmental effects than nutrient use per se. At EU-15 level this gross nitrogen balance decreased from 65 to 55 kg N/ha over 1990 to 2000 (EEA, 2005). Interestingly, this decrease is mainly due to higher outputs and not so much lower inputs – hence the nutrient-use efficiency has increased drastically. Figure 4.10 shows

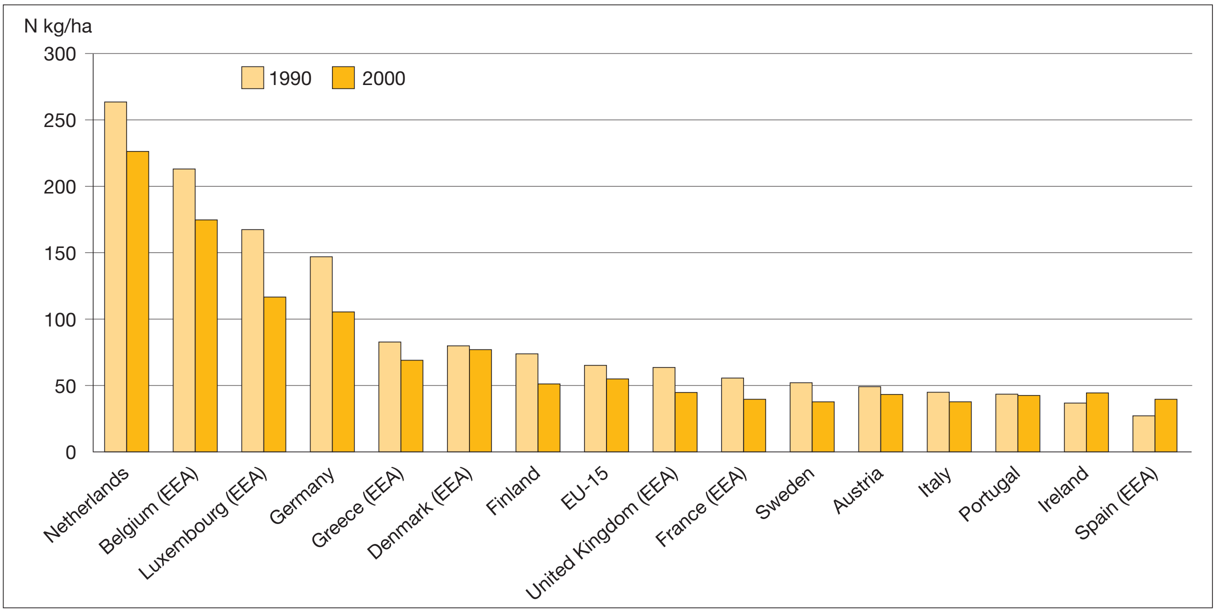


Figure 4.10. National gross nitrogen balances (kg/ha) in 1990 and 2000. In Belgium (Flanders) the first calculation is for 1998; in Sweden the first calculations are for 1995. The country name followed by (EEA) indicates balances that have been calculated by the EEA on the basis of EU-level data. (Source: EEA 2005)

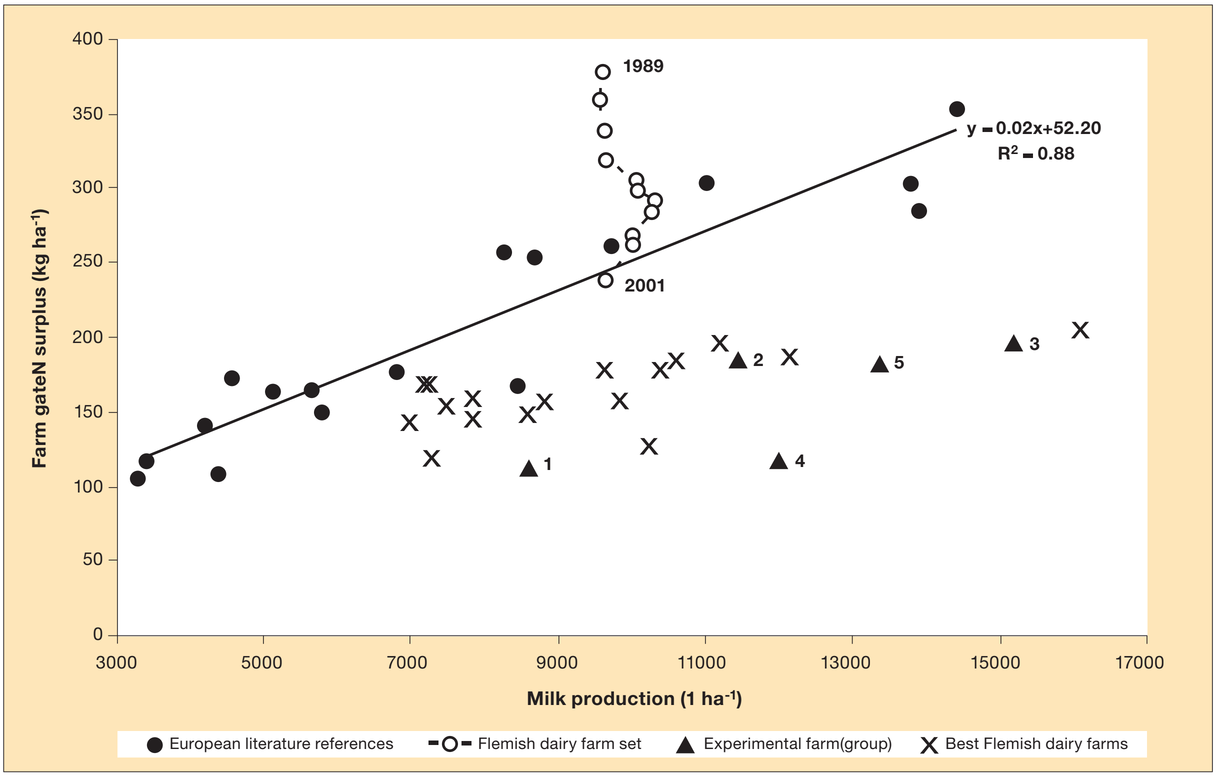


Figure 4.11. Farm-gate N surpluses in relation to production intensity. Data of literature references, average of the Flemish specialised dairy farm set (1989-2001), progressive Flemish dairy farms (2000 and 2001) and Dutch experimental farms (1. Bioveem; 2. Vel and Vanla; 3. Koeien en Kansen; 4. De Marke; 5. A.P. Minderhoudhoeve). (Source: Nevens et al. 2006)

the enormous variations across countries, as well as the significant decreases in surpluses in some countries over the 1990-2000 decade. This is mainly due to large differences in net nitrogen input through manure, which varied between 31 N kg/ha (Spain) to 206 N kg/ha (the Netherlands); fertiliser rates varied between 35 N kg/ha (Austria) and 179 N kg/ha (the Netherlands). Other nitrogen inputs refer to atmospheric deposition, biological nitrogen fixation and seed and planting material: this source ranges from 8 to 44 N kg/ha (Portugal and the Netherlands, respectively).

Variation of nutrient surpluses and nutrient-use efficiency across farms illustrates scope for improving nutrient-use efficiencies (Appendix 4). The variation is high, not only across all farm types, but also within a farm type and within a group of so-called forerunners. Nevens et al. (2006) regressed the farm-gate N surpluses versus the milk production per hectare for dairy systems across Europe (Figure 4.11); clearly, farm-gate surpluses increase with milk production per hectare. At the same time the figure shows how, without sacrificing production, Flemish farms have become much more nutrient-use efficient between 1989 and 2001; this was achieved mainly through reducing N fertiliser input and, second, through reducing concentrate input (Table 4.10). Further, data from progressive (forerunner) farms and experimental farms show that N surpluses can be further decreased substantially. N-use efficiency (N in farm output over total N-input) increased from 15% to 22% between 1989 and 2001 in the Flemish farms and varies roughly between 20 and 40% on forerunner farms in the Dutch Cows and Opportunities project (Oenema and Aarts, 2005).

(b) Environmental effects associated to resource use and resource-use efficiency

Various environmental effects were implicitly or explicitly covered in the previous sections, but some deserve an explicit mention here.

Greenhouse gas emissions

The important greenhouse gases related to agriculture are carbon dioxide, nitrous oxide and methane. Per ton of gas, nitrous oxide is 310 times more powerful in terms of global warming than carbon dioxide; methane is 21 times more powerful than carbon dioxide. In 2004, the share of agriculture in total greenhouse gas emissions in the EU-15 amounted to 9%; this was 10% lower than in 1990 (EEA, 2005; EEA, 2006b). This may be attributed particularly to lower nitrous oxide (minus 8.2%) due to lower N-fertiliser use and to lower methane emissions (minus 9.4%) due to lower number of cattle, the prime source of methane. Reduction of the third source of greenhouse gas emissions, carbon dioxide, is less significant and mainly related to energy use. Agriculture also makes a further contribution to reducing greenhouse gas emissions through production of bio-energy (presently it produces 3.6% of total renewable energy).

Soil erosion

Soil erosion is particularly evident in arid regions in Europe (southern and western Spain, northern Portugal, southern Greece and central Italy), where long dry periods are followed by heavy, erosive rains falling on steep slopes with fragile soils (EEA, 2005), and where soil cover is only partial in space or time (i.e., for important parts of the year the land is fallow). In these regions erosion may exceed 5 tons/ha/year.

Table 4.10. Average characteristics of the specialised dairy farms in the Flemish Farm Accountancy Data Network and of a subgroup of 18 progressive farms with regard to the N-use efficiency (data for 2000 and 2001) (Source: Nevens et al. 2006)

Topic	Unit	Progressive group *n* = 18	All dairy farms *n* = 148	Progressive group compared to all	
				Absolute	Relative (%)
Utilized area	ha	34.2	32.3	+1.9	106
Stock density	LU ha^{-1}	2.92	3.01	−0.09	97
Milk production	1 ha^{-1}	9399	9831	−432	96
Milk production	1 cow^{-1}	5552	5925	−373	94
N surplus	kg ha^{-1}	163	250	−87	65
N use efficiency	%	38.3	22.0	+16	174
Mineral ferlilizer use	kg Nha^{-1}	87	139	−52	63
Concentrate use	kg Nha^{-1}	78	96	−18	81
Share of heifers	%	31	34	−3	91
Yearly income	€ per labour unit	31059	27478	+3581	113

Ammonia

Ammonia emissions in Europe are mainly the result of volatilisation from livestock urine and manure. Between 1990 and 2002 these emissions decreased by 9%, which is likely to be caused mainly by a reduction in livestock numbers (EEA, 2005). In countries with high livestock densities and very intensive systems, such as the Netherlands, ammonia emissions decreased in the same period by ca. 45%. This is the result not only of reduction in the number of animals, but particularly also of manure application legislation and improved housing.

Pesticides

The number of crop protection agents is very high and moreover the active ingredients change over time. This makes it extremely difficult to draw unambiguous conclusions about the total use of pesticides in agriculture and their environmental impact. Amounts of active ingredients may remain fairly constant whereas their environmental impact may decrease substantially, due to less toxic components, and vice versa. In the Netherlands (atypical in the sense that pesticide use is relatively high in the Netherlands), total use of active ingredients of pesticide decreased by 50% between 1990 and 2003 (LEI, 2005), due to changes in cropping systems, new varieties, more precise application techniques, new active ingredients and better disease monitoring. The decrease in use of soil fumigation agents takes the largest share; for other types of pesticides the decrease is only modest. For a real comparison of pesticide impact in time, toxicity of the various components to soil, water and air must be considered and data are largely lacking to do this properly.

Biodiversity

Biodiversity and landscape are interrelated with agricultural practices. Figure 4.12 provides a hypothetical relationship between intensity of agriculture and biodiversity (EEA, 2004). This scheme provides rationale to political concern for High Nature Value (HNV) farmland. However, relationships between intensity of agriculture and biodiversity are typically scale-dependent and must be studied at multiple scales. This is reflected in issues such as an Ecological Main Structure, for which not just local biodiversity values (on agricultural land) count, but typically the biodiversity that can be obtained at entire system level. Intensive systems are generally more productive and this requires lower areas to produce a certain amount of food. Hence, at European level less land is needed for agriculture and more land can be used for nature conservation purposes (cf. Rabbinge and Van Latesteijn, 1992).

Farmland bird populations are assessed to have decreased by ca. 20% over the past two decades, though they have tended to stabilise recently (Figure 4.13). This decrease is associated with an intensification and specialisation of agricultural systems and practices with increased external inputs (nutrient and pesticides), a decline in habitats and less variability in landscape. Reidsma et al. (2006) reviewed the relationship between types (including intensity) of farming and ecosystem quality (Table 4.11). Ecosystem quality is defined here as the mean abundance of species originally present in a natural ecosystem relative to their abundance in undisturbed situations.

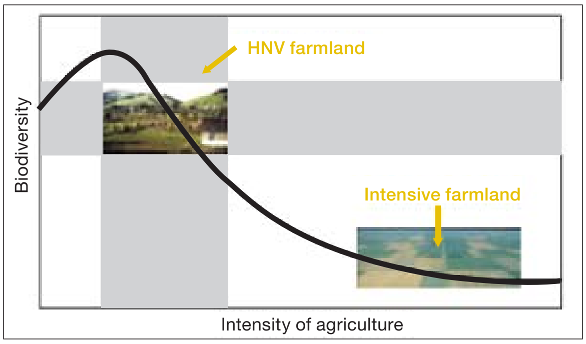


Figure 4.12. Hypothetical relationship between agricultural intensity and biodiversity; HNV farmland = High Nature Value farmland. (Source: EEA, 2004; adapted from Hoogeveen et al. 2001)

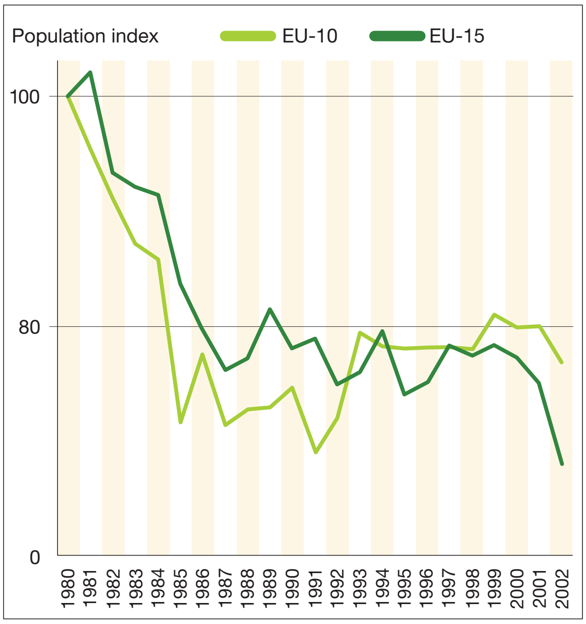


Figure 4.13. Common farmland bird trend from 1980 and 2002 in EU-15 and EU-10 member states (Source: EEA, 2007 – http://dataservice.eea.europa.eu/)

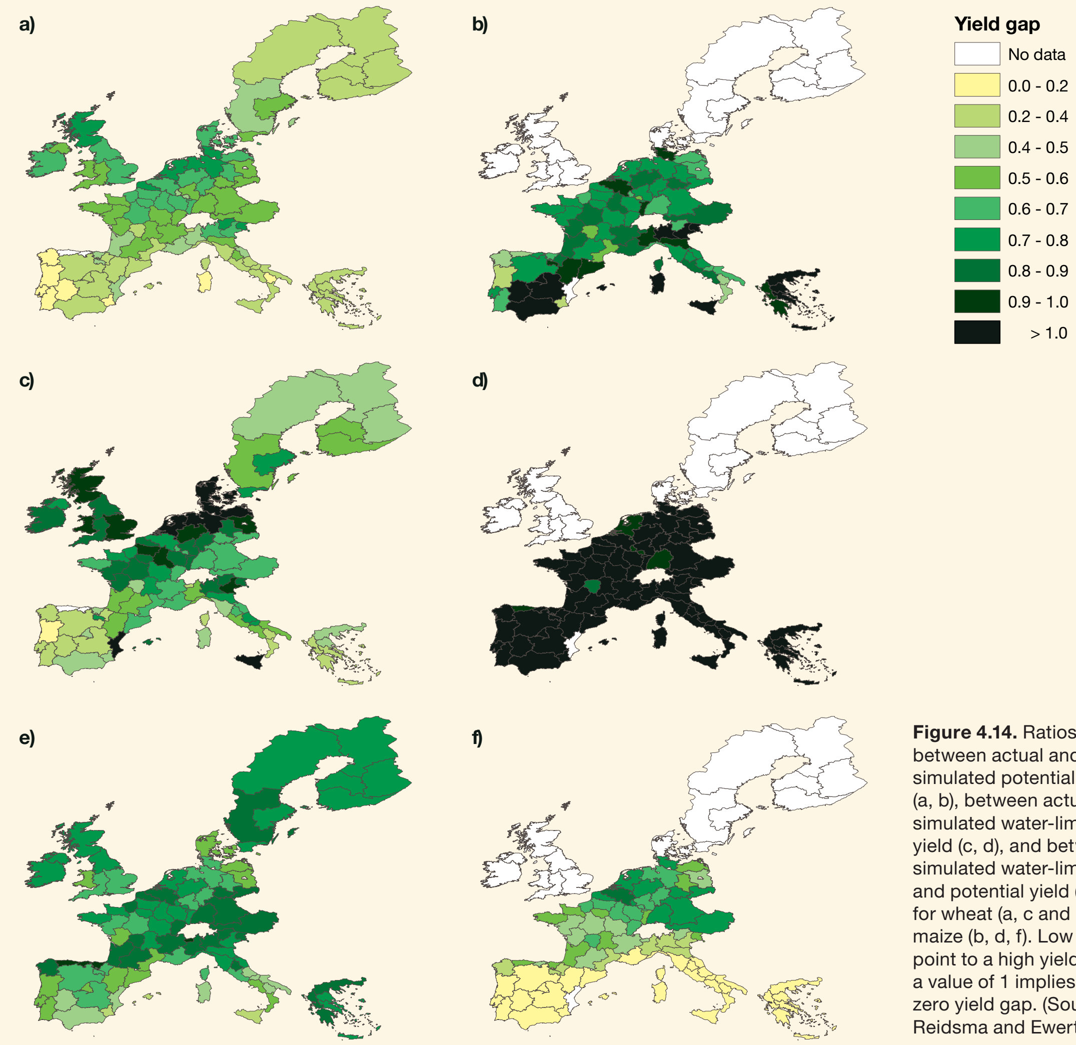


Figure 4.14. Ratios between actual and simulated potential yield (a, b), between actual and simulated water-limited yield (c, d), and between simulated water-limited and potential yield (e, f) for wheat (a, c and e) and maize (b, d, f). Low values point to a high yield gap; a value of 1 implies a zero yield gap. (Source: Reidsma and Ewert, 2005)

Table 4.11. Classification of (annual and permanent) cropping systems (Source: Reidsma et al. 2006)

	Criterium Organic	Criterium Irrigation	Criterium Intensity[a]	Class[b]	Ecosystem quality
Irrigated	Non-organic	Irrigation		17 (37)	5%
Highly intensive	,,	No irrigation	> 250 €/ha	16 (36)	5%
Intensive	,,	,,	80-250 €/ha	15 (35)	10%
Extensive	,,	,,	< 80 €/ha	11 (31)	25%
Highly intensive organic	Organic	Irrigation OR	> 250 €/ha	14 (34)	15%
Intensive organic	,,	No irrigation	80-250 €/ha	13 (33)	20%
Extensive organic	,,	,,	< 80 €/ha	12 (32)	35%

[a] Intensity = costs of: fertiliser and soil improvers, crop protection products and feeding stuffs for grazing livestock.
[b] Classes without brackets are for cropping systems, with brackets for permanent cropping systems.

(c) Yield gap analysis

In the previous section we have presented and analysed trends. In a few cases we have started with the outlook, by assessing what the best farmers or forerunners already achieve. A more science-driven approach to underpin outlooks is provided through the principles of production ecology. Production ecological knowledge and insights allow computation of potential yield levels, given genetic characteristics of plants/crops, temperatures and carbon dioxide concentrations in the atmosphere. This is under the assumption of no yield limitation due to water and nutrients and absence of reducing factors due to weeds, pests and diseases (Van Ittersum and Rabbinge, 1997). The absence of yield limitations and reductions can be achieved through perfect management. Although it may be difficult or uneconomic to realise such perfect management in reality, the potential yield (or water-limited in case of absence of irrigation and assuming rain-fed agriculture) provides a benchmark for productivity of current agriculture and scope for improvement in terms of agricultural management. The ratio between actual and potential or water-limited yield is defined as the yield gap (low values point to a high yield gap; a value of 1 implies a zero yield gap) and provides an indication for the scope of improving land productivity through agricultural management. The ratio between water-limited and potential production points to the potential gains in productivity through irrigation.

Figure 4.14 provides an example of such yield gap analysis for wheat and maize. Note, that in some regions the actual yields of maize are higher than the computed potential yields. Theoretically this is not possible, but the simulations were performed with relatively old varieties and related crop parameters, so potential and water-limited yields of present varieties have been underestimated.

Relative to water-limited yields, yield gaps of wheat are small for NW Europe and substantial for Scandinavia and Mediterranean countries (Figure 4.14c). It suggests that for wheat the potential of further improving nutrient management and crop protection is particularly significant in Scandinavia and southern regions. The ratio between water-limited and potential yield levels (Figure 14e) suggests the potential of irrigation: this is clearly very significant for Mediterranean regions, but also for some regions in France and Germany.

For maize the picture is quite different: Figures 14b and d suggest that maize is often irrigated and that the maize crop could further benefit from irrigation where it is currently not irrigated.

In theory, similar reasoning and analysis could be applied to livestock systems (cf. (Van de Ven et al., 2003), though in practice this is far more complicated and has not been done so far.

For the wheat crop, similar conclusions were drawn by Rabbinge and Van Diepen (2000), but these analyses were also performed for new member states and European countries outside the EU. Yield gaps are generally even larger in these countries, i.e., generally actual yields are less than 60% of water-limited yields and in some countries even below 40%. Yield gap analyses provide an insight into the scope for increasing land productivity in various regions in the EU, but can also be used to provide an indication of how much more could be produced at aggregated level. Rabbinge and Van Diepen (2000) did this for Europe (including Ukraine and Russia) and concluded that wheat production at aggregated level has only reached 43% of its water-limited levels. That indicates an enormous scope for further increase in productivity, even within the current agricultural areas (i.e., without expanding agricultural areas).

(d) Use of Genetically Modified crops in agriculture

Due to the EU's very conservative policy towards the use of Genetically Modified crops (and organisms), the use of GM crops in the EU is very low compared to several other countries (Table 4.12). Figure 4.15 shows the main crops for which GM varieties are currently used and their share in the total area with GM crops.

(e) Relative cost prices of agriculture in the EU

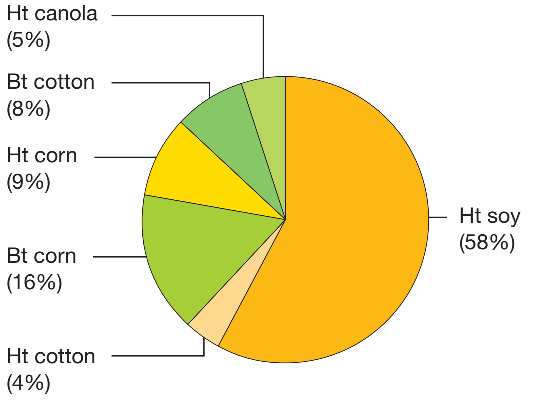
Various factors are important to assess international competition: cost prices, scope to improve productivity and efficiency from an economic point of view (including economies of scale) and scope to improve productivity and efficiency from an agri-environmental point of view. For international competition the relative cost price of producing agricultural commodities is important. The "cash costs" of production are important in establishing competitiveness in the short-run, whereas in the longer-run also other economic costs, such as family labour, owned land and own capital, as well as economies of scale are relevant. Figure 4.16 presents the cash costs for milk production, expressed per 100 kg of product for selected EU and non-EU milk producers. A more comprehensive picture of cost prices and the scope to improve these is important to assess future competitiveness of European agriculture.

Table 4.12. Global area of Genetically Modified crops in 2006 by country (Source: ISAAA, 2006)

Rank	Country	Area (million hectares)	Biotech crops
1*	United States of America	54.6	Soybean, corn, cotton, canola, squash, papaya, alfalfa
2*	Argentina	18.0	Soybean, corn, cotton
3*	Brazil	11.5	Soybean, cotton
4*	Canada	6.1	Canola. corn, soybean
5*	India	3.8	Cotton
6*	China	3.5	Cotton
7*	Paraguay	2.0	Soybean
8*	South Africa	1.4	Corn, soybean, cotton
9*	Uruguay	0.4	Soybean, corn
10*	Philippines	0.2	Corn
11*	Australia	0.2	Cotton
12*	Romania	0.1	Soybean
13*	Mexico	0.1	Cotton, soybean
14*	Spain	0.1	Corn
15	Colombia	<0.1	Cotton
16	France	<0.1	Corn
17	Iran	<0.1	Rice
18	Honduras	<0.1	Corn
19	Czech Republic	<0.1	Corn
20	Portugal	<0.1	Corn
21	Germany	<0.1	Corn
22	Slovakia	<0.1	Corn

*14 biotech mega-countries growing 50,000 hectares, or more, of biotech crops.

Source: ISAAA Brief 35-2006 – Global Status of Commercialized Biotech/GM Crops: 2006.



Sources: Various including ISAAA, Canola Council of Canada, CropLife Canada, USDA, CSIRO, ArgenBio

Figure 4.15. Global areas sown under Genetically Modified crops in 2005 (Source: ISAAA, 2006) Bt corn: corn with a small amount of genetic material from the soil bacterium, *Bacillus thuringiensis*; the gene of interest produces a protein that kills Lepidoptera larvae, in particular, European corn borer. This is an alternative to spraying insecticides for control of corn borer. Ht crops: herbicide tolerant crops.

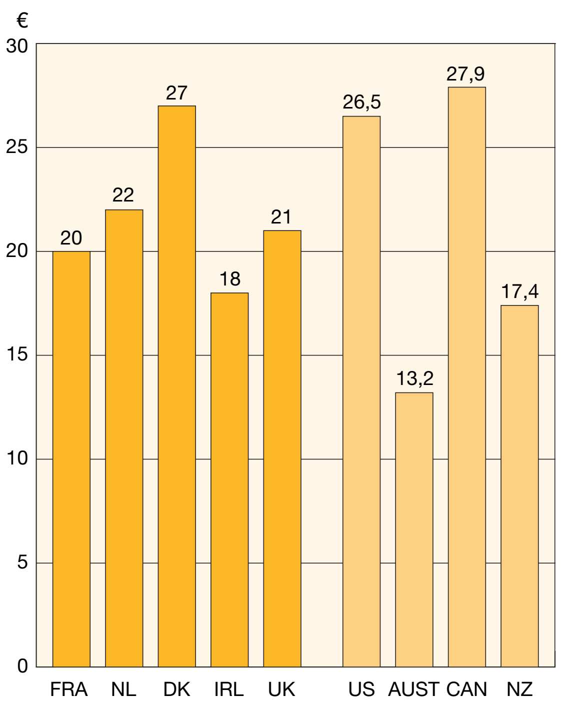


Figure 4.16. Dairy production and its cash costs in the EU and non-EU countries, expressed in €per 100 kg product volume, 1998-1999 (Source: Boyle, 2004)

4.1 Current systems and future scenarios for food production activities

4.1.4 Important drivers for agricultural production in the EU

4.1.4.1 Introduction

Recently the European Commission commissioned a scenario study, Scenar 2020 (Nowicki et al., 2007), that identifies and analyses the future trends and driving forces framing the European agricultural and rural economy with a time horizon of 2020. In this report the exogenous (to agricultural systems) drivers were assumed to be demographics, (macro-)economic growth, consumer preferences, agri-technology and world markets. Policy-related drivers were Common Agricultural Policy (market policies, direct payments and rural development policy), biofuels, enlargement, WTO and other international agreements and environmental policies. We took these drivers as a starting point for this section, but with some modifications. The aim of the ESF/COST Forward Look is to define a research agenda for the production, processing and consumption aspects of European food systems. By definition, such a research agenda must address strategic issues, which have a longer time horizon than 2020. Hence, we believe climate change should be part of the driving factors. Further, we combined macro-economic growth and world markets. Consumer preferences will be dealt with separately in another chapter of this report. Finally, we singled out "biofuels" as they have such obvious implications for agricultural production. Below we briefly discuss these factors which play a role in the defined scenarios and are important to arrive at a robust research agenda.

The driving forces are presented from a European perspective in a global context. Clearly, agricultural production is not a major concern in the EU presently. Also, future scenarios with respect to changes in cropland and grassland tend to indicate major declines in areas needed to feed the European population (Rabbinge and Van Latesteijn, 1992; Rounsevell et al., 2005). However, we assumed first that significant research investments will be needed to realise such predicted changes, and, secondly, that Europe also has to play a role in terms of research and development to solve challenges at a global scale.

4.1.4.2 Demographics

The European population is predicted to decrease from 731 to 709 million in 2030 and 664 million in 2050 (United Nations, 2006), while the median age of the population will increase drastically from 39 years in 2007 to 46 and 47 in 2030 and 2050, respectively. This contrasts with global developments. In 2007 the world population was 6.7 billion individuals, while this number is predicted to increase to 8.3 billion in 2030 and 9.2 in 2050; the median age increases from 28 years to 34 and 38, respectively. Until 2030 almost 100% of the population growth will occur in lower- and middle-income countries.

These figures ignore inward migration from Africa and non-EU parts of Europe. Currently this is adding about 0.3 million per year but, while important in some countries, is unlikely to affect the overall population decrease.

4.1.4.3 Economic growth and world market

Actual scope for productivity increase of agriculture depends on biophysical *and* on economic factors: prices and total costs of production may well lead to the fact that lower yield levels are more profitable than attainable from a biophysical viewpoint. At more macro-economic level, Hafner (2003) found in a global study of historical cereal yields of 188 nations that productivity growth is correlated to per capita GDP, next to latitude (which corresponds to climate). Effects of GDP may be interrelated with availability and affordability of inputs, perhaps presence of agricultural subsidies and the level and quality of research, education and extension. It is thus likely that yield gaps will become smaller in new member and southern member states of the EU when their per capita GDP increases (see also Figure 4.4b).

Per capita GDP is also highly correlated to meat consumption. It is predicted that global consumption of animal foods may double between 2000 and 2050 (Steinfeld et al., 2006). This much more affects the demand for biomass for food through the required feed inputs (Delgado, 2003; Smil, 2002). For instance, an affluent western diet, in which animal proteins have a significant share, involves a three-times larger input of grain equivalents than the adequate vegetarian diet that is still normal in many developing countries (Penning de Vries et al., 1995). Such developments will affect European agriculture through a higher global demand for feed.

Markets for food consumption (in terms of volume) in the former EU-15 may well be saturated, but it seems likely markets in the new member states and other parts of Europe will grow further, particularly because of changes in diets and higher consumption of beef with relatively unfavourable feed conversion coefficients. Global changes in demography and economic growth will increase demand for food at a global scale. This will have implications for Europe, the precise effect depending on the degree of liberalisation and globalisation (Rosegrant et al., 2001; Nowicki et al., 2007; Rosegrant et al., 2008), but for several commodities Europe seems competitive whereas for beef production, for example, this is not the case. Structural change (number and size of farms) will be a major effect of liberalisation.

4.1.4.4 Climate change

Effects of climate change are an interplay of effects of elevated carbon dioxide concentrations, temperature, rainfall and options for adaptation and mitigation. Van Ittersum et al. (2003) provide an example of a systematic analysis of each of these factors and their interaction for wheat crops in an area in Western Australia with a Mediterranean climate. The common denominator of studies (e.g. Olesen and Bindi, 2002; Maracchi et al., 2005) assessing consequences of climate change on European agricultural production suggests that in northern regions climate change may have positive effects on agriculture assisted through introduction of new crop species and varieties, higher crop production (effects of carbon dioxide and temperature rises) and expansion of suitable areas for crop cultivation. Disadvantages may be an increase in the need for plant protection, the risk of nutrient leaching and the turnover of soil organic matter. In southern areas disadvantages will predominate. The possible increase in water shortage and extreme weather events may cause lower harvestable yields, higher yield variability and a reduction in suitable areas for traditional crops. This vulnerability of Mediterranean regions is confirmed by Schröter et al., (2005a; 2005b). The question, stressed by many authors, then is whether options for mitigation and adaptation, particularly in southern parts of the EU, are adequate to counterbalance effects of climate change. Also, many studies do not account properly for the greater risks for extreme events.

4.1.4.5 Technology and research investments

Figure 4.4 is illustrative of the results of technological progress and development over the past decades. Some researchers project such historical trends into the future with slight variation under different scenarios (Ewert et al., 2005). This extrapolation is questionable and at least major investments in research and development will be required to maintain the yield increases at the levels observed over the past decades. In several places in the world and in Europe we can still expect great progress in productivity thanks to principles of the green revolution – the yield gap is still enormous (Section 4.1.3.2 (c)). In other places, where yields are usually closer to the potential levels, diminishing returns of input use are evident. Returns on nitrogen fertilisation, for example, are clearly diminishing or have reached a plateau; yield gains can only be achieved through mutual optimisation of inputs. From a genetic point of view, improved harvest indices no longer seem a promising route to increase yield potentials substantially (Shearman et al., 2005; Reynolds et al., 2005). Several authors argue that yield potentials of cereals are source-driven rather than sink-driven. In other words, yields of rice (and probably other crops) cannot be increased further through a reallocation of biomass within the crop through changing the architecture of plants and crops. In crops where breeding has been less prominent or with an indeterminate architecture, breeding for a different architecture may still offer ample scope (e.g., rapeseed – Berry and Spink, 2006).

In the major cereals, higher light-use efficiencies and hence photosynthesis are needed to boost yield potentials. The most prominent route proposed for rice, for example, is to target C4 rather than C3 rice (Sheehy et al., 2007). Breeding for, for instance, C4 rice is proposed as a route that must be investigated and, if successful, might lead to yield increases of up to 50%, considering differences in productivity between maize and rice crops grown under the same conditions and with similar growing seasons (Sheehy et al., 2007). Further, it would not only boost potential yield levels, but also be very beneficial for water- and nitrogen-use efficiency. However, even if successful, turning C3 crops into C4 crops will only be effective in relatively warm climates. So for many of the temperate regions in Europe breeding for C4 is not a viable route. Yet, we believe that from a global perspective, some drastic breakthroughs, such as turning C3 crops into C4 crops, are the only way we can cope with the enormous challenge of feeding the world with a 50% higher population, drastic increased demand for livestock products and, at least presently, demands for bio-energy. Europe has its role to play here, both in terms of production per se, and in terms of research capacity.

Yin and Struik (2007) critically assess some of the pathways of using C4 biochemistry and physiology in C3 plants; they argue that some perspectives may look promising at a particular experimental level (short time span and at plant or crop level with a certain leaf area index), whereas they may not hold up when scaling up processes to a growing season or full crops. Negative feedback may well compensate positive effects at micro level. Yet, a large international consortium is currently formed to take up the challenge of developing C4 rice, or at the very least some alternative non-C4 possibilities to raise yields (Mitchell and Sheehy, 2007). Yin and Struik (2007) suggest that crop systems biology is needed to take advantage of modern functional genomics and traditional sciences (such as crop physiology and biochemistry) in understanding and manipulating crop phenotypes relevant to agriculture. This not only applies to the case of C4 rice, but applies to all kinds of breeding attempts in which genomics plays a role — the need for scaling up such knowledge and its potentials to the crop and cropping system level is urgent.

The case of C4 is presented here as a complex example to make the point that trend breaks are needed to face global challenges and that breakthroughs are needed from biotechnology, hand in hand with progress at systems level, i.e., the field, crop, animal and production system level. Other challenges for breeding, biotechnology and agricultural management relate to coping with abiotic stresses, especially climate change, resistance to biotic stresses, coping with new diseases in response to pathogens and vectors moving in response to climate change and transports across the globe, development of integrated crop and livestock management systems that efficiently cope with multiple environmental stresses.

Koning et al. (in press) show that growth rates of investments in agricultural research have declined over the past 10-20 years. They also point out the risk of short-sighted expectations: food production at global scale and in all developed countries has not been and is not yet an issue of political concern. The long-term perspectives that this may change do not affect investments in research and development at present, whereas breakthroughs require a really long-term perspective. Cassman and Liska (2007) also plead for rapid action to improve global targeting of research and development funds to assure an acceleration in food production capacity while protecting natural resources and environmental quality.

4.1.4.6 Policy-related drivers

In various parts of the world, agricultural policies increasingly evolve as integrated policies, or even become part of integrated policies, such as for instance environmental or rural development policy programmes. This may occur within the larger frame of agreements on sustainable development. In Europe the share of so-called first pillar policies (Common Agricultural Policy), though still very substantial, is decreasing at the expense of second pillar polices (Rural Development). Within the first pillar, subsidies have been substantially decoupled from production prices towards farm subsidies since the latest Common Agricultural Policy reform in 2003, and it seems likely this will continue. Subsidies are partly coupled to meeting certain management requirements or conditions, for instance related to nutrient or pest management (cross-compliance). Globally, within the frame of World Trade Organisation negotiations, direct support of production is decreasing, generally in favour of other farm-based, environmental or rural development policies. Future evolutions of policies are hard to predict and largely depend on world views and developments. This driver therefore recurs very prominently in the definition of scenarios (see Section 4.1.6). Recent developments as to supporting biofuel production demonstrate the strong effect policies can have on agricultural production and prices (see below). The current increase in prices of major agricultural commodities, due to a combination of increased demand for biofuel production, low harvests in various parts of the world and increased demand for feed and food from China, has already led to discussions on lowering set-aside areas, and increasing milk quota.

4.1.4.7 Energy scarcity and biofuels

Renewable energy sources currently account for 6% of the total EU-25 energy consumption; prime sources are biomass (ca. 2/3 of renewables), waste and hydro; the contribution from solar energy is still very minor. Most of the biomass comes from wood or wood waste and only a very small fraction (3% of the renewable energy) came from biofuels in 2003. The target for renewable energy sources in 2010 is 12%, which requires a substantial rise in the use of biomass. The share of renewable electricity in the EU-25 was 12.8% in 2003; here large-scale hydropower is the dominant contributor (EEA, 2006a) and biomass contributes only ca. 15%. The EC's biofuel directive aims at a 5.75% share of biofuel in total fuel for transport (transport energy accounting for ca. 30% of the total energy consumption in the EU-25).

All these figures point to great pressure on agricultural land to contribute to biomass production in the near future. In 2003, the agricultural sector contributed 2.23 million tons of oil equivalent (Mt OE), including 67% biofuels, 13% short-rotation forestry, 3% biogas and 17% use of straw. In 2003, 1.6 million ha of land were used for biofuel production. To give an indication of the possible pressure, the Biomass Action Plan of the EC proposes a number of measures to increase the production and use of biomass for energy use to reach some 150 Mt OE in 2010 (EC, 2005; EEA, 2005). It has been estimated that even the objective of realising 5.75% biofuel of total fuels would require close to 10% of the EU-25 agricultural land (Nowicki et al., 2007). Internationally, claims for maize for bio-ethanol in the USA are estimated to reach 30% of the maize crop, while Indonesia and Malaysia, for example, are planning to use 40% of their current palm oil output for production of biodiesel, both for the year 2010 (Biopact, 2006; Food and Agricultural Policy Research Institute, 2006).

It will be important here to discriminate between short-term policy aims (say up to 2020) and longer-term developments and the need to focus on other renewable energy sources rather than biomass.

Analysis of energy-use efficiency of agriculture (crops and feed production) around the globe indicate a fairly low efficiency in the EU-15 compared with other parts of the world, in particular Canada, Argentina and, to a lesser extent, USA and Australia (Slesser and Wallace, 1982; Bonny, 1993; Conforti and Giampietro, 1997). The output/

input ratio in the EU-15 was estimated at 1.5 whereas that in Australia, Canada and USA was 2.1 on average. Output/input ratio was much higher in Argentina (ca. 10). This may indicate a relatively high vulnerability of European agriculture to high energy prices.

For the coming 15 years or so, there will be a need to make agriculture more energy-efficient to be competitive internationally in the face of high energy prices and to manage its contribution to greenhouse gas emissions. At the same time, agriculture will face implications of high demands for biomass production for bio-energy, at least in the short and medium term, until alternative and more efficient renewable energy sources have been sufficiently developed and made economically attractive. First generation bio-energy technology will compete directly with food and feed, whereas second generation bio-energy might compete (also) with soil fertility as waste and residue products are the prime source for this technique.

4.1.5 The three questions

In this section we relate the information on current agricultural production (Section 4.1.3 – Table 4.2) and the drivers (Section 4.1.4 – Table 4.13 below) to the three overarching questions presented in the introduction of this paper. As indicated, answering the questions is equivalent to speculation, due to uncertainties as to exogenous drivers, but we will hint at evident trends and indicate what kind of analysis and information is needed to answer the three questions. A scenario approach, as presented in the final section, assists in further investigating the three questions.

1. Will there be substantial changes in agricultural resource use in Europe as a consequence of intensified production systems and policies on energy security/diversity?

It is likely that intensification in European agriculture will continue. As a consequence, some areas currently producing food crops and animals will come out of food production, i.e., less land will be needed in Europe for food production in the decades to come (Rabbinge and Van Latesteijn, 1992; Rounsevell et al., 2005). At the same time the demand for biomass to produce biofuel will increase; land that might be reverted to forest and/or recreational space may be used for this. The degree of land abundance for food production and reversion to biomass production for biofuel will largely depend on political choices within the EU (e.g., quota systems, set-aside policies and subsidies on biomass for biofuel) that also intervene with technological development and the actual use of new technologies. In the short to medium term, biomass production for bio-energy will have substantial effects on land use. Given its intensity, European agriculture is fairly susceptible to higher energy prices; it will have to become more energy efficient. Clearly, data as shown in Figures 4.9, 4.10 and 4.11 show there is ample scope for a more resource-use efficient, yet intensive agriculture. Finally, shortage of water for irrigated agriculture in the Mediterranean region combined with warming in northern latitudes will result in production of some high-value horticultural and vegetable crops moving north.

Table 4.13. Relative importance of the drivers on the three questions underlying this chapter on future scenarios for food production activities

Driver	Question 1	Question 2	Question 3
Demographics		×	
Markets and economic growth		×	
Climate change	×		
Technology and research	×	×	×
Policy development	×	×	×
Energy scarcity and biofuels	×	×	×

2. Will changes in global food markets (resulting, for example, from industrialisation in China, India and South America, energy security policies in the USA, and climate change in sub-Saharan Africa) result in changed production systems in Europe?

Globally, it seems very likely there will be higher demand for food and non-food production from European agriculture. There are three reasons for this: (1) population growth in developing countries; (2) economic development and its effect on consumption of animal proteins; (3) increasing demands for non-food production. Increased demand for food by China is already affecting world trade; this is likely to continue. In India the situation is different because of a greater focus by the government on self-reliance. The switch to maize production for biofuel has had a short-term effect on markets but the longer-term consequences are uncertain, given that more land may come back into production as a consequence of higher cereal prices. The proximity of Europe to Africa is likely to have effects on European production, especially if the USA uses cereals that have historically gone to Africa during times of famine. The degree to which such issues will manifest themselves will be highly dependent on global developments, political choices and precise demographics.

Production potentials are there, both at European (e.g. Rabbinge and Van Diepen, 2000) and global level (Penning de Vries et al., 1995), but their exploitation requires significant investments to overcome yield gaps and improve resource-use efficiencies. European agriculture is typified by a high number of very small farms. Partly as a result of this, its cost price seems to be relatively high. Comparative analyses of international cost prices of major agricultural commodities seem scarce. Such analyses would be even more useful when extended with negative and positive externalities associated with the production. A comparison of cost prices and a systematic life cycle analysis of agricultural goods across the globe would be helpful to reveal optimum production systems (optimum from various perspectives related to sustainable development) under patterns of globalisation and regionalisation. That in turn can provide a basis for policy development.

3. Will new technologies be adopted, in Europe or elsewhere, that result in "best" methods of food production, enhanced environmental management and healthy foods?

Answering this question very much depends on how new technologies are defined, but overall the question must be answered positively. New technologies in terms of new cultivars, integrated crop-, water-, nutrient- and pest-management practices are continuously adopted. If new technologies refer to genetically modified crops or organisms, it is obviously a political choice driven by public opinion that determines their adoption. Evidently, pressure for adoption of genetically modified organisms (and hence changing European policies as to this subject) will increase.

New cultivars with durable disease resistance are being developed. A significant impact of genomics on this in field production is some 15-20 years away. Better nutrient and water management will increasingly be adopted, especially if energy costs push fertiliser costs higher. Public policy requirements for sustainability and biodiversity will ensure that new technologies need to be developed to achieve the policy goals. Genetic modification is only one of several technologies that will play a role here. The precise type of new technologies may differ between future developments towards either further globalisation or regionalisation. In the former case, emphasis may be more on high-tech and resource-use efficiency, whereas in the latter case prevention of local emissions may be a prominent objective.

4.1.6 The Forward Look scenarios coloured for agricultural production

The four scenarios that have been defined in the ESF/COST Forward Look were named after the buttons of a tape recorder: what could happen to European food systems if we press the button "fast forward", "pause", "rewind" or "play"? The assumption behind this approach is that it provides a means of identifying a research agenda which anticipates discontinuities, considers wider contextual developments, and is relevant to the design of policy concerning European food systems (see Chapter 3 by Wilkinson et al.). The four scenarios are related to the driving forces described in Section 4.1.4, in particular to the drivers on economic growth and global markets and policy development. Below we attempt to characterise ("colour") the four scenarios by describing their possible implications for agricultural production. This is a highly speculative exercise, but it is relevant to keep in mind that its purpose is not to predict any future, but to map the uncertainties within which a robust research agenda must be drafted.

Scenario A
Fast Forward (Continuing 2007 for another 20 years)

Under this scenario there is a strong continuation of intensification of agricultural production; farming systems will further specialise (separation of different production sectors on-farm, but at higher levels they may well mix) and scale up in size. Current trends will continue and agricultural production will concentrate in areas and regions where this can be done in the most efficient way (efficient mostly from an economic perspective). Resource-use efficiency will be a key concept here, but it is likely resource use will be expressed predominantly in monetary terms. Systems may well be vulnerable to large-scale epidemics because of a globalising agriculture with large trade flows and a narrowing of the set of cultivars or varieties in use. In this scenario, it seems likely that much land will be freed up for other purposes than food production due to a high productivity.

Scenario B
Pause (Globalising markets and higher perception of risk)

In this scenario, society responds actively to perceived risks, which can be of various kinds (environmental, social and economic) as a result of global drivers such as climate change, large-scale epidemics, obesity and resource depletion and scarcity. The need for "trust" in the food system is crucial. This probably results in higher cost prices because of a focus on more (quality) control in food production systems. People will be much more cautious about what they eat and drink. Tracking and tracing, supported through life-cycle assessments, give incentives to efficient, yet low-risk production systems. This has enormous implications for the entire food chain, including processing, packaging, retailing and consumption. Also in this scenario it is still likely that in several parts of the world (including Europe) land can be freed up from food production purposes. Resource-use efficiency will be approached from multiple angles, not just economic. Net effects on biodiversity may well be positive, as agriculture is concentrated on relatively small areas.

Scenario C
Rewind (Global crisis, act local)

Agricultural food production will regionalise. Trade and transport flows decrease and people prefer food from within the region (which can still be fairly large, but generally food comes from the same continent). Seasonality of availability of products will increase and there will be less diversity. Also enormous efforts will be needed to prevent local food shortages (not so much in Europe but in, for instance, parts of Asia). As in Scenario B, trust in the food system is important and this is achieved through a combination of extensive tracking and tracing and local production. Food miles will be low; food self-sufficiency of regions is an important aim and protectionism prevails. Production does not take place in the most suitable places nor in the most efficient way. Food production will require much more land than in the previous scenarios, which has implications for other functions of land. Also, overall resource-use efficiencies will decrease. Requirement of agricultural labour is much higher in this scenario (and scenario D) than scenarios A and B.

Scenario D
Play (Regionalised markets and low perception of risk)

The assumption in this scenario is that production systems with low use of external inputs will prevail. This could be organic production or a Tuscany-type of agriculture. Certainly on a hectare basis energy use will be relatively low, though this may be less evident for the entire sector. For most resources their use efficiency will be relatively low in this scenario. Locally, biodiversity may benefit from this type of production; globally, food production will require much more land than in Scenarios A and B and this is at the expense of nature conservation and land available for, for example, biomass production. Agro-biodiversity (i.e., the pool of genes used in agricultural cultivars, varieties and breeds) will be relatively high. Multifunctional types of agriculture will probably flourish. Trust in food is less of an issue in this scenario than in the previous – it is mainly obtained through the assumption that organic and locally-grown food is safe. Production methods are relatively labour-intensive in this scenario.

A characteristic of the scenario approach as applied here is that it seeks answers to predominantly reactive developments. In other words, it does not focus on shaping the future of food production systems by actively formulating policies, measures or allocating research funds to reach a particular end. If so desired by society, areas for agricultural production and means of agricultural production can fulfil various roles. Apart from delivering food, they can also have a recreational function, support the conservation of biodiversity, or be a supplier of bio-energy. Moreover, specific targets could also be formulated as to the function of agriculture as a source of food. Foods with improved sensory properties could be targeted, or more importance could also be attached to the production of foods with health-promoting components, and breeding could be supported to achieve this.

In retrospect, we feel that the scenario approach applied in this ESF/COST Forward Look has not sufficiently opened up our analysis of possible future developments in food production activities. Some of the assumptions ascribed to the scenarios seem arbitrary and lack scientific underpinning, e.g., the proposition that low-input or high-input agriculture have particular implications or that society would become highly perceptive to eventual perceived risks of various kinds (environmental, social and economic) and act on that. By contrast, recent history has shown that although consumers react immediately and violently to the occurrence of a food scare, for instance bovine spongiform encephalopathy (BSE), they usually return to their trusted behaviour, a process that is facilitated by providing the public with proper information.

4.1.7 Towards a research agenda

Based on Sections 4.1.3-4.1.5, we suggest the following research topics are robust to the differences between the four scenarios. In other words, we expect these research topics to be relevant in any of the four future scenarios and hence in any imaginable future.

The five research topics below have the purpose: (1) to better understand the pros and cons of the present systems from an integrated perspective, while adequately accounting for different scales and economic, environmental and social aspects; (2) to increase resource-use efficiencies such that yield levels at fixed levels of resources can be lifted (or the same yield levels can be achieved with less input); (3) to lift potential yield levels; (4) to adapt the layout and management of production systems, at different levels of scales, to mitigate factors of global change; (5) to design and develop production systems that have dual purposes in terms of food and feed production, bio-energy, biodiversity, landscape and resource conservation. The proposed topics 3 and 4 can be understood in the frame of the production ecological concept (Van Ittersum and Rabbinge, 1997), a concept that discriminates between yield defining, limiting and reducing factors.

Concretely, we propose the following overarching research topics:

1. Characterisation of production systems with respect to productivity and efficiency, environmental impact and socioeconomic implications at different scales: integrated assessment of agricultural systems at field, farm, regional and global level (including life cycle analysis: all aspects of production, transport and consumption);
2. Enhancement of resource-use efficiency, viz. of water, fertiliser and energy (Gregory et al., 2002), at different levels;
3. Assessment of the possibilities to stretch the yield potential further (both to make it possible to achieve higher potential yields and to achieve intermediate yield levels “more easily”, i.e., with less input or effort) (see Section 4.1.4.5);
4. Determination of proper adaptation strategies of production systems at different scales, i.e. field, farm and land use level, with respect to global changes: this refers to climate change, greater risks for epidemics in livestock production sectors, for example, sudden and perhaps temporary rises in demand for agricultural products such as presently with demand for biofuels (see Section 4.1.4.4 and 4.1.4.7);
5. Development of production systems with higher dual contributions, i.e., to both food production and aims such as bio-energy (for example, when second generation techniques become available and residues can be used for this, the trade-off between soil fertility and bio-energy may become urgent), landscape and biodiversity values, etc. (Section 4.1.4.7).

We strongly advocate a follow-up to this ESF/COST Forward Look that takes a wider perspective with an integrated scenario analysis not only based on current drivers but also on societal aims and ambitions that a dedicated research agenda could help to realise.

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References

Andersen, E., B. Elbersen, F. Godeschalk and D. Verhoog (2007). Farm management indicators and farm typologies as a basis for assessments in a changing policy environment. *Journal of Environmental Management* 82: 353-362.

Bailey, A.P., W.D. Basford, N. Penlington, J.R. Park, J.D.H. Keatinge, T. Rehman, R.B. Tranter and C.M. Yates (2003). A comparison of energy use in conventional and integrated arable farming systems in the UK. *Agriculture, Ecosystems & Environment* 97: 241-253.

Berry, P.M. and J.H. Spink (2006). A physiological analysis of oilseed rape yields: past and future. *Journal of Agricultural Science* 144: 381-392.

Biopact, 2006. Palm biofuel survives low crude oil prices-official, http://biopact.com, September 2007.

Bonny, S. (1993). Is agriculture using more and more energy? A French case study. *Agricultural Systems* 43: 51-66.

Boyle, G. (2004). *Competitiveness concerns at the production and processing level: the example of the dairy sector*. In: Workshop on Enhancing Competiveness in the Agro-food sector: making policies work. Vilnius, Lithuania.

Cassman, K.G. and A.J. Liska (2007). Food and fuel for all: realistic or foolish? *Biofuels, Bioproducts and Biorefining* 1: 18-23.

Conforti, P. and M. Giampietro (1997). Fossil energy use in agriculture: an international comparison. *Agriculture, Ecosystems & Environment* 65: 231-243.

De Wit, C.T. (1992). Resource use efficiency in agriculture. *Agricultural Systems* 40: 125-151.

Delgado, C.L. (2003). Rising consumption of meat and milk in developing countries has created a new food revolution. *Journal of Nutrition* 133: 3907S-3901S.

Doorenbos, J. and A.H. Kassam (1979). *Yield response to water*. FAO irrigation and drainage paper no. 33, Food and Agriculture Organization of the United Nations, Rome, Italy.

EC (2000). *Communication from the Commission to the Council and the European Parliament, Indicators for the Integration of Environmental Concerns into the common agricultural policy*. COM (2000) 20 final.

EC (2005). *Biomass Action Plan*. Communication from the Commission. European Commission, Brussels.

EEA (2004). *High nature value farmland – characteristics, trends and policy challenges*. EEA report, European Environment Agency, Copenhagen, Denmark.
EEA (2005). *Agriculture and environment in EU-15 – the IRENA indicator report*. EEA Report, No. 6/2005, European Environment Agency, Copenhagen, Denmark.
EEA (2006a). *Energy and environment in the European Union – Tracking progress towards integration*. EEA Report, European Environment Agency, Copenhagen, Denmark.
EEA (2006b). *Greenhouse gas emission trends and projections in Europe 2006*. EEA Report, European Environment Agency, Copenhagen, Denmark.
Eurostat (2006a). *The agricultural economy, the 2006 Agricultural Year*. http://ec.europa.eu/agriculture/agrista/2006/table_en/en31.htm, September 2006.
Eurostat (2006b). *The 2006 Agricultural Year 3*. Economic data 3.1 The agricultural economy, http://ec.europa.eu/agriculture/agrista/2006/table_en/en31.htm.
Eurostat (2006c). *Statistical and Economic Information – Report 2006*. Rural development in the European Union, http://ec.europa.eu/agriculture/agrista/rurdev2006/index_en.htm.
Eurostat (2006d). *Rural Development in the European Union*. Statistical and Economic Information Report 2006
http://ec.europa.eu/agriculture/agrista/rurdev2006/index_en.htm.
Eurostat (2007). Eurostat Home page http://epp.eurostat.ec.europa.eu, September 2007.
Ewert, F., M.D.A. Rounsevell, I. Reginster, M.J. Metzger and R. Leemans (2005). Future scenarios of European agricultural land use: I. Estimating changes in crop productivity. *Agriculture, Ecosystems & Environment* 107: 101-116.
FAO (2007). AQUASTAT, http://www.fao.org/nr/water/aquastat/main/index.stm, September 2007.
Food and Agricultural Policy Research Institute (2006). *Baseline update for U.S. agricultural markets*. FAPRI-UMC Report #12-06, University of Missouri-Columbia, September 2007.
Gregory, P.J., J.S.I. Ingram, R. Andersson, R.A. Betts, V. Brovkin, T.N. Chase, P.R. Grace, A.J. Gray, N. Hamilton, T.B. Hardy, S.M. Howden, A. Jenkins, M. Meybeck, M. Olsson, I. Ortiz-Monasterio, C.A. Palm, T.W. Payn, M. Rummukainen, R.E. Schulze, M. Thiem, C. Valentin and M.J. Wilkinson (2002). Environmental consequences of alternative practices for intensifying crop production. *Agriculture, Ecosystems and Environment* 88: 279-290.
Gronroos, J., J. Seppala, P. Voutilainen, P. Seuri and K. Koikkalainen (2006). Energy use in conventional and organic milk and rye bread production in Finland. *Agriculture, Ecosystems & Environment* 117: 109-118.
Hafner, S. (2003). Trends in maize, rice, and wheat yields for 188 nations over the past 40 years: a prevalence of linear growth. *Agriculture, Ecosystems & Environment* 97: 275-28
Hoogeveen, Y.R., J.E. Petersen and P. Gabrielsen (2001). *Agriculture and biodiversity in Europe*. Background report to the High-Level European Conference on Agriculture and Biodiversity, STRA-CO/AGRI (2001) 17. Council of Europe/UNEP, Paris.
Hulsbergen, J.J., B. Feil, S. Biermann, G.-W. Rathke, W.-D. Kalk and W. Diepenbrock (2001). A method of energy balancing in crop productivity and its application in a long-term fertilizer trial. *Agriculture, Ecosystems & Environment* 86: 303-321.
ISAAA (2006). *Global status of commercialized biotech/GM Crops:2006*. ISAAA Brief.
Koning, N., G. Becx, T. van Boekel, W. Brandenburg, J. van den Broek, G. van Hofwegen, M.K. van Ittersum, R. Jongeneel, H. Schiere and M. Smies (in press). *Long-term global availability of food: continued abundance or new scarcity?* Wageningen University, The Netherlands.
LEI (2005). *Land- en tuinbouwcijfers 2005*. LEI Wageningen UR and Centraal Bureau voor de Statistiek, The Hague, The Netherlands.
Maracchi, G., O. Sirotenko and M. Bindi (2005). Impacts of present and future climate variability on agriculture and forestry in the temperate regions: Europe. *Climatic Change* 70: 117-135.
Meul, M., F. Nevens, D. Reheul and G. Hofman (2007). Energy use efficiency of specialised dairy, arable and pig farms in Flanders. *Agriculture, Ecosystems & Environment* 119: 135-144.
Mitchell, P.L. and J.E. Sheehy (2007). *Surveying the possible pathways to C4 rice*. In: Sheehy, J.E., Mitchell, P.L., Hardy, B. (Eds.), Charting new pathways to C4 rice. Los Banos (Philippines): International Rice Research Institute, pp. 399-412.
Nevens, F., I. Verbruggen, D. Reheul and G. Hofman (2006). Farm gate nitrogen surpluses and nitrogen use efficiency of specialized dairy farms in Flanders: Evolution and future goals. *Agricultural Systems* 88: 142-155.
Nowicki, P., H. van Meijl, A. Knierim, M. Banse, J. Helming, O. Margraf, B. Matzdorf, R. Mnatsakanian, M. Reutter, I. Terluin, K. Overmars, D. Verhoog, C. Weeger and H. Westhoek (2007). *Scenar 2020 – Scenario study on agriculture and the rural world*. Contract No. 30 – CE – 0040087/00-08. European

Commission, Directorate-General Agriculture and Rural Development, Brussels.
OECD (1993). *OECD core set of indicators for environmental performance reviews: a synthesis report by the group on the state of the environment*. Environment Monographs, Organisation for Economic Cooperation and Development, Paris.
OECD (2007). http://www.oecd.org, September 2007.
Oenema, J. and H.F.M. Aarts (2005). *Koeien & Kansen – Hoe efficiënt worden de mineralen benut in "Koeien & Kansen"?*. Report Plant Research International, Wageningen.
Olesen, J.E. and M. Bindi (2002). Consequences of climate change for European agricultural productivity, land use and policy. *European Journal of Agronomy* 16: 239-262.
Penning de Vries, F.W.T., H. van Keulen and R. Rabbinge (1995). *Natural resources and limits of food production in 2040*. In: Bouma, J., Kuyvenhoven, A., Bouman, B.A.M., Luyten, J., Zandstra, H.G. (Eds.), Eco-regional approaches for sustainable land use and food production, Proceedings of a symposium on eco-regional approaches in agricultural research, 12-16 December 1994, ISNAR, The Hague.
Rabbinge, R. and C.A. van Diepen (2000). Changes in agriculture and land use in Europe. *European Journal of Agronomy* 13: 85-99.
Rabbinge, R. and H.C. van Latesteijn (1992). Long-term options for land use in the European community. *Agricultural Systems* 40: 195-210.
Reidsma, P. and F. Ewert (2005). *The adaptive capacity of European agriculture under different climate and management conditions*. In: Proceedings from the NJF Seminar No. 380, Adaptation of crops and cropping systems to climate change. Odense, Denmark.
Reidsma, P., T. Tekelenburg, M. van den Berg and R. Alkemade (2006). Impacts of land-use change on biodiversity: An assessment of agricultural biodiversity in the European Union. *Agriculture, Ecosystems & Environment* 114: 86-102.
Reynolds, M.P., A. Pellegrineschi and B. Skovmand (2005). Sink-limitation to yield and biomass: a summary of some investigations in spring wheat. *Annals of Applied Biology* 146: 39-49.
Rosegrant, M.W., M.S. Paisner, S. Meijer and J. Witcover (2001). *Global food projections to 2020: emerging trends and alternative futures*. IFPRI, Washington, DC.
Rosegrant, M.W., S. Msangui, T. Sulser and C. Ringler (2008). *Future scenarios for agriculture: plausible futures to 2030 and key trends in agricultural growth*. Background paper for the World Development Report. IFPRI, Washington D.C.,
Rounsevell, M.D.A., F. Ewert, T. Reginster, R. Leemans and T.R. Carter (2005). Future scenarios of European agricultural land use. II. Projecting changes in cropland and grassland. *Agriculture, Ecosystems & Environment* 107: 117-135.
Schenkel, Y. (2006). *Energy as a driver for European agriculture and forest, bioenergy and bioproducts*. In: SCAR paper. 42 pp.
Schnepf, R. (2004). *Energy use in agriculture: background and issues*. CRS Report for Congress, Congressional Research Service (CRS), The Library of Congress.
Schröter, D., W. Cramer, R. Leemans, I.C. Prentice, M.B. Araujo, N.W. Arnell, A. Bondeau, H. Bugmann, T.R. Carter, C.A. Gracia, A.C. de la Vega-Leinert, M. Erhard, F. Ewert, M. Glendining, J.I. House, S. Kankaanpaa, R.J.T. Klein, S. Lavorel, M. Lindner, M.J. Metzger, J. Meyer, T.D. Mitchell, I. Reginster, M. Rounsevell, S. Sabate, S. Sitch, B. Smith, J. Smith, P. Smith, M.T. Sykes, K. Thonicke, W. Thuiller, G. Tuck, S. Zaehle and B. Zierl (2005a). Ecosystem Service Supply and Vulnerability to Global Change in Europe. *Science* 310: 1333-1337.
Schröter, D., W. Cramer, R. Leemans et al. (2005b). Ecosystems Service Supply and Vulnerability to Global Change in Europe. *Sciencexpress*. pp. 1-11.
Shearman, V.J., R. Sylvester-Bradley, R.K. Scott and M.J. Foulkes (2005). Physiological processes associated with wheat yield progress in the UK. *Crop Science* 45: 175-185.
Sheehy, J.E., A.B. Ferrer, P.L. Mitchell, A. Elmido-Mabilangan, P. Pablico and M.J.A. Dionora (2007). *How the rice crop works and why it needs a new engine*. In: Sheehy, J.E., Mitchell, P.L., Hardy, B. (Eds.). Charting new pathways to C4 rice. Los Banos (Philippines): International Rice Research Institute, pp. 3-26.
Slesser, M. and F. Wallace (1982). *Energy consumption per tonne of competing agricultural products available to the EC*. Information on agriculture, (Commission of the European Communities), 85.
Smil, V. (2002). Eating meat: evolution, patterns, and consequences. *Population and Development Review* 28: 599-639.
Steinfeld, H., P. Gerber, T. Wassenaar, V. Castel, M. Rosales and C. de Haan (2006). *Livestock's long shadow; environmental issues and options*. FAO, Rome.
Tzilivakis, J., D.J. Warner, M. May, K.A. Lewis and K. Jaggard (2005a). An assessment of the energy inputs and greenhouse gas emissions in sugar beet (Beta vulgaris) production in the UK. *Agricultural Systems* 85: 101-119.
Tzilivakis, J., K. Jaggard, K.A. Lewis, M. May and D.J. Warner (2005b). Environmental impact

and economic assessment for UK sugar beet production systems. *Agriculture, Ecosystems & Environment* 107: 341-358.
United Nations (2006). *World Population Prospects: The 2006 Revision* and *World Urbanization Prospects: The 2005 Revision*. Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat. http://esa.un.org/unpp, August 31, 2007.
Van de Ven, G.W.J., N. de Ridder, H. van Keulen, and M.K. van Ittersum (2003). Concepts in production ecology for analysis and design of animal and plant-animal production systems. *Agricultural Systems* 76: 507-525.
Van der Knijff, A., J. Benninga and C. Reijnders (2004). *Energie in de glastuinbouw van Nederland*. Ontwikkelingen in de sector en op de bedrijven t/m 2003, report no. 3.04.13, LEI, The Hague, The Netherlands.
Van Ittersum, M.K. and R. Rabbinge (1997). Concepts in production ecology for analysis and quantification of agricultural input-output combinations. *Field crops research* 52: 197-208.
Van Ittersum, M.K. and J. Wery (2007). *Integrated assessment of agricultural systems at multiple scales*. In: Spiertz, H., Struik, P.C., Van Laar, H.H. (Eds.). Scale and complexity in plant systems research: gene, plant, crop relations. Springer, pp. 303-317.
Van Ittersum, M.K., S.M. Howden and S. Asseng (2003). Sensitivity of productivity and deep drainage of wheat cropping systems in a Mediterranean environment to changes in CO2, temperature and precipitation. *Agriculture, Ecosystems & Environment* 97: 255-273.
Van Ittersum, M.K., F. Ewert, T. Heckelei, J. Wery, J. Alkan Olsson, E. Andersen, I. Bezplepkina, F. Brouwer, M. Donatelli, G. Flichman, L. Olsson, A.E. Rizzoli, T. van der Wal, J.E. Wien and J. Wolf (2008). Integrated assessment of agricultural systems – A component-based framework for the European Union (SEAMLESS). *Agricultural Systems* 96: 150-165.
Venturi, P. and G. Venturi (2003). Analysis of energy comparison for crops in European agricultural systems. *Biomass and Bioenergy* 25: 235-255.
Yin, X. and P.C. Struik (2007). *Crop systems biology*. In: Spiertz, J.H.J., Struik, P.C., Van Laar, H.H. (Eds.). Scale and complexity in plant systems research: Gene-Plant-Crop relations. Springer, Dordrecht, The Netherlands, pp. 63-73.
Zwart, S.J. and W.G.M. Bastiaanssen (2004). Review of measured crop water productivity values for irrigated wheat, rice, cotton and maize. *Agricultural Water Management* 69: 115-133.

Appendix 1 (detailed data of Table 4.2)

Land use and output in different regions in Europe based on EU statistics up to 2005

Region			Agricultural area (2004)				% of agricultural area	
Number	Name	Country	1000 ha per MS	1000 ha per region	% of land per MS	% of land per region	Arable[1] (2005) per MS	Arable[1] (2005) per region
1	Nordic	Finland	2253	5407	7	7	99	93
		Sweden	3153		7		90	
		Norway						
2	British Isles	Ireland	4307	21377	61	68	28	38
		United Kingdom	17069		70		40	
3	Western	Belgium	1394	52765	46	52	61	66
		Denmark	2664		62		92	
		France	29632		54		62	
		Germany	17020		48		70	
		Luxembourg	128		50		46	
		Netherlands	1927		52		57	
4	Mediterranean	Cyprus	158	46355	17	45	64	51
		Greece	3960		30		70	
		Italy	13159		44		53	
		Malta	10		30		85	
		Portugal	3819		42		38	
		Spain	25249		50		49	
5	Alpine	Austria	3254	3254	39	39	42	42
		Switzerland						
6	North Eastern	Czech Republic	3631	21867	46	50	75	75
		Poland	16301		52		76	
		Slovakia	1935		39		70	
7	South Eastern	Bulgaria	5331	26008	48	56	92	72
		Hungary	5862		63		77	
		Romania	14324		60		63	
		Slovenia	491		24		35	
8	Baltic	Estonia	770	5017	17	29	71	66
		Latvia	1642		25		63	
		Lithuania	2604		40		66	
	EU-27	EU-27	182048		42	42		61
	EU-15	EU-15	128989		40	40	57	57

[1] Cyprus, Bulgaria, Romania: 2003 data

					Horticulture		Irrigable area		Organic farming	
	Perm.[1] crops (2005) per MS	Perm.[1] crops (2005) per region	Perm.[1] pasture (2005) per MS	Perm.[1] pasture (2005) per region	Horti-culture[2] (2001-2004) per MS	Horti-culture[2] (2001-2004) per region	Irrigable area (2005) per MS	Irrigable area (2005) per region[3]	Organic farming (2003) per MS	Organic farming (2003) per region
	0	0	1	7	0.7	0.5	70500	4.4	7.1	10.5
	0		10		0.3		167 000		13.0	
							117 140			
	0	0	72	62	0.2	0.7	0	1.0	0.7	3.4
	0		60		0.8		208 380		4.3	
	2	3	37	31	5.1	1.6	21710	10.0	1.7	2.9
	0		8		0.5		432 030		6.2	
	4		34		1.7		2 706 480		2.0	
	1		29		1.0				4.3	
	1		52		1.8				2.3	
	2		40		5.1		407 920		2.0	
	27	21	1	27	14.8	10.9	45850	21.6	0.1	4.6
	30		0		33.1		1 593 780		6.2	
	17		30		10.8		3 972 670		8.0	
	10		0		3.4		3 020		0.0	
	21		40		6.3		616 970		3.2	
	22		28		8.1		3 765 130		2.9	
	2	2	56	56	0.7	0.7	119 420	3.7	10.1	10.1
	1	2	24	22	1.0	2.9	47030	1.6	7.0	1.6
	2		21		3.6		124 200		0.3	
	1		27		1.1		180 140		2.5	
	3	3	4	24	3.5	3.6	111 600	4.1	0.1	0.7
	3		18		3.8		152 750		2.6	
	3		33		3.7		808 370		0.3	
	6		60		1.7		4 430		4.3	
	1	1	28	32	2.4	2.0		0.1	5.4	1.8
	1		36		1.6		790		1.6	
	1		31		2.2		4 420		0.9	
		7		32	4.3	4.3			3.4	3.4
	9	9	34	34	4.7	4.7			4.2	4.2

[2] 3 to 4 year average

[3] some countries no data

Appendix 2

Area under arable crops (1 000 ha), by crop, 2004. (Source: Eurostat, 2007; Eurostat, 2006b; Eurostat, 2006c)

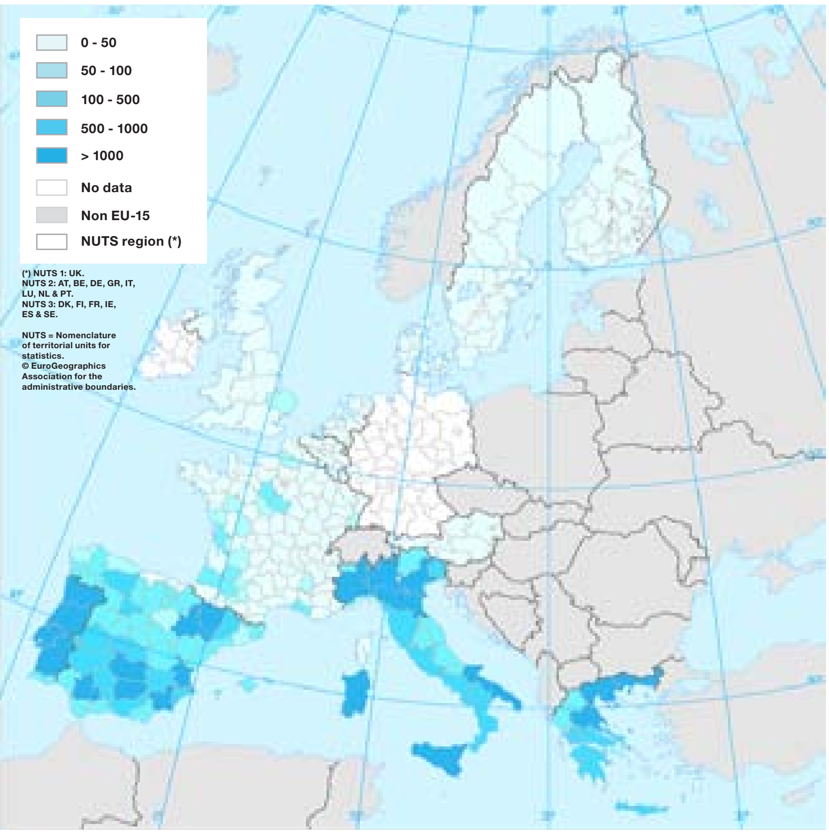
	Wheat	Rye	Barley	Oats	Corn	Potatoes	Sugar beet	Silage maize
Belgium	213	1	39	.	52	67	88	167
Czech Republic	863	59	469	59	88	36	71	216
Denmark	675	32	707	61	.	41	50	130
Germany	3 101	621	1 974	227	454	293	439	1 290
Estonia	76	9	128	***34***	.	23	0	1
Greece	839	10	90	43	251	36	33	4
Spain	2 152	91	3 170	477	480	98	103	90
France	5 231	33	1 626	124	1 796	***157***	384	1 451
Ireland	103	0	183	20	0	13	30	0
Italy	2 338	3	307	147	1 194	73	217	269
Cyprus	***5***	.	.	***0***	.	***6***	.	.
Latvia	166	42	138	54	.	46	***14***	***2***
Lithuania	355	56	293	53	1	69	23	14
Luxembourg	12	1	9	2	0	1	0	12
Hungary	1 173	45	331	69	1 234	31	62	103
Malta	.	.	.	.	.	2	.	.
Netherlands	139	3	48	2	22	165	98	224
Austria	290	46	191	30	179	22	45	76
Poland	2 311	1 550	1 014	520	412	713	292	286
Portugal	189	29	13	57	135	48	8	108
Slovenia	32	1	15	2	46	7	5	27
Slovakia	369	33	224	25	147	24	35	96
Finland	225	27	532	326	.	27	30	.
Sweden	404	24	393	226	.	31	48	5
United Kingdom	1 994	4	1 006	***122***	0	147	154	117
Bulgaria	1 040	9	329	43	383	31	1	30
Romania	2 296	22	425	208	3 239	266	21	34
EU-27	26591	2 750	13652	2 930	10116	2 472	2 252	4 751

Data from previous year

Source: Eurostat.

Appendix 3

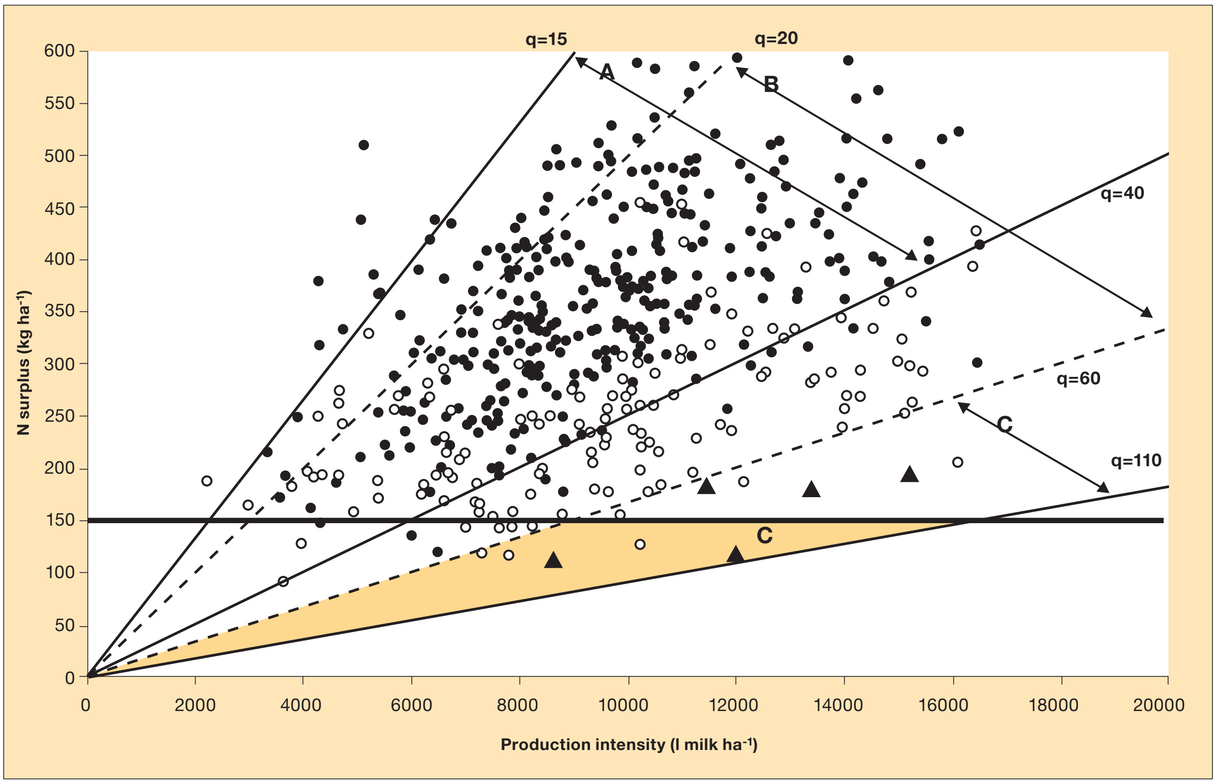
Regional water abstraction rates for agriculture (million m^3/year) during 2000



The map illustrates the IRENA 22 sub-indicator that estimates regional water abstraction rates for agriculture, calculated by weighting national reported water abstraction rates by regional irrigable area. The 41 regions with the highest use of water for agricultural purposes (more than 500 million m^3/year) are all located in southern Europe. United Kingdom estimations are based on 1997 data for irrigable area and reported water abstraction rates. Ireland, Luxembourg and Germany do not provide data on irrigable area for NUTS regions. (Source: EEA, OECD, Eurostat).

Appendix 4

Farm-gate N surpluses in relation to production intensity: Flemish dairy farms in 1989-1990 (solid circles) and in 2000 and 2001 (open circles). Dutch experimental farms or farm groups (triangles). Isoquants of eco-efficiency (q, l milk/kg N surplus). (Source: Nevens et al., 2006)



4.2 Current systems and future scenarios in food processing

4.2.1 Introduction

This paper describes a set of food system activities at the European level, within the framework of the ESF/COST Forward Look "European Food Systems in a Changing World", i.e., the set of activities on food processing.

In the first part of this paper, the present situation regarding the food system activities is discussed in the context of key choices facing society at large. The key questions outlined below serve as the entry point to frame the discussions, i.e.:

- What are the projected new processing technologies that will most affect health, lifestyle, values (enjoyment and intangibles) and how?
- How will geographical shifts in food production impact the EU food processing industry and its competitiveness?
- What will be the sustainability issues that most affect the processing industry and how?

This paper is set around these three questions after a short introductory description of the present food industry in Europe. In each case, the questions are used as an entry point to present the current trends and developments in food processing in Europe.

Next, the four scenarios – as developed in the course of the ESF/COST Forward Look project – are described. The four scenarios are "fast forward (globalised markets – low crisis)", "pause (globalised markets – high crisis)", "play (regional markets – low crisis)" and "rewind (regional markets – high crisis)". The outcome is translated into a research agenda.

4.2.2 The European food and drink industry in 2007

4.2.2.1 The European food sector in figures

In Europe, 480 million customers are daily served with a large variety of foods. They ask for value for money, no safety concerns, convenience, high quality, healthy, culturally diverse and authentic food, produced more and more in an eco-friendly way. This challenges the largest manufacturing sector in Europe, the food and drink industry with 3.8 million people employed at 280 000 companies and a turnover of 836 billion €, to be reliable and innovative (Confederation of the EU food and drink industry – CIAA, 2007). In addition, the food sector is highly fragmented with only 0.9% of large companies and 3.6% medium-sized. The remainder operates at small or micro scale. The turnover of SMEs is 47.8%, employment 61.3% and value added 46.2% (Sebok, 2007).

Which changes have been made in the past years? In 2004, over 4 million people were employed (ETP Food for Life, 2006), meaning a reduction of 5%. Also, the global export market share of Europe (excluding EU New Member States) declined from 24 to 20% in a period of 10 years. Since the food and drink industry transforms over 70% of agricultural raw materials produced in Europe, the reduction has a much wider impact in the total food chain.

In general, growth could be generated by moving up the value chain and strengthening export performance. This could be realised through more (efficient) innovation strategies. The Joint Research Centre of the European Commission in Seville has made an overview of industrial R&D investments (JRC IPTS, 2005)[3]. The food sector's share is only 1% of all R&D investments in Europe (calculated on the basis of the largest companies), ranking the food sector as number 15[4]. These low rates are underlined by the CIAA. Business expenditure on R&D as a percentage of total output is 0.24%, far below Japan (1.2%), for example. Therefore, the following question could be put, "Do we need a radical change in the policies related to research, development and innovation in the food sector in Europe?"

In spite of the above, the following elements have – and will have – a positive impact on innovation strength:

- the operating profits of food producers are more or less averaging those of all industrial sectors (JRC IPTS, 2005);
- the food sector is globally still by far the largest sector in terms of (added) value (CIAA, 2007);
- the potential of making use of R&D investments from other industrial sectors (for example, biotechnology, engineering, ICT; all showing higher percentages than those of the food sector) will have a positive impact on the innovation strength of the food sector;
- convenient, functional, healthy and consumer target-group specific foods all provide opportunities for adding value to raw materials;
- the R&D departments of stakeholders have started to join forces, e.g. in the European Technology Platform Food for Life (ETP, 2005);
- the potential of medium-sized and larger small-scale enterprises in R&D trajectories is substantial and may lead to regional innovation clusters.

3. It should be noted that innovation and R&D investments are not 1:1 related; however, the R&D investment percentage gives an indication of the innovation strength of a sector.
4. The pharmaceutical and biotechnology sector is ranked no. 3 with a share of 18%.

4.2.2.2 The food processing landscape

The food processing landscape is defined as a part of the agri-food chain from either harvest or slaughtering to distribution towards retail or out-of-home consumption ("the food industry environment"). In Western society foods are to a large extent produced on an industrial scale. A rough estimate would be that some 80-90% of foods has undergone some treatment, from very simple to very complex. Over the past 100 years or so, traditional food processing methods have gradually changed into more science-orientated approaches, although the artisanal roots of many food processes can still be recognised. There is still even a market for foods produced in the traditional way (or claimed to be produced in the traditional way). For the sake of clarity, we would like to define processing technology as the use of science-based techniques to reach a goal in society; in this particular case the goal is production of high-quality foods. Defined in this way, the word "technology" is different from the word "technique", which need not be science-based (techniques have existed for as long as mankind) whereas technology has only emerged since the late 19th century.

Today, technologies for food processing are subject to many changes for several reasons. First, the market for food products has drastically changed in the last decades, from "bulk" production in large quantities to a more consumer-oriented approach. For the food manufacturer this comes down to much more attention to food quality, as this has become a decisive factor in keeping or obtaining a market position. Such an approach has, of course, a large impact on the technologies to be applied. The basic point is: what are the technological possibilities to meet consumer demands? Another reason for changing technologies is an economic push, for instance in order to achieve higher productivity and/or cost reduction (for instance, less labour-intensive) and to increase process reliability. Also environmental demands or, more generally, the desire for sustainable food production may be a reason for change. Yet other reasons are changes in the availability and composition or properties of the raw materials, besides the normal biological variability, for instance due to genetic modification. Remarkably, changes caused by technology push are rare in the food industry, although they can be found: for instance, high-pressure treatment of foods or extrusion cooking. Irradiation technology is another example but with limited success because of rejection by the consumer.

Extensive impressions of the present state of the art of new and existing food technologies are presented by Yano et al. (1994) and in a multi-authored book edited by Gaonkar (1995). In addition, the Journals "*Trends in Food Science and Technology*" and "*Food Technology*" frequently offer reviews about new developments in Food Science and Technology.

4.2.2.3 Sustainability, a key issue in processing

The discussion on sustainability in food chains is extremely complex, even more so if the use of raw materials for both food and non-food applications is taken into account. Here, the food processing domain is considered. Why does sustainability deserve attention in food processing? What are the basic issues? What is the need for eco-friendly processing? What facts underpin the importance of sustainability? What dilemmas and trends should be considered? Are models available or being developed that provide insight? What are potential solutions and what is the current status?

In food processing, the key sustainability issues are:

- optimal use of raw materials, leading to food constituents and full products that fit consumer demands and consumers' perception of required quality;
- efficient usage of water, energy, packaging materials and other materials required in the processing trajectory (cleaning materials, processing aids, etc.);
- economic efficiency of sustainable processing schemes;
- processing methodologies that are reliable and in line with customer perception, social and cultural values.

The need for eco-friendly processing is back on the agenda due to the debate on climate change. The contribution of food consumption to global warming as part of total consumption (housing, clothing, leisure, etc) is substantial. the Percentages of 30% are mentioned for the Netherlands (Nijdam, and Wilting (2003). Eco-friendly processing is directly and indirectly influenced by increasing prices of raw materials and energy, depletion of resources (fish, for example), availability of arable land (for example, impacting availability of resources for meat production), the eutrophication potential and, at a global level, food security in underdeveloped countries in general. The latter requires processing equipment suitable for flexible and low-cost use under widespread, often hard, conditions.

Recent studies show that the energy consumption of the manufacturing domain as part of the food chain is ~20%, taking into account all food categories (meat, fish, dairy, fruit, vegetables, potatoes, oils and fats, grain and starch, sugar, beverages and other foods, Arthur D. Little and SenterNovem, 2006; more detailed by Foster et al., 2006).

One could argue about the real impact of innovations in the entire food chain. A variety of methodologies has been developed, such as Life Cycle Analysis (and its extended version including social and economical data), In the Netherlands, the average food intake corresponds to 2500 kcal/day, i.e. 60 PJ/year for the Dutch population. The energy required to produce this amount of food is 540 PJ/year of which over 100 PJ is required for processing. Note that the total energy consumption in the Netherlands is 3000 PJ/year.

High-pressure sterilisation has the potential to substantially reduce the energy consumption in the processing-out-of-home chain because shelf-stable foods – with fresh characteristics – will not require freezing and defrosting in the catering environment.

Lean Production Means (adopted from the automobile sector), Industrial Ecology and Symbiosis models, Food Miles, etc. The production of tomato ketchup serves as an example for the use of LCA methodology (Andersson and Ohlsson, 1999). The total energy input is 25 MJ/kg, of which processing (28%), packaging (30%) and re-packing (23%) contribute most. The percentages for primary production, transport, retail and storage are all ~5%. Eco-friendly improvements in packaging and processing will, therefore, have the main impact. For other food products, the energy input balance could be completely different, for example, in which glasshouse production, fertilisers and cooled distribution are dominating factors.

In general, the processing efficiency in terms of energy, water and packaging materials for the entire European sector becomes more transparent (see for facts, reports of FPME for packaging materials, CIAA, Food Industry magazines, European projects for waste valorisation such as AWARENET and REPRO). Key topics that either already are or should be addressed – according to recommendations in most studies – are reduction of meat consumption, process intensification, efficient cooling and drying and reduction of calorie intake (satiety).

It can be concluded from reading their newsletters that the large food manufacturing associations and stakeholders are putting more emphasis on sustainability issues. They all stress that real breakthroughs in innovation are needed, that they require substantially higher R&D budgets (see Section 4.2.2.1), especially because of changing consumption patterns, increased demand for convenience and freshness, dilemmas concerning health aspects of food in order to prevent diseases, etc. As presented below, breakthrough innovations are possible at the smaller scale and provide convincing arguments for larger-scale developments.

The attention for eco-friendly processing has led to the first concrete innovations. A new procedure for roasting coffee has been developed requiring 99% less water. Implementation of volumetric instead of surface heating technologies has led to 50% energy reduction. New bag-in-box systems substantially reduce packaging materials and energy consumption by 70%.

Overall, these developments are based on a technology push mechanism. The combined technology-push and market-pull trend will lead to the required breakthrough innovations.

4.2.2.4 Food and nutrition as drivers for novel processing schemes

We are in the middle of the transition towards healthier diets. Europe is now experiencing an increase in diseases such as obesity, coronary heart disease and diabetes. This is the result of changing lifestyles and diets high in fat, sugar, salt, cholesterol and low in vegetables and fibres for example (Eurofound, 2004; CIAA, 2007; Dutch Health Council, 2007). Guidelines from Health Councils are helping consumers and producers focus on a more balanced lifestyle and improved products. Behavioural change is the key next stage of the nutritional transition.

Without doubt, obesity is one of the main concerns for public and private stakeholders. The European project "Diogenes" has defined a multi-disciplinary approach to advanced understanding of how obesity can be prevented and treated from a dietary perspective. It integrates studies of dietary, genetic, physiological and psychological, and behavioural factors (Diogenes, 2005).

Healthy food is, therefore, one of the main drivers for novel processing schemes. The challenge is to produce food menus that are rich in dietary fibre and micro-nutrients, low in salt and "bad fats", allergen-free, convenient and tasty. Mild processing schemes, bio-processing and micro-engineering could play a crucial role here as described in the next chapter.

From a food safety point of view, healthy food is also the main issue. In the first instance, safe food processing methods that are relatively mild could be well-implemented. Financial means and capacity development are bottlenecks for integration of processing schemes in local industries.

4.2.2.5 Safety as a driver

Safety is – and always will be – one of the key drivers for new developments in food manufacturing. For over a decade, the European Hygiene Engineering and

Design Group (EHEDG) has been developing protocols for handling safety issues in the industry. Concerning larger industries for the time being, current processing lines are being thoroughly investigated and improved according to safety standards, e.g., piping materials, valves, treatment chambers, cleaning procedures, downtime operation, etc. New processing plants are being developed based on hygiene concepts. For the future, completely new designs are expected, e.g., full cylindrical processing modules and introduction of robots at larger scale (Gray et al., 2005).

The White Paper on food safety of the European Commission established the general principles of European Food Regulation and led to the adoption of regulation on food law in 2002. As an outcome, the European Food Safety Agency (EFSA) was set up in the same year. For the first time, this has led to an integrated approach in Europe with legislation in force covering a variety of food safety issues in the full chain. Measures relating to food additives, flavourings, food composition, and microbiological criteria have a direct effect on processing procedures and new developments. The novel food legislation challenges the industry and may be a burden for innovation especially for small and medium-sized enterprises.

Some further considerations on food safety are presented in the box page 69.

4.2.3 What are the projected new processing technologies that will most affect health, lifestyle, values (enjoyment and intangibles) and how?[5]

4.2.3.1 Food processing and its goals

The goal of food technology is to convert raw materials into high-quality food products at the lowest possible cost; the objectives of food technologies can be classified in four categories (Figure 4.17). There are, of course, several other possibilities for classification – see, for instance, Niranjan (1994) for another example – but we found this classification useful to discuss new and existing technologies.

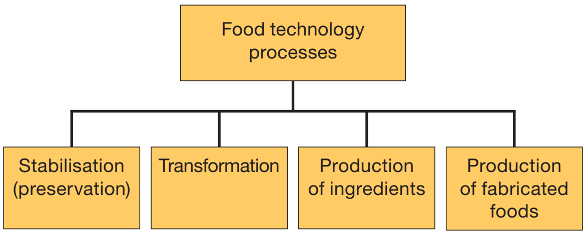


Figure 4.17. Overview of types of food processes

Processes to preserve foods (stabilisation processes)

Food products are usually non-equilibrium systems, i.e., are in a state of thermodynamic instability. A very important goal of food technology is to bring the food into a (pseudo) stable state, meaning that the stability of the food is higher than its lifetime. In order to achieve that, several aspects can be recognised.

Microbial stabilisation: first and foremost, foods ought to be safe from a microbiological point of view. Pathogenic micro-organisms (or sometimes their metabolites) should be removed or eliminated. Furthermore, spoilage due to micro-organisms should be prevented: e.g., to prevent souring of milk, mould growth in bread, yeast fermentation in fruit juices. The most frequently used process in this respect is heating: pasteurisation (often the minimal heat treatment to ensure absence of pathogens) or sterilisation (no micro-organisms left, complete microbial stability).

5. This paragraph (except sections 4.2.3.2 and 4.2.3.3) is largely a revised and updated text that was published earlier as Boekel, M.A.J.S. van (1998). Developments in technologies for food production. In: Jongen, W.M.F. and M.T.G. Meulenberg (eds). Innovation of food production systems – Product quality and consumer acceptance. Wageningen Pers, Wageningen. pp. 87-116.

European Food Systems in a Changing World: Food Safety Concerns

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Foodborne diseases encompass a wide spectrum of illnesses and are an important cause of morbidity and mortality worldwide. However, the price we pay for unsafe food and the full dimension of the problem, particularly the burden arising from chemical and biological contaminants in food, is currently still not completely elucidated. Precise information on the extent of foodborne diseases is needed to adequately inform policy makers and allocate appropriate resources for food safety control and intervention efforts. The outlines of an improved public health system for the surveillance of and response to foodborne infections should be developed in accordance with the rapidly changing field of food safety concerns.

The new foodborne contaminants have continued to grow over the last few decades and this trend is expected to continue. Global climate change has an impact on the microbial and viral migration of foodborne contaminants to water and soil resources, consequently contaminating primary production in soil and aquatic areas. Understanding the circulation and cycle of foodborne pathogens is not sufficient to be able to develop a comprehensive proactive approach to current and new incoming food systems. The information received from the annual zoonose's data collection gives a general picture of the foodborne pathogens situation in food and animals in the EU. However the data is not always harmonised and we still have data gaps. Sometimes substantial variations are observed between the reported occurrence levels amongst the EU Member States and this should be considered when results are interpreted. A relevant system approach should be introduced to investigate the outbreaks in order to define the point at which contamination is likely to have entered the food supply chain, and to understand the circumstances in which this occurred. Foodborne viruses may cause a range of clinical syndromes, varying from diarrhea to meningitis and rash illnesses and yet the EU has no systematic surveillance of selected foodborne viral diseases. Although most countries have some level of reporting of foodborne illness outbreaks, only a few include viral foodborne illness.

Microbiological quality control criteria for food globally rely on standards that have been developed for bacterial foodborne infections. There is now substantial data which prove that these criteria are insufficient to protect from viral foodborne infections, and that the extent of foodborne viral illness is significant. It is important to understand the fundamental differences between viruses and bacterial pathogens in order to design improved strategies capable of controlling both classes of pathogens. In view of the lessons of the past decades, in which several new viral disease problems emerged, developing ways to control foodborne viral illness should become a priority, all the more so because the food market has now become a global one.

As a consequence of changing lifestyles, the knowledge about how to cook food safely as a basic human skill has been considerably reduced, especially in the domain of nutrition and the hygiene of food and its preparation. Finally, new nutrition patterns have been developed for personalised nutrition and relevant foods are produced to underpin these new styles; these come under threat from fresh foods, which are produced in more difficult environmental circumstances due to water and soil pollution.

References

Ammon, A. and R. Tauxe (2007). Investigation of multi-national food borne outbreaks in Europe: some challenges remain. *Epidemiology and Infection*, 135(6): 887-889.

EFSA (2006). The Community Summary Report on Trends and Sources of Zoonoses, Zoonotic Agents, Antimicrobial Resistance and Food borne Outbreaks in the European Union in 2005. *The EFSA Journal*, 94.

McMeekin, T.A. (2007). Predictive microbiology: Quantitative science delivering quantifiable benefits to the meat industry and other food industries. *Meat Science*, 77: 17-27.

Raspor, P. and M. Jevšnik (2008). Good nutritional practice from producer to consumer. *Crit. rev. food sci. nutr.*, 48(3): 276-292.

Raspor, P. (2008). Total food chain safety: how good practices can contribute? *Trends food sci. technol.* 19: 405-412.

Chemical stabilisation: some chemical reactions cause a decrease in quality of foods. Examples are the Maillard reaction (non-enzymatic browning reaction, causing discoloration, off-flavours, loss of nutritional quality, perhaps formation of toxicologically suspect compounds), and fat oxidation (causing off-flavours and loss of nutritional quality). In such cases, it is necessary to minimise unwanted reactions as much as possible.

Biochemical stabilisation: raw materials of both plant and animal origin contain enzymes that can cause deterioration of the materials: e.g., protein breakdown by proteases, fat breakdown by lipases, enzymatic browning by polyphenol oxidase. In as far as these changes are undesired, such enzymes should be destroyed, or at least inhibited.

Physical stabilisation: foods should be physically stable, that is to say, they should not show phase separation (demixing), should not dry out, keep a certain consistency, etc.

A very important aspect with all preservation technologies is packaging. It forms the barrier between the food and its environment, it can protect the food from recontamination and other undesired influences from the environment (such as oxygen). Packaging has therefore a large effect on food quality.

Transformation processes

Raw materials are transformed into foods via a variety of processes, such as fermentation (via micro-organisms or enzymes, e.g., cheese, olives, tea leaves, cocoa, beer, wine), extrusion (e.g., snacks from starch containing raw materials), hydrogenation of fats, emulsification, extraction (e.g., fruit juices), etc. Frequently, the resulting food product does not resemble the raw material in appearance and properties. For instance, cheese is completely different from milk, bread is different from wheat, orange juice different from oranges.

Separation processes

Separation processes are used to obtain components or ingredients from raw materials: for instance, processes to obtain starch from potatoes or maize, milk proteins from milk, sugar from sugar cane or beet, oil from soy beans or olives. Typical processes used are phase separations (filters, membranes, centrifugation) and molecular separations (crystallisation, distillation).

Manufacture of fabricated foods

Fabricated foods are foods that are made from various ingredients and they are developing strongly in the food market these days. Traditional foods such as bread or cheese can be seen as fabricated foods. Examples of "new" foods are cheese in which milk fat is replaced by a fat of plant origin, replacement of milk proteins in milk products by, for instance, soy protein, cocoa-butter substitutes, bakery products, ready-made meals. A very successful fabricated food has been margarine, basically an imitation of butter. An example that was not very successful is TVP ("texturised vegetable protein"), an attempt to produce meat substitutes. Functional foods, claimed to have a specific health effect, also belong to the category of fabricated foods.

4.2.3.2 Developments in food processing

Science-driven and society-driven research, alone and in combination, have triggered developments in processing technologies. The predominant developments are discussed below.

A. Developments in stabilisation technologies

Heating processes

The most widely-used existing stabilisation technology is, of course, heat treatment. Heating inactivates micro-organisms and enzymes, hence it enables the production of safe foods which can be kept. The drawback is, however, that heating may impair the quality of the heated food. Chemical reactions are accelerated at high temperature and cannot be prevented. They cause loss of nutritional value (destruction of vitamins, for example), organoleptic changes (for instance, brown discolouration and off-flavours due to the so-called Maillard reaction). Heating technology may be optimised, however, to still produce safe and stable foods but with the least heat damage possible. Use is then made of the different temperature sensitivity of microbial inactivation (usually having a high activation energy) and "normal" chemical reactions (mostly with lower activation energy). Figure 4.18 gives a schematic impression of this phenomenon.

The approach results in the HTST (high temperature short time) and UHT (ultra-high temperature) processes, which have gained popularity, especially in the dairy industry. Many new technologies are in fact based on this optimisation of time-temperature combinations (balance between microbial and enzyme inactivation on the one hand, and as little heat damage as possible on the other hand). This optimisation includes attempts to reduce residence time distribution and heating-up and cooling-down periods in the equipment to avoid over-processing. Furthermore, aseptic packaging technology is a prerequisite for this optimisation because packaging has to be done after heating.

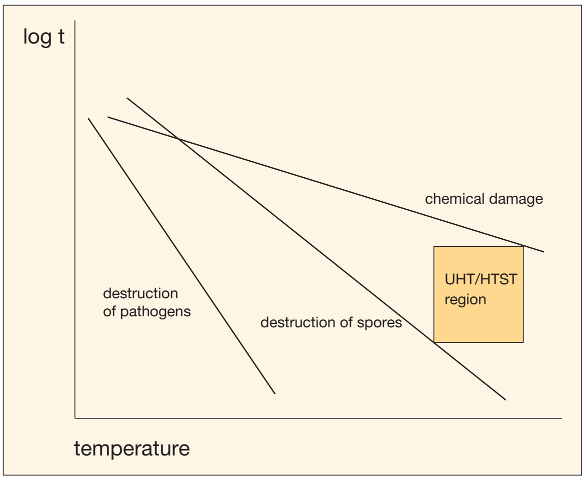

Figure 4.18. Heat treatment. Schematic presentation of time (t) – temperature combinations giving the same effect of microbial inactivation and chemical damage.

Heating of foods containing particulates poses special problems because liquid and solid phases are heated at different rates. In addition, particulates are easily damaged by pumps, in heat exchangers and during the filling process. One solution is to heat solid and liquid phases separately and remix them again before filling (Bengtsson, 1994). Some new developments are discussed below, such as nonthermal processes (Mertens and Knorr, 1992) and combination of preservation methods (Leistner, 1992).

There are also some new developments in the traditional canning of foods, where it has been shown that variable retort temperatures can be more beneficial for the quality of the resulting product than holding at a fixed maximum temperature (Durance, 1997). In addition, it results in energy-efficient processes with reduced processing time and production cost. This can be achieved with the aid of computer simulations and automated process control.

Microwave heating

Microwave heating is, of course, widely known because of its application in the home. It can also be used on an industrial scale, though frequently in combination with conventional heating methods. The process allows a rapid heating-up and in-depth heating of the material as the heat is generated within the food and continuous processes are possible. Rapid cooling is, however, not possible, and neither is regeneration of heat. In addition, microwave heating can also be done with packaged food. According to Bengtsson (1994), the largest application of microwave technology is for tempering to just below the ice-melting temperature of frozen meats and fruits. A problem remaining with microwave heating is that the electromagnetic field is not homogeneous so that heating rates within the food can be different.

High-frequency heating (near 27 MHz) is simpler than microwave heating and can be done with larger amounts. However, high-frequency heating is less flexible, more bulky and less frequency stable and is used, if at all, in combination with conventional technologies (Bengtsson, 1994).

Electrical resistance heating (ohmic heating)

If electrical conductivity of food components is about equal and if neither the voltage nor electrical current applied is excessively high, this technology is suitable for rapid and mild heating of liquids and solids, though rapid cooling and regeneration of heat is not possible. Its application on an industrial scale is still limited but is expected to grow in the future (Bengtsson, 1994). Applications are continuous cooking, pasteurisation and sterilisation in combination with aseptic packaging. The main advantages of the method are very rapid and even heating and absence of overheating at the tube walls (Fryer and Li, 1993; Parrot, 1992). Heating of particulate-containing foods is more advantageous with this technique than with conventional heating. An overview on ohmic heating (IFT Symposium, 1996) was given including product development and economic aspects. It was concluded that ohmic heating holds considerable promise for some food processes, especially for processing low-acid foods. Ohmic operational costs were found to be comparable to those for freezing and retort processing of low-acid products.

Infrared heating

With infrared (IR) heating, heat is transferred by radiation; shortwave IR (wavelength near 1 μm) and intermediate IR (wavelength near 10 μm) offer possibilities to heat quickly with a penetration depth of 5 mm. Energy is converted into heat by interaction with molecules in the (surface of the) food, as opposed to conventional oven heating where heat is transferred via convection of circulating hot air. The features of infrared heating are (Sakai and Hanzawa, 1994):

- efficient heat transfer to the food;
- the surrounding air is not heated;
- more uniform heating and rapid heating rates;
- compact and automatic constructions are possible.

Possible industrial applications are in continuous baking, drying and grilling, thawing and pasteurisation, but the technique is not yet widely used in the food industry (Bengtsson, 1994). Regeneration of heat is not possible.

4.2 Current systems and future scenarios in food processing

High electric field pulses

High-voltage micro- or millisecond pulses (field strengths in the order of 15-30 kV/cm) cause microbial cell damage ("electroporation"), thus inactivating the cells while damage to food components does not seem to occur so that the sensory quality is not impaired (retention of flavour, nutrients and a fresh-like taste). Inactivation of proteases is also reported (Vega-Mercado et al., 1997), but a limitation of the technique is that it does not inactivate spores (Knorr et al., 1994), though Marquez et al. (1997) claim that spores can be inactivated at increased temperature or increased time gap between pulses. Inactivation depends on factors such as electric field intensity and/or number of pulses, temperature, pH, ionic strength, conductivity of the medium. The advantage is that an instant distribution throughout a conductive food system is reached with short treatment times and very little heating. However, this nonthermal stabilisation technique seems not (yet) commercially attractive (Bengtsson, 1994), though prototype equipment is available and products such as fruit juices and liquid eggs could be industrially processed by this technology in the future (Vega-Mercado et al., 1997, Qin et al., 1995).

Pulsed light

Pulsed light with the power of an intense flash of sunlight-like light, having a spectrum between 200 nm and 1 mm and maximum emission between 400-500 nm, has bactericidal power, and the technique can thus be used to extend shelf life of foods and to kill micro-organisms on packaging materials (Dunn et al., 1995). Pulsed light is reported to have a higher bactericidal effect than conventional UV light and may have a potential for baked goods, meat, seafood (Dunn et al., 1995). However, the destructive effect on micro-organisms is limited to surfaces and to transparent media.

Ultrasound

This technology can be divided in two applications: low- and high-intensity ultrasound. Low-intensity ultrasound (power < 1 $W \cdot cm^{-2}$) is useful as an analytical tool for studying physico-chemical properties of foods (McClements, 1995); it could also be used in-line during production as it is a non-invasive and non-destructive method. High-intensity ultrasound (typically in the power range of 10-1 000 $W \cdot cm^{-2}$) causes physical disruption and promotes chemical reactions involving radicals (such as oxidation) by generating intense pressure, shear and temperature gradients (McClements, 1995). Although enzyme and micro-organism inactivation is possible, its greatest potential is probably in emulsification, deaggregation, degassing, induction of crystallisation, and phase separation. It may also facilitate heat and mass transfer in, for instance, drying processes. The potential of high-intensity ultrasound still needs to be translated into low-cost equipment before it will be used in food processing (IFT Symposium, 1994a).

Irradiation by γ-waves

This was indeed a completely new technology to stabilise foods, developed in the 1940-1950s. The principle is based on inactivation of micro-organisms and enzymes due to formation of radicals induced by the radioactive waves. If the radiation intensity becomes too high, chemical damage to the food itself also occurs, for instance, fat oxidation may become a problem, as fat oxidation is initiated by radicals. However, processing conditions are well established and good quality foods can be produced (IFT Symposium, 1994b). This technology is, however, not a success because of rejection by the consumer, who associates the technique with radioactive foods. Although this is of course a misconception because the foods do not come into contact with radioactive material, the technology is at present not able to show its potential. It is now being used for limited purposes only, such as sterilisation of spices and condiments, or to prevent some unwanted physiological changes in stored fruits and vegetables, such as potatoes, strawberries, mushrooms. Irradiation is not suited for inactivation of specific parasites but more to ensure safety from a variety of foodborne pathogens and to prolong shelf life (Loaharana and Murrell, 1994). Irradiation will perhaps be used more in the future in combination with other methods of food preservation (Thakur and Singh, 1995). An example is the combination of refrigeration and irradiation to improve the safety and shelf-life of fresh meat and poultry (Murrano, 1995).

High-pressure treatment

This is probably the most promising new technology to stabilise and preserve foods, which already has some application, especially in the fruit and vegetable area. The potential of high pressure had already been known for a long time, but the application was limited by technical difficulties, which now seem to have been overcome. The pressure range of interest is in the range of 400-600 MPa and the working principle is based on inactivation of enzymes and micro-organisms, probably because of irreversible protein denaturation. Because the temperature at which the high-pressure treatment is given can be low, heat damage does not occur; pressure is distributed evenly throughout the food and the resulting food is almost like fresh. High-pressure technology also opens the possibility of inducing some structure, as gelation of proteins or starch can be the result of the treatment (e.g., Messens et al., 1997). However, less desirable changes may also occur as it was found that lipid oxidation in fish muscle was enhanced by high pressure (Oshima et al., 1993). A drawback of high-pressure treatment is that it cannot yet be done in continuous mode, though a semi-continuous process can be used by overlapping batch units. There is much research being carried out on high-pressure treatment at the moment – see, for instance, Ledward et al. (1995); IFT Symposium (1993).

Cooling and freezing

Stabilisation by cooling and freezing is also a frequently used process. The working principle is the slowing down of reaction rates (both chemically and physiologically). Sensory and nutritional quality is usually not impaired by the process itself, apart from possible damage in the case of freezing when ice crystals are formed (damaging cell structures, for instance) and changes induced by the resulting high ionic strength and pH changes. Cooling and freezing cannot result in completely stable products: even at low temperature chemical and biochemical reactions continue, albeit at a slow rate. As soon as the temperature increases, degradative reactions (including growth of micro-organisms) become prominent. There are no really new developments in this field, apart from technical improvements, such as savings in energy requirements, rate of freezing, and improved process control (George, 1993). New possibilities will perhaps arise with increased knowledge on controlling ice crystallisation and growth and manipulation of the phase states of frozen water. Another possibility is to add a sugar-like trehalose to prevent ice crystal growth due to the ability to form a glass (Scher, 1993; Roser, 1991) Using extremely high freezing rates, it may be possible to go directly into the glassy-state region even from high levels of unfrozen water (Bengtsson, 1994). Osmotic concentration of cut fruits and vegetables changes the solid matter content so that the glassy state is reached at higher temperature than normal when freezing; such a process should give higher quality retention (Bengtsson, 1994). The effect of deep freezing and the glassy state has been discussed by Goff (1992). Another development is the use of antifreeze proteins to block undesirable nucleation and ice-crystal growth (Swienteck, 1992), but whether this is a realistic option in food technology remains a question. High-pressure technology in combination with low temperature also offers possibilities to control freezing and thawing of foods (Bengtsson, 1994).

Minimal processing

To satisfy the consumer demand for fresh foods which nevertheless have a substantial shelf life, minimal processing is becoming popular. Minimal processing is a somewhat vague concept, as it may actually involve substantial processing, but what is meant is that foods are produced with a fresh-like quality and containing only natural ingredients. Minimal processing can be described as (for the consumer) invisible processing and can be applied at various stages of the food distribution chain: processing, storage, packaging (Ohlsson, 1994). It is especially of interest for fruit and vegetables. Ahvenainen (1996) has given an overview and she distinguishes two purposes in minimal processing: i) keep the produce fresh, yet supply it in a convenient form without losing nutritional quality; ii) the shelf life should be sufficient to make distribution to the consumer feasible.

Hurdle technology

The concept of hurdle technology is actually not very new but receives renewed attention these days in relation to minimal processing of foods. It means that existing and novel preservation techniques are combined to give a series of preservative factors which are called hurdles that cannot be overcome by micro-organisms (Leistner and Gorris, 1995). Examples of hurdles are temperature (heating, cooling), water activity, pH, redox potential, preservatives (chemical agents, bacteriocins). Novel preservative factors are gas packaging, ultra-high pressure treatment, edible coatings, use of bacteriocins (Leistner and Gorris, 1995). Hurdles should not be taken too literally: in most cases it is not so that micro-organisms overcome one hurdle and then face another one; rather, it is the synergistic effect of factors (the combination of pH and water activity, for example).

The concept of hurdle technology was more or less reinvented in the meat industry for the production of sausages, and can be used now also in the production of fruit and vegetables, bakery, dairy and fish products (Leistner and Gorris, 1995).

Sous-vide

Sous-vide cooking is vacuum cooking of raw materials and/or foods in heat-stable vacuumised pouches under controlled conditions of temperature and time (Schellekens, 1996). The process is especially suitable for ready-made meals and is claimed to give better quality (sensorial as well as nutritional) than normally-cooked meals. Long heating times and relatively low heating temperatures are used to avoid thermal damage. However, the use of a low heating temperature gives a rather limited pasteurising effect and hence a limited shelf life at 0 °C. To improve the microbiological safety of *sous-vide* cooked products, the concept of hurdle technology is used.

The packaging material in which the foods are heated is subject to strict requirements: it should be heat-stable, have low permeability for gases, have sufficient mechanical strength, and it should, of course, be food-grade (no migration of components from the package to the food). *Sous-vide* cooking is a semi-continuous process and is used mostly in catering (Schellekens, 1996).

4.2 Current systems and future scenarios in food processing

Drying and concentration

Water is a very important compound in food and has a great impact on the chemical, microbiological and physical stability of foods. Food preservation and food quality depend to a large extent on appropriate management of food moisture (van den Berg, 1991). The reactivity of water is the key factor, more than the water content. Food scientists are accustomed to use water activity as the important factor in this respect. However, there is some debate in literature as to whether this is the right parameter (van den Berg, 1991; Franks, 1991; Slade and Levine, 1991; Roos et al., 1996; Fennema, 1996). It is beyond the scope of this chapter to go into detail; suffice to say that the concept of water activity in relation to food stability is still useful but it should not be taken as the definitive parameter as is sometimes suggested in textbooks.

Removal of water from foods is thus done for stabilisation purposes, and/or to reduce transport costs. Removal of water can be done in three ways:

- as gas/vapour, by evaporation (usually under reduced pressure to avoid too high a temperature)
- as liquid (water) by reverse osmosis
- as solid (ice) by freeze concentration.

An overview of dehydration techniques was given by Cohen and Yang (1995). Evaporation can be seen as the traditional method for concentration and is frequently used for liquid foods such as fruit juices and milk products. The oldest drying technique is undoubtedly solar drying (in the open air), used for fruit, vegetables, meat, fish. Another technique from antiquity is smoking of meat and fish. (In addition to drying, antimicrobial agents are transferred from the smoke to the product, thus improving stability.) A somewhat more sophisticated technique than solar drying is convection drying in drying chambers, mostly with hot air passed over the product.

Modern drying technology uses spray drying, in which a liquid product is atomised through a nozzle or via a fast rotating wheel in small drops surrounded by hot air. Fast evaporation takes place and powder particles result. Products as instant coffee, tea and milk powder are examples. Spray-drying is often used in combination with fluidised-bed drying, in which particulate solids are levitated in an upward-flowing gas (mostly hot air). Often, it is useful to agglomerate powder particles to some extent, thus improving properties such as free flowing, bulk density and instant properties. Jet agglomeration is a newer technology to agglomerate particles in turbulent free jets of steam (Schuchmann et al., 1993). It has the advantage that materials containing volatile compounds can be processed, due to the short residence time and a narrow residence-time distribution.

Drum-drying is a technique in which water is evaporated from a liquid product on the surface of a heated drum; the technique is used for instance for production of gelatine, but is otherwise not used very much because of possible heat damage.

Freeze-drying (lyophilisation) is a technique in which frozen water is removed from frozen food under high-vacuum without the water going through the liquid phase. Freeze-drying results in very little damage to the product and the resulting powder can usually be redispersed very well. However, the process is slow and expensive, and therefore not much used in food industry.

Osmotic drying is a dehydration technique in which products are soaked in a concentrated sugar or salt solution. In such processes, three types of mass transfer take place: i) water flowing out of the product; ii) solute transfer from solution to product; iii) a leaching out from the product's own solutes. As opposed to traditional soaking techniques (salting, candied fruit), osmotic dehydration involves significant water removal with limited and controlled solute incorporation (Raoult-Wack, 1994). Optimisation of the process is now possible and new applications could be developed, for instance with fruit and vegetables, meat and seafood. The industrial application is until now limited to semi-candied fruit production (Raoult-Wack, 1994). At any rate, osmotic dehydration is to be used mainly as a preprocessing step (to save energy and improve product quality) since the process will generally not yield a stable product on its own.

Novel dehydration techniques employ lower temperatures and/or decreased drying times. Examples are microwave drying, dielectric drying, and microwave-augmented freeze-drying (Cohen and Yang, 1995). Drying by microwave in combination with hot air allows controllable water transport in relation with surface evaporation for accelerated dehydration and less volume change. Drying with microwave under strong volume expansion gives possibilities for new fat-free snacks (Bengtsson, 1994). Centrifugal fluidised-bed drying is the same as conventional fluid-bed drying but uses a rotating chamber to speed up the drying process. Ball drying uses a screw conveyer in hot air, and the material within the drying chamber comes into direct contact with heated balls made from ceramic or heat-conductive material; drying occurs primarily by conduction. Ball drying is only useful for small particles; the advantage is that lower temperatures can be used (e.g. 70 °C). Ultrasonic drying produces small droplets via a nozzle and then by further cavitation using ultrasonic energy within a drying chamber. Cohen and Yang (1995) concluded that there is no one best drying technique, it depends on the type of product and the susceptibility of the products to heat, and of course on the cost of processing.

Reverse osmosis is a relatively new technology, for instance used in the dairy industry to remove water from whey. Freeze concentration is also relatively new and is used for fruit juices, coffee extracts, beer, wine, tea (Deshpande et al., 1984), and the possibilities for milk products have also been explored (van Mil and Bouman, 1990). The advantages of freeze concentration are that the process takes place at low temperature, hence no flavour loss and no significant microbial and/or enzymatic activity, and little or no undesirable physical or chemical changes. In principle, there are two stages in the method: i) crystallisation (e.g., in a scraped-surface heat exchanger) and ii) separation of the ice crystals by centrifugation or wash column. A major drawback of freeze-concentration is that the costs are three to four times higher than for evaporation or reverse osmosis, so a cost-benefit analysis should be made (van Mil and Bouman, 1990).

Packaging

Packaging is important to keep processed foods stable. Packaging of foods can be done via traditional canning and bottling, and also via aseptic packaging technology in cartons and pouches. Aseptic packaging means that a product is packed free from undesired micro-organisms (removed or eliminated in a preceding operation) in packaging material that is also free from undesired micro-organisms (EHEDG report, 1993). No new packaging technologies seem to have really been developed recently, but there is a constant search for better packaging materials such as plastic materials and flexible aluminium pouches. As was pointed out by Cleland (1996), it is not just packaging but rather the combination of stabilisation/preservation and packaging that counts.

Another development in packaging technology is controlled atmosphere (CA) and modified atmosphere packaging (MA) in which metabolic processes in the food are controlled via gas composition. CA is done in a storage room with monitoring and active adjustment of gas composition, mainly for bulk storage and transport of fruit and vegetables (Kader et al., 1989; Church, 1994; Peppelenbos, 1996). The proportion of the gas mixture in CA is maintained at the original level throughout. MA refers to a different gas composition as compared to ambient air without active control of gas composition; the gas composition within the package is the result of the balance between metabolic rates of the product and diffusion characteristics of the package and as a result the gas composition will change over time. Gases used in MA are oxygen, nitrogen or carbon dioxide. MA is used for fruit and vegetables, fresh pasta, cooked and chilled meat and seafood, prepared salads (Church, 1994). Gas packaging has also an effect on micro-organisms and can thus influence shelf life with regard to microbial stability (Labuza et al., 1992).

Vacuum packaging is another possibility in which air is removed from the product in a package, which should then have of course a low oxygen permeability. Active packaging means packaging methods and agents that actively influence shelf life of food, such as oxygen scavengers (Ohlsson, 1994). For environmental reasons, research is being done into edible coatings made of proteins, starches, waxes, to be used as biodegradable films to package foods. Limitations are that such films are sensitive to moisture and are thus not well suited to package dry, frozen and semi-moist foods (Ohlsson, 1994).

B. Developments in transformation processes

The most important, centuries-old but still widely-used transformation process is fermentation. Fermentation is actually biotechnology *avant la lettre*. It is the process in which micro-organisms or enzymes are used to transform raw materials into foods. The success of this transformation is undoubtedly that it involves (usually) a lactic acid fermentation as a result of which the food becomes safe (no pathogens can grow at low pH) and can be kept longer. Although fermentation processes and fermentation products have been known for a long time, a major change has occurred more recently because the general principles are now well understood so that the process can be controlled. In addition, genetic modification of micro-organisms has made it possible to tailor the properties of micro-organisms or enzymes to the need of the specific process. It has also opened the possibility of obtaining non-traditional sources of enzymes. An example is the use of rennet (chymosin) in the cheese industry to clot the milk. Traditionally, this enzyme is obtained from the stomach of young calves, but nowadays the enzyme is also produced by genetically modified microbes.

As far as new fermentation technologies are concerned, traditional batch methods are replaced by continuous methods, for instance in the brewing of beer, or the manufacturing of yoghurt. Use of immobilised enzymes can greatly reduce production costs, but care must be taken that the resulting products are of the same quality as the traditional products. It is actually more an optimisation of existing technologies than the application of really new technologies. Some new developments can perhaps be found in solid-state fermentation, as it becomes possible to control this process better.

A subject related to fermentation is the use of "probiotics", bacteria that are claimed to support the bacterial flora in the gut so as to help in preventing infectious diseases, or even colon cancer. It remains to be established whether probiotics have indeed beneficial effects in the intestinal tract (O'Sullivan, 1992). In any case, foods containing probiotics are on the market, and much research is being carried out in this field. For food technologists it is of importance to develop technologies for probiotic-containing foods, so that these foods are acceptable to the consumer as well as able to carry the probiotic bacteria to the place of destination without loss of their activity.

Solid-state, or solid-substrate, fermentation are processes in which raw materials are used as such (i.e. without addition of water) for fermentation by micro-organisms. An example of a product produced in this way is tempeh, which is the result of fermentation of soya beans by the mould *Rhizopus oligosporus*. The design of solid-substrate fermentors is still largely empirical, and the possibilities of optimising these kinds of (mostly traditional) processes need to be explored (de Reu, 1995).

Physical transformation processes, such as extrusion and emulsification, are discussed in the section on technologies for fabricated foods.

C. Developments in separation technologies

A review of methods for bioseparations has been given by Singh and Singh (1996). They consider four sequential steps: removal of insolubles (e.g., by filtration, centrifugation); isolation of fractions (e.g., by extraction, adsorption); purification of components or fractions (e.g., by chromatography); and refining of the product (e.g., by water removal, crystallisation). According to Singh and Singh (1996) the cost of the final product is invariably dominated by the concentration in the initial raw material; isolation is the key step to controlling cost.

Membrane technology

Membranes can be used to concentrate, fractionate and purify materials; it is a pressure-driven process. The technology can be subdivided into microfiltration (membranes retain particles in the size range of microns), ultrafiltration (membranes retain molecules of the size of proteins, several thousand daltons, depending on the cut-off value of the membrane) and reverse osmosis (only water is removed). Then there is nanofiltration which is in between ultrafiltration and reverse osmosis. Applications are in the dairy and fruit juice industry, to concentrate milk, whey, fermentation broths, fruit juices. Also production of alcohol-reduced beers and wines is possible with membrane technology, as well as extraction of colours and aromas. Membrane technology is energy efficient, thermal damage can be limited to a minimum, and is easy to scale up. The limitations are in fouling of the membranes and lack of durability. However, new membrane materials are continuously introduced, for instance, ceramic membranes that withstand high temperatures, organic solvents and are resistant over a wide pH range (Cuperus and Nijhuis, 1993).

Pervaporation is a membrane technique in which the permeate is directly evaporated on the other side of the membrane, followed by condensation in a low temperature condenser. It thus results in a vapour permeate (later on condensed) and a liquid retentate. The driving force for the mass transfer of permeants from the feed to the permeate is a gradient in chemical potential by applying a difference in partial pressures of the permeants across the membrane. Difference in partial pressures can be realised by reducing the total pressure on the permeate side or by sweeping an inert gas on the side of the membrane (Karlsson and Trägårdh, 1996). The technique can be used for recovery of aromas or aroma concentration; also de-alcoholisation of beer, wine and liquor is possible (Singh and Singh, 1996; Karlsson and Trägårdh, 1996).

Electrodialysis is a membrane technology in which molecules or ions are separated in an electric field using charged membranes (Bengtsson, 1994). Desalination of whey is an application.

Membrane reactors can also be seen as new technology: they integrate catalytic conversion, product separation and/or concentration, and catalyst recovery into a single operation (Prazeres and Cabral, 1994). For instance, a biochemical reaction can take place and the products of the reaction are removed via the membrane, thus preventing product inhibition, and loss of enzyme. Continuous processes are possible in this way, allowing better process control, higher productivity, more uniform products and the integration of a purification step in the process (Prazeres and Cabral, 1994). These authors also gave an overview of possible applications: hydrolysis of proteins and polysaccharides, synthesis of amino acids and peptides, lactate, aldehydes, alcohols, hydrolysis of fats and oils and production of mono- and diglycerides, to name a few.

Industrial chromatography

Chromatography is a technique that is widely used for analytical purposes because of its superior separating possibilities. However, on an industrial scale application is not so easy because of scaling-up problems and the cost associated with it. Affinity chromatography, in which the target molecules adsorb onto a solid phase (the ligand), is used commercially for production of native biologically-active substances (Singh and Singh, 1996). Applications are in the isolation of proteins and peptides, for instance from milk and whey. Proteins isolated in this way are expensive and will only be used in foods for special applications, for instance, the use of lactoferrin, or bioactive peptides. Another chromatography application is in the separation of fructose from a glucose-fructose mixture using calcium-loaded ion-exchange resins (Singh and Singh, 1996).

The use of immobilised enzymes can also be a kind of chromatography: enzymes are immobilised onto a solid carrier in a column and the substrate is fed through the column. Applications are in the continuous production of beer using immobilised yeast, hydrolysis of galactose using β-galactosidase to produce sweet syrups of glucose and galactose, hydrolysis of proteins (Singh and Singh, 1996).

Conventional and supercritical fluid extraction

Components can be removed from raw materials by extraction using an immiscible solvent. The most widely-used extraction is probably oil extraction from oilseeds, but many other applications exist. Solvents used should be nontoxic, highly efficient and selective, stable, non-flammable, non-explosive, environmentally safe, and inexpensive (Singh and Singh, 1996).

A supercritical fluid is a fluid above its critical temperature and pressure, exhibiting characteristics intermediate between liquid and gas. The liquid-like high density makes it a good solvent while the low gas-like viscosity and lack of surface tension (between the gas and liquid phase) achieves good penetrating and mixing abilities (Rizvi et al., 1995). Supercritical fluids leave residual-solvent-free products (Singh and Singh, 1996). The supercritical fluid for foods *par excellence* is carbon dioxide because it is inert, nontoxic, non-flammable, recyclable, readily available in high purity and leaves no residues (Palmer and Ting, 1995). Its main application until now has been for the production of decaffeinated coffee beans and extraction of hop flavours. A general overview of possible applications for supercritical fluid technology in food processing was given by Palmer and Ting (1995).

Much research is also carried out on production of fractionated fats in which the solid-liquid balance is changed, which is of interest because the technological possibilities of the fractions are greatly enhanced. The largest applications are with palm oil and milk fat (Hamm, 1995; Rizvi and Bhaskar, 1995). The possibilities for fractionation are dry fractionation (crystallisation), solvent fractionation, and detergent fractionation (Hamm, 1995). With regard to solvent extraction, supercritical fluid extraction has received much attention because there is less retention of liquid phase in the separated solid material, and the fractions obtained melt more homogeneously and provide superior selectivity. However, supercritical fluid extraction is less favoured than crystallisation due to high capital investment and operating costs, though Rizvi and Bhaskar (1995) state that “the estimated economic profile of the large-scale commercial plants indicate that supercritical-CO_2 is economically viable for fractionation of milk fat contrary to what may be the generally-held belief”.

Enzymatic and microbial synthesis

Enzymes are mostly used in the food industry to degrade components, not so much to synthesise components. It may well be that enzymatic synthesis will gain interest in the near future because it can yield components of high purity with very little contamination. Biotransformations of proteins and fats are possible to produce components, as well as synthesis of emulsifiers, flavours, peptides and oligosaccharides (Vulfson, 1993). The use of enzymes in low-water media has several advantages, as discussed by Vulfson (1993). In principle, biotechnological methods may offer attractive alternatives as compared to conventional chemical approaches, but the cost of some enzymes may be too high for manufacturing products with low added value. On the other hand, genetic engineering may offer possibilities to increase specificity of enzymes at reduced costs (Vulfson, 1993).

Micro-organisms may also be used to synthesise flavour compounds (Belin et al., 1992) or food colourants (Arad and Yaron, 1992).

Extraction of proteins with reversed micelles

In the search for making novel protein foods, protein sources may come from micro-organisms. Production of protein, by fermentation, using modern biotechnology is possible, but separation and purification of proteins from the fermentation media is still a bottleneck in downstream processing. Use of liquid-liquid extraction to isolate protein is a possible method with selective solubilisation of proteins in reversed micelles as a bioseparation technique (Pires et al., 1996). These authors also discussed strategies of operation and scale-up and concluded that the use of reversed micelles has the potential to be applied in large-scale continuous mode operations.

D. Developments in technologies for fabricated foods

Extrusion

In the extrusion process, mixing, shearing, cooking and shaping can occur, as mechanical and thermal energy is used to transport the material via rotating helical screws through a die; chemical and physical changes take place and the visco-elastic mass (consisting of biopolymers) can be formed into certain shapes (Rizvi et al., 1995). The process can be used for a multitude of products. Cold extrusion, in which only shaping takes places (without cooking), can be used for the manufacture of pasta, cookies, candies, dough, pastry. Cooking extrusion is the process in which raw ingredients are cooked by combined action of shear, heat and pressure, resulting in homogeneous or heterogeneous phases which are fixed by rapid conversion into a rubber-like or glassy state. Swelling on exiting the die may induce a porous structure. New technological possibilities are co-extrusion (e.g., cereals with a soft stuffing), co-expansion (two extruders with a common die). With twin-screw extruders it is possible to emulsify fat, to sterilise spices, to produce microparticulates from proteins, and to restructure and shape fish and meat mince at high water content (Bengtsson, 1994). The use of supercritical fluids in extrusion technology is described by Rizvi et al. (1995); it allows for simultaneous occurrence of expansion, solute incorporation and reduction of melt viscosity, and in the case of carbon dioxide it can also be used to adjust the melt pH. Upon exiting the die, most of the carbon dioxide evaporates. All in all, extrusion technology is very suitable for the production of fabricated foods from all kinds of materials. It is the technique for texturising protein-containing foods, and is promising for the development of novel protein foods (Cheftel, 1992; Ledward and Tester, 1994).

Encapsulation technology

Encapsulation is a technology of packaging solid, liquid or even gaseous materials in small particles that are suspended in the food. In this way, such substances are protected to some extent (for instance, minerals, micro-organisms, enzymes), or cause slow-controlled release (flavours) (Reineccius, 1989; Jackson and Lee, 1991; Pothakamury and Barbosa-Cánovas, 1995). The microparticulate particles can be made from proteins such as gelatine, or by coacervation of biopolymers (e.g. proteins and polysaccharides) or liposomes can be used (Kim and Baianu, 1991). For production of microparticulates, spray-drying, coating, extrusion and freeze-drying can be used (Pothakamury and Barbosa-Cánovas, 1995). Water-soluble polymers can be used to encapsulate hydrophobic materials, and water-insoluble polymers for encapsulation of aqueous materials. The problem for foods is that the materials should be food-grade, and use must be made of food biopolymers, if necessary modified.

Products can also be encapsulated via solid-melt technology (extrusion-type processes), resulting in commercially stable glasses. The primary feature is stability which is particularly significant in minimally packaged products (Popplewell et al., 1995). The authors claim that the new process is versatile, scalable and economical.

Fat replacers

In the search for fat-free or low-fat food products to satisfy the consumer need to eat foods containing less fat, attempts have been made to find fat substitutes. The problem with low-fat or fat-free foods is that they lack the taste and structure of the corresponding fat-containing foods. Fat contributes to structure/texture because it is one of the structural elements of the food. Fat is also a good solvent for flavour substances which tend to be often somewhat hydrophobic of character, hence removal of fat also removes a source of flavour components, or causes a shift in the balance of flavour compounds (Plug and Haring, 1993; IFT Symposium, 1997). Fat replacers should therefore substitute for structure and flavour. There are three types of fat replacers (Lucca and Tepper, 1994): i) based on proteins (total milk protein, whey protein); ii) based on carbohydrates (modified starch, maltodextrins, celluloses, guar gum); iii) fat-based (emulsifiers, medium-chain triacylglycerols, acaloric lipids, i.e., lipids resistant to digestive enzymes). A serious problem with fat replacers based on proteins or carbohydrates is that they are not well-suited to be used in cooking oils or for frying.

Glassy foods

Low moisture foods (confectionery, cereals, snacks, powdered foods) are often solid, amorphous materials with a glassy structure that may become plasticised as a result of an increase in water content or temperature. The amorphous state of foods may result from a rapid removal of water from food solids that occurs during such processes as extrusion, spray drying and freezing. Amorphous states (rubber or glass) are non-equilibrium states with time-dependent properties; in contrast, crystals, solutions and melts are physically-stable equilibrium states. Physical properties of low-moisture and frozen foods have been related to the glass transition temperature (which is actually a temperature range rather than one specific temperature). Below the glass transition temperature an amorphous solid is a glass, and above the glass transition temperature it is a rubber (usually a more viscous state, though not necessarily) and there is a drastic change in molecular mobility above the glass transition temperature resulting in a dramatic decrease in stability of a food. It is actually a glass-rubber transition. Water plasticises food polymers and (even when present in trace amounts) drastically decreases their glass transition temperature and may thus have a detrimental effect on food quality.

The glass transition temperature is thus very important for food quality and shelf life of amorphous foods, such as powders. It is also important for frozen foods, as ice formation causes freeze-concentration of dissolved components and, as a result of that, freezing temperature decreases for the remaining water. At a sufficiently low temperature the freeze-concentrated phase may solidify into the glassy state and ice formation stops. The freeze-concentrated phase contains unfrozen water within the ice-phase. In the glassy state, foods are very stable because the molecular mobility of components is very limited so that degradative reactions cannot occur. However, above the glass transition temperature all kinds of changes take place in dehydrated foods: caking, stickiness, oxidation, non-enzymatic browning reactions (Maillard reaction).

The glass transition temperature depends obviously on the composition of foods (especially the water content), and on the temperature. State diagrams are useful tools to predict and control the stability of dehydrated foods (Roos et al., 1996; Slade and Levine, 1991; Fennema, 1996). Knowledge about glass transitions in general represents a powerful tool for food technologists, and this development has been a major breakthrough in the past decade. With knowledge of state diagrams, it is easier to select ingredients that raise the glass transition temperature and thus extend shelf life. Besides composition of the food, choice of processing conditions is equally important in choosing rate of drying, final moisture content and temperature.

Emulsification

Many fabricated foods are emulsions, e.g., infant formulae, clinical foods, creams, desserts, sauces, dressings, ice cream. There are oil-in-water emulsions, in which the oil is dispersed in the aqueous phase (e.g., mayonnaise), water-in-oil emulsions, in which water is dispersed in a lipid phase (e.g., margarine), and multiple emulsions (W/O/W) are also possible.

In order to make emulsions, emulsifiers, i.e., surface active agents, are necessary. It is important to distinguish between the making of emulsions and the stability of emulsions (Walstra, 1996). Emulsifiers are necessary both for the formation and the stabilisation of emulsions, but they may act differently in both processes. A thorough discussion about formation of emulsions is given by Walstra (1983), including the effect of various types of emulsifiers and ways to produce emulsions with some attention to emulsifying machines. Industrial production of emulsions is mostly done using high-pressure homogenisers, rotor-stator stirring, via ultrasonic vibration, or via a colloid mill, and combinations are of course also possible.

Emulsions need to be stable during processing and during storage. However, emulsions are inherently unstable from a thermodynamic point of view: they tend to demix. There are various types of instabilities possible: flocculation, creaming, (partial) coalescence, Ostwald ripening (Walstra, 1996). In general, the size of emulsion droplets needs to be in the order of one micrometer (there is in fact a globule size distribution). Emulsion stability depends on the surface active agent(s) present (in this respect often named stabilisers), partial crystallisation of the oil phase (hence on temperature), flow conditions, viscosity of the continuous phase, etc. (Walstra, 1996). Emulsion droplets greatly contribute to the structure (consistency) of a food product, and are carriers of essential fatty acids, vitamins and flavour substances, hence important from a nutritional and sensorial point of view.

A large number of emulsifiers and stabilisers are available. Proteins can fulfil both tasks but there are also numerous low molecular surfactants, such as lecithins, monoglycerides. An overview can be found in Dickinson (1993).

Structuring by phase separation

Hydrocolloid mixtures can be used as functional food additives. Interactions between macromolecules may result in thermodynamic incompatibility or in complexing, thereby affecting physico-chemical properties and structure (Ledward, 1993; Tolstoguzov, 1995). Synergistic as well as antagonistic effects are possible. The macromolecules of interest are proteins and polysaccharides. An example of exploiting such macromolecular interactions is the production of a caviar analogue (Tolstoguzov, 1995). Other applications are conceivable, for instance, water-in-water emulsions, consisting of spherical drops of a protein solution in a polysaccharide solution and vice-versa. Knowledge of phase-behaviour of macromolecules components in foods in both liquid and solid systems is of great importance for controlling the structural functions of food hydrocolloids. For instance, development of low-fat products leads to more usage of macromolecules and their interactions. Also, use of natural food ingredients puts more emphasis on physical interactions and physical processes (heating, drying, high pressure, extrusion) rather than on chemical modification. Applications are conceivable for infant formulae, sports drinks, functional foods, convenience foods and snacks.

To summarise the above, an overview of new developments in food technology is presented in Table 4.14 (page 81). For further reading on recent developments in new technologies, see:

Doernenburg, H. and D. Knorr (1998). Monitoring the impact of high-pressure processing on the biosynthesis of plant metabolites using plant cell cultures. *Trends in Food Science and Technology* 9(10): 355-361.

Fellows, P.J. (2000). *Food processing technology, principles and practice*. Woodhead Publishing, Cambridge.

Gijsbertsen-Abrahamse, A. (2003). *Membrane emulsification: process principles* Wageningen UR. ISBN 9058088456. p. 104.

Goot, A.J. van der, and J.M. Manski (2007). Creation of novel microstructures through processing. In: *Understanding and controlling the microstructure of complex foods*. McClements, D.J. (ed). Woodhead Publishing Limited Cambridge. p. 389-410.

Goot, A.J. van der, S.H. Peighambardoust, C. Akkermans and J.M. van Oosten-Manski (2008). Creating novel structures in food materials: the role of well-defined shear flow. *Food Biophysics* (in press).

Graaf, S. van der (2006). *Membrane emulsification: droplet formation and effects of interfacial tension*. Wageningen UR. ISBN 9085043484. p. 159.

Hassan, S., N. Purwanti, A. Rinzema, K. Schroën and R. Boom (2008). Polylactide microspheres prepared by premix membrane emulsification – Effects of solvent removal rate. *Journal of Membrane Science* 310(1-2, 5): 484-493.

Hendrickx, M. and D. Knorr (2002). *Ultra high pressure treatments of foods*. Aspen Publishers, USA.

Jongen W.M.F. and M.T.G. Meulenberg (2005). *Innovation in Agri-Food systems*. Wageningen Academic Publishers, the Netherlands.

Joseph, T. and M. Morrison (2006). Nanotechnology in Agriculture and Food. In *The Nanoforum Report* 2006 (www.nanoforum.org).

Knorr, D., B.I.O. Ade-Omowaye and V. Heinz (2002). Nutritional improvement of plant foods by non-thermal processing. *Proceedings of the Nutrition Society* 61(2): 311-318.

Lelieveld, H.L.M., S. Notermans and S.W.H. Haan (2007). *Food preservation by pulsed electrical fields*. Woodhead Publishing, Cambridge.

Ludikhuyze, L., A. van Loey, Indrawati, C. Smout and M. Hendrickx (2003). Effects of combined pressure and temperature on enzymes related to quality of fruits and vegetables: from kinetic information to process engineering aspects. *Critical Reviews in Food Science and Nutrition* 43(5): 527-586.

Manski, J.M. (2007). *Flow-induced structuring of dense protein dispersions*. PhD thesis. Wageningen University, Wageningen. ISBN 9085046106. 222 pp.

Manski, J.M., A.J. van der Goot and R.M. Boom, R.M. (2007). Advances in structure formation of anisotropic protein-rich foods through novel processing concepts. *Trends in Food Science and Technology* 18 (11): 546-557.

Peighambardoust, S.H. (2006). *Development of dough under Shear flow*. PhD thesis. Wageningen University, Wageningen. ISBN 9085043573. 187 pp.

Peighambardoust, S.H., R.J. Hamer, R.M. Boom and A.J. van der Goot (2008). Migration of gluten under shear flow as a novel mechanism for separating wheat flour into gluten and starch. *Journal of Cereal Science* (in press).

Raso J. and V. Heinz (2006). *Pulsed electrical fields technology for the food industry*. Springer Verlag, Germany.

Richardson, P. (2004). *Improving the thermal processing of foods*. Woodhead Publishing, Cambridge.

Sagis, L. M. C., R. de Ruiter, F.J.R. Miranda, J. de Ruiter, K. Schroen, A.C. van Aelst, H. Kieft, R. Boom and E. van der Linden (2008). Polymer Microcapsules with a Fiber-Reinforced Nanocomposite Shell *Langmuir* (Letter) 24(5): 1608-1612.

Schubert, H. and M. Regier (2005). *The microwave processing of foods*. Woodhead Publishing, Cambridge.

Smith, J.C. and Y.H. Hui (2004). *Food processing: principles and applications*. Blackwell Publishing. USA.

Weiss, J., P. Takhistov and J. McClements (2006). Functional materials in food nanotechnology. *Journal of Food Science* 71(9): R107-R116.

Zwan, E.A. van der (2008). *Emulsification with microstructured systems.– process principles*. PhD thesis. Wageningen University, Wageningen.

4.2.3.3 Science-driven concepts

Continuous innovation is imperative for any food processing company to stay in business. This is caused by the need to keep up with the competition with respect to ongoing developments, but is also necessitated by the limited life cycle of food products in the market. Life cycles are becoming increasingly shorter. The industry tackles this need for innovation and technological progress with science-driven concepts as well as society-driven concepts. With respect to science-driven concepts, the complexity of raw materials and food matrices has challenged the creativity of scientists in different science areas, especially nanotechnology, biotechnology, information and communication technologies (ICT).

In nanotechnology the four key topics are: (i) filtering, fractionation and concentration; (ii) emulsions, texture and delivery systems (release systems); (iii) sensor-systems and –processing; and (iv) packaging and logistics (Prisma, 2006). In biotechnology, novel schemes for producing foods, ingredients and enzymes are addressed including waste valorisation. For ICT, the main focus points are food safety (e.g., detection of contaminants, allergens, hormones, pathogens), security, quality,

Table 4.14. Overview of new developments in food technology

Type of technology	Developments	Characteristics	Suitable for	Drawbacks
Preservation by thermal treatment	HTST, UHT	less heat damage, heat regeneration	fluids, fluids containing particulates	not suitable for "solid" foods
	ohmic heating	rapid and even heating	fluids and fluids containing particulates. Low-acid foods	no heat regeneration
	infrared heating	efficient and rapid heat transfer	baking, drying, grilling, thawing	no heat regeneration, low penetration depth
	microwave	rapid heating	all kinds of foods	uneven heating, no heat regeneration
	sous-vide	mild heating in vacuumised pouches, sensoric quality improved	all kinds of foods, catering	shelf life limited
Preservation by nonthermal treatment	high-pressure	no thermal damage, freshlike quality	fruits, vegetables	not continuous, expensive
	high-electric field pulses	little thermal damage, high sensoric quality	conductive foods	no inactivation of spores, high cost
	pulsed light	no thermal damage	packages	only active at surfaces, or in transparent liquids
	γ-irradiation	no thermal damage	fruits, vegetables, spices, condiments, meat	not accepted by consumer
	ultrasound	facilitates heat and mass transfer, physical disruption	to be used in combination with other techniques	high cost, little microbial stabilisation
	drying, concentration	removal of water, glassy foods	all kinds of foods	
	glassy foods	solid amorphous materials, very stable below glass transition temperature	low moisture foods (confectionery, cereals, powders, frozen products)	stability critically dependent on glass transition temperature
Preservation in the cold	rapid freezing	formation of glass	all kinds of foods	
Hurdle technology & minimal processing	combination of preservation technologies	less quality loss	dry meat products, fruits, vegetables	microbial safety is critical
Packaging	aseptic packaging	combination with continuous processes	fluids, fluids containing particulates	special hygienic design of equipment
	modified atmosphere (MA) and controlled atmosphere packaging (CA)	interference with metabolic processes of the food	fruits, vegetables, meat, seafood	
Fermentation	continuous processes	higher production rates, standardised quality	milk products, alcoholic beverages	
	solid-substrate	better control of fermentation	solids, such as soy beans	
Separation	membranes	separation of ingredients at large scale	liquid foods	fouling of membranes
	chromatography	separation of ingredients in high purity	liquids	expensive
	enzymatic synthesis	high purity	peptides, colourants, emulsifiers, flavours	expensive
	supercritical fluid extraction	efficient extraction of ingredients	coffee beans, hops, oils and fats	high cost
	reversed micelles	protein extraction	novel protein foods	
Fabricated foods	extrusion	shaping and/or cooking	snacks, pasta, pastry, novel protein foods	
	emulsification	emulsion droplets contribute to structure, flavour, nutritional value	fat-containing products	
	phase separation	structure formation by food hydrocolloids	gel-like foods, novel protein foods, meat and fish-like products	

logistics, traceability, automation and robotisation, data management and bio-informatics.

The science areas are based on concepts adapted from physics, chemistry, biology, mathematics and computer sciences. In addition, the impact of human physiology and neuro-psychology in the food domain is taking on more importance because of the link between consumer science, nutrition, food science and technology. Finally, molecular gastronomy is a brand new concept covering the different research disciplines, presenting cooking as a chemical and physical experience.

When one considers nano-, bio- and information and communication technologies from a food engineering point of view, new concepts have been introduced like miniaturisation, process intensification, bio-processing, conceptual tailor-made designs (for product and process) and novel mild processes. The concepts are now readily translated in novel processing schemes to be applied in industry.

4.2.3.4 Society-driven processing concepts

In the previous section, the science-driven concepts, often arising from curiosity and creative knowledge, have briefly been discussed. Here, consumer and market trends are the starting point for a view on food processing concepts (Cap Gemini, 2002). Consumer-oriented concepts have increasingly gained in importance in Europe since the Second World War. Before that time, the food market predominantly consisted of products that agricultural producers and food processors decided to offer for sale. Since then, agricultural mechanisation and large-scale use of chemical fertilisers and pesticides has increased production levels and contributed to market saturation. Nowadays, successful sales require a consumer-orientated approach; a product can only be successful in the market if it satisfies consumers' demands. The implementation of such a consumer-orientated approach requires insight into the motives that drive consumers in their decision-making process while shopping for their food products.

An important societal development to consider here is the so-called mass-individualisation (van Boekel and Linnemann, 2007). Rapid demographical changes cause fragmentation and diversification of households. Important demographical developments are a shift in the age profile of consumers and an increased influence of ethnic groups in western societies. The ultimate implication hereof was accurately expressed by the director of a Dutch supermarket chain when he said that there are 15, 16, or 17 million markets in the Netherlands, depending on the number of independent individuals in the country (Andreae, 1995).

Changing societal needs is another autonomous development that influences the direction of technological developments. The most striking example here is the case of the increased occurrence of obesity among the European population. Although our life styles are completely different from those of our grandparents and great-grandparents, our caloric intake is not. Where many of our ancestors spent long days in the fields doing physical labour, we limit our activities frequently to office work behind a computer. Obesity is a consequence which in its wake causes cardio-vascular diseases and diabetes, resulting in high medical and disablement costs.

In addition, the present generation of consumers has a much broader understanding of what quality in a food product means to them. In the past, quality was a characteristic that was mainly based on the overall composition of a food, like the amount of fat in milk. Nowadays, consumers are also aware of the presence of not only minor components such as vitamins and minerals, but also of non-nutrient components of foods with a physiological activity such as antioxidants.

Moreover, product quality is not limited anymore to mere intrinsic product properties, but also includes many aspects of the way in which a food is produced, like whether or not the production was organic, without child labour, fair trade, environmentally-friendly with respect to the use of non-renewable energy sources, water, etc.

In response to these different societal trends and as a means of offering a target to the food processing industry, seven consumer prototypes were formulated (Linnemann et al., 1999). Note that no single consumer fits 100% in one of these images. In everyday life it is more likely that a person expresses, for instance, the characteristic behaviour of one type of consumer during weekdays (e.g., a focus on convenience), and of another during the weekends (e.g., looking for health food). The prototypes are the following:

- *The environment-conscious consumer*, who prefers unprocessed foods (fresh) or foods from short production chains, foods from organic farming, focuses on technological efficiency.
- *The nature- and animal-loving consumer*, who is interested in methods for primary production, concerned about genetic modification, finds animal welfare an important issue, focuses on ethical efficiency of production systems.
- *The health-conscious consumer*, who prefers fresh products which support health trends, e.g., low-calorie, low-fat, rich in vitamins and minerals, and all other sorts of foods with alleged health-protecting or health-promoting properties.

- *The convenience consumer*, who goes for snacks, fast food, take-out meals, ready-to-eat meals, foods that are easy to prepare, restaurant food.
- *The hedonic consumer*, who prefers (exotic) specialities, delicacies, foods with added value, food as entertainment and a pleasant pastime, restaurant food, foods of high sensory quality.
- *The price-conscious consumer*, who prefers homemade meals, with ingredients of a favourable price/quality ratio (e.g., products from large-scale production, or alternative, cheaper raw materials).
- *The variety-seeking consumer*, who seeks diversity in raw materials, ingredients and fabricated foods for homemade meals, as well as diversity in the type of meal (from elaborate homemade meals to convenient dining out).

Food and health, safety, sustainability, convenience, individualism, healthy ageing and authenticity, etc. are all asking for an enormous flexibility in food processing (CIAA, 2005, 2007). Not only just-in-time, but also just-in-place, just-as-requested, just-personalised, just-sustainable are key phrases.

This has led to a renewed focus and further research on a number of technologies that allow (NovelQ, 2006):

- more fresh foods with characteristics close to those of its raw material;
- functional foods with specific ingredients based on new bio-processing concepts;
- convenient, ready-to-eat meals (solid and liquid) and full menus (pick and choose options at retail and food service);
- valorisation and minimisation of waste streams for food and non-food applications as well as reduction of air emission, waste water and energy consumption;
- rapid screening and monitoring using a range of analysing techniques for safe food production (processing parameters, hygiene, traceability);
- flexible, miniaturised, regionally applicable – even for home preparation options – processing including proper working conditions (ergonomics, health and safety);
- development of intelligent packaging concepts.

The society-driven processing concepts have forced the industry to think backwards “from fork to farm” (IPTS, 2002). In the food processing domain, this is translated into reversed engineering. New systematic approaches to food engineering systems (SAFES methodology) are currently being developed (Fito et al., 2005).

4.2.4 How will geographical shifts in food production impact the EU food processing industry and its competitiveness?

4.2.4.1 Global trends impacting on food processing

Geographical shifts in food production have considerable impacts on food processing in Europe. This is for example reflected by the Rotterdam harbour case. In the past, raw materials were shipped to Rotterdam, the Netherlands. Either in the Netherlands or in Western Europe, added value was created. Now, Rotterdam harbour has been transformed into a “reshipping terminal” for maritime containers. Added value is more and more created in the countries producing agricultural raw materials, having a direct impact on the profitability of the harbour and hinterland economy. Clear examples are Brazil and China, in which growth rates for added value are substantially higher than in Europe.

The CIAA has stated that the competitiveness of the European food and drink industry should be stimulated via four actions. First, the efforts to increase R&D investments must be sustained, requiring a conducive regulatory environment and lower administrative costs. Second, the legislative environment must be improved with respect to self- and co-regulation mechanisms. Third, access to competitive agricultural raw materials should be ascertained (including an adequate policy for biofuels and -products). Fourth, the performance of trade policy and export should be improved to maintain a competitive position.

The currently-running 6th Framework Programme European project FINE (Food Innovation Network Europe) is not focused on the position of multinationals in a global context but on the competitiveness of regional clusters (FINE, 2007). The strength of clusters is often overlooked when considering Europe as a whole. Despite this, excellent examples of clusters could be pointed out, e.g., the shoe cluster in Italy (Porter, 1996) and the Sophia-Antipolis science park concept in France. Cross-sectorial innovations are well supported in strong clusters. This is the competitive advantage of Europe in food processing since European cuisine is rich and based on relatively well-protected food concepts. Nowadays we recognise the protected designation of origin (PDO; Parma ham, Camembert), the protected geographical indication (PGI; Jambon d’Ardenne, Aachener Printen), traditional speciality guaranteed (TSG; mozzarella, Kriek beer). PDO certifies that production and processing take place in a specific region. PGI allows part of the production and processing possibly to be outside the region. TSG certifies that traditional preparation guidelines are met but production and processing regions are freely chosen in the European territory [EC, Brussels, 5.1.2006, COM(2005) 698 final/22005/0275 (CNS)].

Future challenges are directly related to adding more value, pros and cons of protection mechanisms, legislative aspects and export positions.

4.2.4.2 Tailor-made in Europe

The previous section has provided the framework for novel processing schemes and how to add value. In Sections 4.2.3.2 and 4.2.3.3 scientific and societal drivers (miniaturisation, reversed engineering and molecular gastronomy approaches, convenience, flexibility in menus, etc.) have been addressed. Combining those insights, one could imagine processing very near to the moment and place of consumption.

Boom et al. (2007) have visualised this in the following scheme (Figure 4.19).

This means that factories retain economy of scale operation; however, assembly and differentiation will take place closer to the consumer. The designs of miniaturised processing units and related costs will determine the potential for tailor-made schemes in Europe.

4.2.4.3 Concepts for Agri-Food business complexes including food processing

As a follow-up of the cluster formation in regions, one may even consider agri-parks in which the output of one producing activity serves as input for the next, and so on (Smeets, pers. communication, 2006). Here, the concept could be further extended towards processing units within these agri-parks. The term “agri-food business complex” expresses an integrated approach towards localised production of added value products with low emissions (solid, liquids and gas as waste streams being used within the complex). A highly efficient agri-food business complex is extremely difficult to achieve, as previous discussions on zero waste have pointed out.

The clustering of activities is historically interesting from an eco-friendly point of view. Numerous companies have been set up to use raw materials optimally. In the past, Unilever could be considered as an example using palm trees as a source for food and non-foods. Often, economic pressures have led to specialisation and focus of business activities. Consequently, food and non-food activities have been split up to a degree that specific consumer goods – and their full production chain – could be well identified.

The driver for efficiency of making full use of raw materials in the mid 20th century has been replaced by the driver for transparency in chains and focus of activities. Now, the food sector (and other sectors as well) is quite far in the transformation towards society-driven requirements (health, convenience, etc.). For the future, one may expect that – based on the debate on climate change and related bio-based discussion – the driver will again be efficient use of raw materials in both food and non-food applications, but now much more linked to consumer/citizen demands and perceptions. Inevitably, new networks will arise in which profitability of joint food and non-food activities will be discussed.

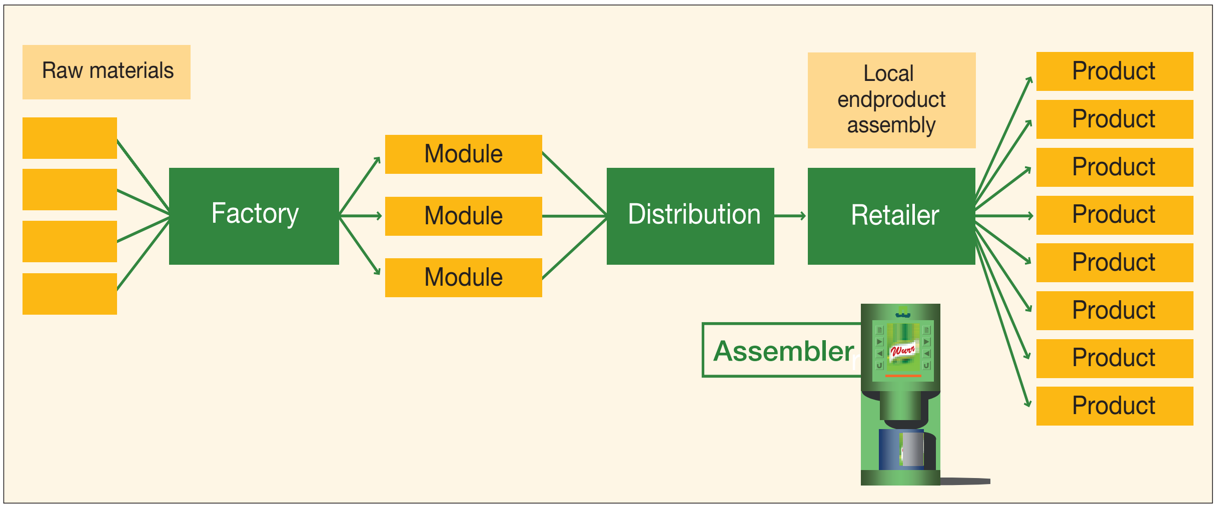

Figure 4.19. Conceptual design of a food processing chain that produces close to the moment and place of consumption (Source: Boom et al., 2007)

4.2.4.4 Overall consequences

The impact of the above-mentioned developments on the European agri-food sector is hard to foresee. One could argue that the transfer of large-scale manufacturing technologies to cheaper labour countries would negatively influence the industrial competitiveness of Europe as a whole; added value and new services in manufacturing in Europe are therefore high on the agenda of the ETP Manufuture (2006). On the other hand, the share of the agri-food industry as part of the entire industrial sector will then be enlarged as long as Europe remains an agri-food producing continent (Wijnands et al., 2007). The latter consideration is true if the export position of Europe remains strong. Here, the required import volumes of fast developing countries like China and India may be beneficial for Europe.

Even more important is the European position in the consumer-driven, bio-based network linking once again food and non-food activities. Here, Europe may have a competitive advantage if the existing foundation of clusters is well exploited.

4.2.5 What will be the sustainability issues that most affect the processing industry and how?

4.2.5.1 Key sustainability issues

The main sustainability issues have been discussed in Section 4.2.2.3. Here, a quantitative overview will be presented in order to define the most crucial topics for the next sections including some figures.

a. Energy, some figures (Table 4.15)

b. Water, some figures

In the UK, 70% of water in the food manufacturing industry is used for cleaning and disinfection. Processing schemes and cleaning procedures will be redefined. Overall, food production globally requires 75% of fresh water (Profetas, Aiking et al., 2006).

c. Efficiency of usage of raw materials, some figures:

- Waste streams in Europe for sugar beet are 4.8 Mton, brewers' spent grain 3.4 Mton, fruit pulp > 1.5 Mton, onions 0.5 Mton (EU-strep REPRO project, 2007).
- In total, an overall figure of around 220 million tons/ year of generated food waste and by-products has

Table 4.15. Data on energy use for several activities in the production chain for some commodities (for the Netherlands as an example)

Nace	Sub-sector	Farming	Transport	Fertiliser	Storage	Processing	Distribution Retail	Consumer	Total Energy consumption (PJ)	
Code										%
151	Meat	14	20	10		10	16	45	115	21
152	Fish	1				1	4	10	16	3
153a	Fruit & vegetables	58	14	10	3	4	12	25	126	23
153b	Potatoes	2	5	15	3	7	6	18	56	10
154	Oils & fats		1			11	2	3	17	3
155	Dairy	10	2	30	1	15	10	12	80	15
156	Grain & starch		2	15	2	11		1	31	6
158	Sugar	1	2			15	1	1	20	4
158	Other food	1	2			10	1	1	15	3
159	Beverages		5			7	2	4	18	3
157	Feed	8	14	10		13	1		46	9
	PJ	95	67	90	9	104	55	120	540	100
	%	18	12	17	2	19	10	22	100	

(Source: Arthur D. Little and SenterNovem, 2006)

been obtained in the European Study Awarenet (2004). It is true that a substantial part is already used for further valorisation. However, substantial improvements are still required, reviewing the full list of waste and by-product percentages. Some examples: fish canning 30-65%, fish filleting-curing-slating-smoking 50-75%, beef slaughtering 40-52%, fresh-soft-cooked cheese production 85-90%, fruit and vegetable juice processing 30-50%, potato starch production 80%, sugar production from sugar beet 86%, vegetable oil production 40-70%.
- From a consumer goods' point of view, the resource efficiency in salads and vegetables is 60-70% in the UK (Voedingsmiddelenindustrie, 2002).

d. Packaging materials, some figures:
- In the UK, 50% of all packaging materials is used in the food sector;
- The Food Processing and Machinery Equipment Group (FPME), World Packaging Organisation and CIAA have provided excellent overviews on the number of packaging materials used, wastage and recycling.

4.2.5.2 From meat to plant-based protein sources

The Dutch PROFETAS study shows that the environmental benefits from a transition of animal to plant protein may be a factor of 3-4 for land use and energy, but even 30-40 for water requirement and acidification as well as contributing substantially to improved animal welfare. It is debated whether the focus should be on meat replacements or improved plant protein foods. Future challenges require new processing methods for improved-texture, plant-based foods. Also, processing should be considered in view of food and non-food applications to gain optimal benefit from plant-based resources.

4.2.5.3 Process intensification

In 2000, Stankiewicz and Moulijn presented their now well-known article, "Process Intensification" in Chemical Engineering Progress". As stated, the processing sector as a whole will transform itself in the direction of compact, safe, energy-efficient and environmentally-friendly processing (Boom, 2001). Concepts of intensified c.q. integrated processing instead of widely-used unit processes have also been introduced in the food manufacturing industry. Several new R&D trajectories have been initiated, e.g., combined extrusion and extraction in one single path in extruders or membrane reactors. The new approach is based on reviewing and combining functions or changes, not unit processes as described in Section 4.2.3.1.

4.2.5.4 Waste valorisation

The valorisation of waste, co- and by-products is considered from a market opportunity focus. What upgrading schemes really do deliver well-priced end-products? The full potential in the pharmaceutical, nutraceutical, cosmetic, flavour, feed and bio-energy sectors, for example, needs to be reviewed. Here, the bottleneck is unfamiliarity with valuable upgrading schemes and potential applications for end-products. In a European project, the food waste problem was thoroughly investigated and quantified (Awarenet, 2004). In a follow-up project, various valorisation routes for onion, brewers' spent grain and red cabbage was researched (REPRO, 2007). The next step should be based on a reversed chain approach, starting with potentially interesting consumer goods based on waste streams.

4.2.5.5 Efficient water usage

Water is used in the processing industry in different ways, e.g., for supply, production of food, sanitation and separation (Water Supply and Sanitation Technology Platform, WSSTP, 2006). The vision of this platform is "Water Safe, Strong and Sustainable", and has been conceived and drafted by five working groups, consisting of water sector experts and representatives of water sector stakeholders. The vision paints a picture of what could be achieved by 2030 if resources for research and development were made available and targeted to respond to the issues and challenges that the European water sector is facing.

The European Hygiene Engineering and Design Group and the *Codex Alimentarius* have created guidelines on recycling of water (EHEDG, 2004, www.codexalimentarius.net). Recycling of water causes two main problems, namely concentration of organic and inorganic substances and growth of micro-organisms (often at higher processing temperatures). A list of best practices is given by Napper (2006).

4.2.5.6 Reduction of packaging materials

The revised targets of the Directive 2004/12/EC should stay the same for the foreseeable future. These are 55-80% for recycling, 60% for recovery, and then 60% for recycling of glass and paper and cardboard, 50% for metals, 22.5% for plastics and 15% for wood (source FPME, 2007). These targets have a direct impact on novel packaging methods such as changing to biodegradable packaging materials like polylactic acid (corn/potato based), and polyhydroxyalkanoates (sugar/vegetable oil/waste based). A substantial number of patents have recently been filed for biodegradable polymers. Also more sophisticated processing methods may avoid repacking. High-pressure processing or microwave heating are examples in which products are preserved in the final package itself. Finally, creative thinking may lead to substantial reduction of materials, e.g., in the case of bag-in-box solutions.

4.2.6 The Forward Look scenarios coloured for food processing

The ESF/COST Forward Look scenarios as presented in Figure 4.20 are four possible futures that come into being when two societal developments are combined, namely related to public concerns about the occurrence of food scares and crises and to the way in which the food market is operating.

Let us first consider the risk perception axis. A situation in which the majority of consumers are worried about the safety of their foods and are afraid of large-scale food scares will force the food processing industry to take measures to secure the trust of consumers in their products. Such measures could include detailed contracts with the producers of the raw materials in which the mode of operation and mechanisms to control compliance are put down. Field visits by independent controlling institutions may be implemented. Additional safety control measures will be applied to the processing operations in the factories themselves (e.g., more Hazards Analysis Critical Control Points – HACCP). Tracking and tracing systems will need to be expanded. All in all, under conditions of a high risk perception the food processing industry will face high costs to ensure food safety. The costs of implementing all the measures to ascertain food safety slow technological developments down and cause high food prices.

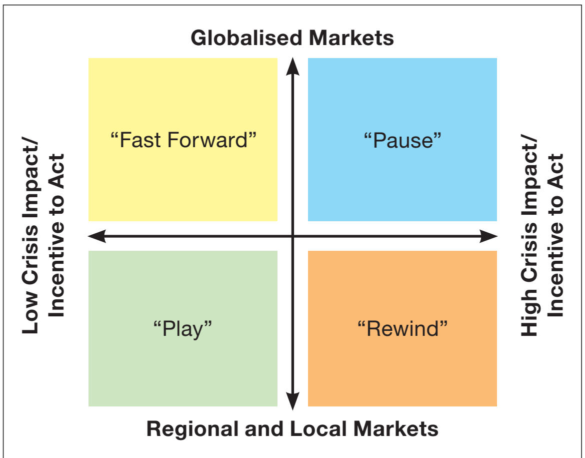

Figure 4.20. The framework of the proto-scenarios

A change on the market development axis towards more regional markets and a lower availability of overseas products might force the food industry to decentralise and use smaller-scale processing which may need to be less sophisticated. Moreover, reliance on regional production could cause problems in year-round supply of raw materials due to the seasonal production under the European climate. As in the case of a high risk perception by consumers, the food industry will face higher production costs which may, again, reduce the budgets available for R&D and thus hamper technological progress.

A future with globalised markets and a low risk perception among Europeans ("Fast Forward") seems to provide the most advantageous circumstances for technological advances in the food processing industry, when confronting the two development axes with the four scenarios. When considering the consumer prototypes introduced in Section 4.2.3.3 (Society-driven processing concepts) it seems plausible that this scenario would best accommodate the wishes of (a) consumers who seek convenience, as this scenario offers most opportunities for technological R&D, (b) hedonic consumers as industrial R&D provide new opportunities and the global markets offer a flow of exotic foods, (c) the variety-seeking consumer (for the same reasons as mentioned for the hedonic consumer), and (d) the price-conscious consumer as this scenario is assumed to result in the lowest food prices.

By contrast, technological development in food processing will be most restrained when the processing industry is required to invest time and money in additional safety control measures and is forced to operate on a more regional scale, i.e., when regional markets prevail and the risk perception is high ("Rewind"). This scenario does not seem to cater for the wishes of any of the consumer prototypes.

In the scenario with a high risk perception and globalised markets ("Pause"), food prices may be relatively high. However, for people who are concerned about their health this does not have to be a serious drawback as they are sure of the safety of their food. Consumers who are very health conscious may flourish in this scenario.

The scenarios with regional and local markets and a low risk perception ("Play") would best suit the environment-conscious and the nature- and animal-loving consumers as these scenarios offer opportunities for short production chains and a close control of production practices.

Finally, Figure 4.21 presents a conceptual model that indicates how food processing technologies can

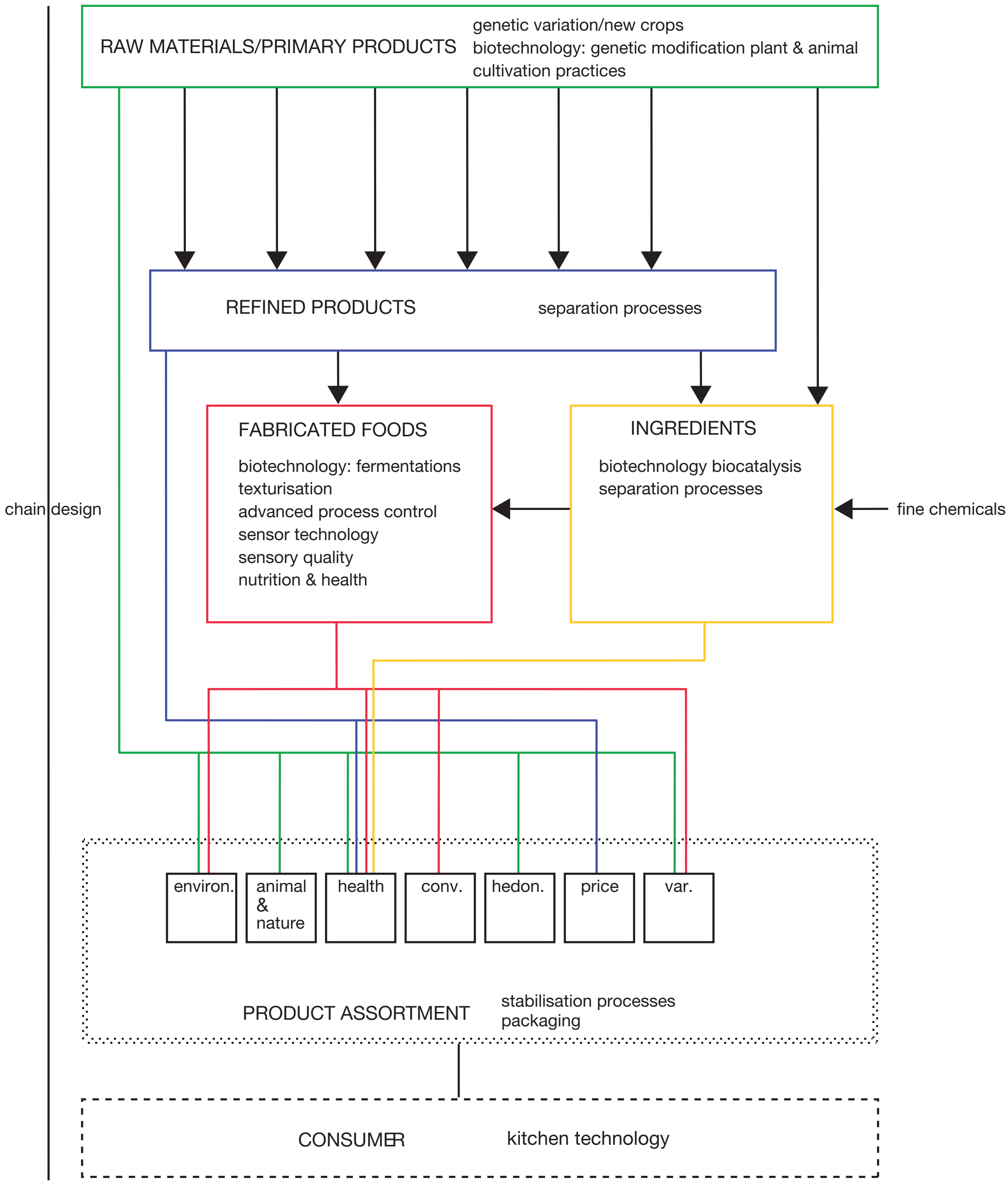

Figure 4.21. Model depicting the relation between different activities in food processing and consumer prototypes (Source: Linnemann et al., 1999)

be coupled to the different consumer prototypes, and, by extrapolation to developments that occur in the four scenarios of this ESF/COST Forward Look.

4.2.7 Research agenda

Concerning processing, the most important issues for policy makers in the coming decades are:

Policy makers should focus on **cross-sector activities** like food technology, food transport and food health. At the interface of sectors, main innovations could be achieved. Also, R&D intensity is usually substantially higher in sectors outside the food domain. Finally, cross-sector approaches allow **cluster formation of SME**. The joint efforts of SME will have a positive impact on economic development in European regions and increase their competitiveness.

Policy makers should prepare an agenda with topics that emphasise the competitive role of Europe in world food systems. For the food processing domain, agenda topics that serve the European consumers may include:

a. Healthy and natural foods;
b. Sustainable food chains;
c. The Food or Fuel discussion in view of renewable resources;
d. The rich and diverse European cuisine as a basis for innovations;
e. Cultural differences in Europe as a driving force for food design (Italian design, Swedish natural approach, etc.);
f. Europe as a global cultural playing field for development of new food concepts (e.g., food concepts for and tested by Indian, Chinese, Brazilian, etc. consumer groups).

Policy makers also need to take initiatives to ensure a leading role in the development of sustainable approaches in food processing (Europe's concerns about a healthy environment) leading to complete new food manufacturing concepts (shelf-stable fresh products, waterless systems, "meat analogues", milk as a high-value multi-ingredient raw material, and food/non-food joint initiatives).

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References

Ahvenainen, R. (1996). New approaches in improving the shelf life of minimally processed fruit and vegetables. *Trends in Food Science and Technology* 7: 179-187.

Andersson, K. and T. Ohlsson (1999). Including environmental aspects in production development: a case study of tomato ketchup. *Lebensmittel-Wissenschaft-und-Technologie* 32(3): 134-141.

Andreae, J.G. (1995). 15 miljoen markten [15 million markets]. Conferentie Massa-Individualisering, WTC Rotterdam. 24 oktober 1995.

Arad, S. and A. Yaron (1992). Natural pigments from red microalgae for use in foods and cosmetics. *Trends in Food Science and Technology* 3: 92-97.

Arthur D. Little and SenterNovem (2006). Major findings and recommendations for next step. Presentation at Platform Chain Efficiency, Sectors food, feed and flowers. SenterNovem meeting. February 2006.

AWARENET (2004). *Handbook for the prevention and minimisation of waste and valorisation of by-products in European agro-food industries*. Nr G1RT-CT-2000-05008.

Belin, J.M., M. Bensoussan and L. Serrano-Carrean (1992). Microbial biosynthesis for the production of food flavours. *Trends in Food Science and Technology* 3: 11-14.

Bengtsson, N. (1994). *New processes and products. An updated guide for people active in food processing, product development and marketing*. SIK, Swedish Institute for Food Research. SIK-report no. 606, 55 p.

Boom, R.M. (2001). "*Technische ontwikkelingen*" *in* Innovatienetwerk "Levensmiddelen in de 21ste eeuw".

Boom, R.M. (2007). *Future perceptions of food; multidisciplinary approach, potential for new technologies*. Presentation for the European Commission at "Perspectives for food 2030".

Boekel, M.A.J.S. van, and A. Linnemann (2007). *The need for food product design*. In: Linnemann, A.R. and M.A.J.S van Boekel (eds). Food product design – an integrated approach. Wageningen Academic Publishers, Wageningen. pp. 15-27.

Cap Gemini, Ernst & Young (2002). A European study of changing lifestyles and shopping behaviour.

Cheftel, J.C. (1992). New protein texturization processes by extrusion cooking at high moisture levels. *Food Reviews International* 8: 235-275.

Church, N. (1994). Developments in modified-atmosphere packaging and related technologies. *Trends in Food Science and Technology* 5: 345-352.

4.2 Current systems and future scenarios in food processing

CIAA (2005). European Technology Platform on Food for Life

CIAA (2007). Benchmarking report 2007 update, the competitiveness of the EU food and drink industry.

Cleland, A.C. (1996). Package design for refrigerated food: the need for multidisciplinary project teams. *Trends in Food Science and Technology* 7: 269-271.

Cohen, J.S. and T.C.S. Yang (1995). Progress in food dehydration. *Trends in Food Science and Technology* 6: 20-25.

Cuperus, F.P. and H. Nijhuis (1993). Applications of membrane technology to food processing. *Trends in Food Science and Technology* 4: 277-281.

De Reu, J.C. (1995). Solid-substrate fermentation of soya beans to tempe. PhD thesis. Wageningen Agricultural University, Wageningen. 154 p.

Deshpande, S.S., M. Cheryan, S.K. Sathe and D.K. Salunkhe (1984). Freeze concentration of fruit juices. *CRC Critical Reviews in Food Science and Nutrition* 20: 173-248.

Dickinson, E. (1993). Towards more natural emulsifiers. *Trends in Food Science and Technology* 4: 330-333.

Diogenes (2005). 6th Framework Programme from the European Commission, http://www.diogenes-eu.org/

Dunn, J., Th. Ott and W. Clark (1995). Pulsed-light treatment of food and packaging. *Food Technology* 49(9): 95-98.

Durance, T.D. (1997). Improving canned food quality with variable retort temperature processes. *Trends in Food Science and Technology* 8: 113-118.

Dutch Health Council, 2007, Richtlijnen goede voeding (guidelines for food and health), 18-12-2006, http://www.gezondheidsraad.nl.

EHEDG (1993). Microbiologically safe aseptic packaging of food products. *Trends in Food Science and Technology* 4: 21-25.

EHEDG (2004). European Hygiene Engineering and Design Group, guidelines for recycling of water, http://www.ehedg.org/

Eurofound (2004). The future of the food and drink sector.

Fennema, O. (1996). *Water and Ice*. In: Food Chemistry, 3rd edition. Ed. O. Fennema, Marcel Dekker, New York, pp. 17-94.

FINE (2007). Strategic objectives for developing innovation clusters in the European Food Industry.

Fito, P., N. LeMaguer, N. Betoret and P.J. Fito (2005). *An advanced food process engineering to design real food and processes: the SAFES methodology*. In: Innovations in traditional foods, Elsevier Publishing.

Foster, C., K. Green, M. Bleda, P. Dewick, B. Evans, A. Flynn and L. Mylan (2006). *Environmental impacts of food production and consumption*. Manchester Business School, DEFRA, London.

FPME (2007). The Voice of the European food processing machinery manufacturers. FPME Newsletter September.

Franks, F. (1991). Water activity: a credible measure of food safety and quality? *Trends in Food Science and Technology* 2: 68-72.

Fryer, P. and Z. Li (1993). Electrical resistance heating of foods. *Trends in Food Science and Technology* 4: 364-369.

Gaonkar, A.G. (1995). *Food processing. Recent developments*. Elsevier, Amsterdam. 315 p.

George, R.M. (1993). Freezing processes used in the food industry. *Trends in Food Science and Technology* 4: 134-138.

Goff, H.D. (1992). Low temperature stability and the glassy state in frozen foods. *Food Research International* 25: 317-325.

Gray, J.O., S. Davis, R.J. Moreno-Masey and D.G. Caldwell (2006). Visions for Automated Food Manufacturing. In: *Proceedings Food Factory of the Future* 3. June 2006.

Hamm, W. (1995). Trends in edible oil fractionation. *Trends in Food Science and Technology* 6: 121-126.

IFT Symposium (1993). Use of hydrostatic pressure in food processing. *Food Technology* 47(6): 149-172.

IFT Symposium (1994a). Ultrasonic applications in the food industry. *Food Technology* 48(12): 67-84.

IFT Symposium (1994b). Food irradiation: recent developments and future prospects. *Food Technology* 48(5): 123-144.

IFT Symposium (1996). Ohmic heating for thermal processing of foods: government, industry and academic perspectives. *Food Technology* 50(5): 242-273.

IFT Symposium (1997). The chemistry of flavor interactions. *Food Technology* 51(1): 59-80.

IPTS (2002). *Reversed Food Chain, from fork to farm*. EUR 20416 EN.

IPTS (2005). *The 2005 EU Industrial R&D investment scoreboard*. EUR 21851 EN.

Jackson, L.T. and K. Lee (1991). Microencapsulation and the food industry. *Lebensmittel Wissenschaft und –Technologie* 24: 289-297.

Kader, A.A., D. Zagory and E.L. Kerbel (1989). Modified atmosphere packaging of fruits and vegetables. *CRC Critical Reviews in Food Science and Nutrition* 28: 1-30.

Karlsson, H.O.E. and G. Trägårdh (1996). Applications of pervaporation in food processing. *Trends in Food Science and Technology* 7: 78-83.

Kim, H.-H.Y. and C. Baianu (1991). Novel liposome micro-encapsulation techniques for food application. *Trends in Food Science and Technology* 2: 55-61.

Knorr, D., M. Geulen, Th. Grahl and W. Sitzmann (1994). Food application of high-electric field pulses. *Trends in Food Science and Technology* 5: 71-75.
Labuza, T.P., B. Fu and P.S. Taoukis (1992). Prediction for shelf life and safety of minimally processed CAP/MAP chilled foods: a review. *Journal of Food Protection* 55: 741-750.
Ledward, D.A. (1993). Creating textures from mixed biopolymer systems. *Trends in Food Science and Technology* 4: 402-405.
Ledward, D.A. and R.F. Tester (1994). Molecular transformations of proteinaceous foods during extrusion processing. *Trends in Food Science and Technology* 5: 117-120.
Ledward, D.A, D.E. Johnston, R.G. Earnshaw and A.P.M. Hastings (Eds.) (1995). *High pressure treatment of foods*. Nottingham Press, Loughborough, UK.
Leistner, L.L. (1992). Food preservation by combined methods. *Food Research International* 25: 151-158.
Leistner, L.L. and L.M. Gorris (1995). Food preservation by hurdle technology. *Trends in Food Science and Technology* 6: 41-45.
Linnemann, A.R., G. Meerdink, M.T.G. Meulenberg and W.M.F. Jongen (1999). Consumer-oriented technology development. *Trends in Food Science and Technology* 9: 409-414.
Loaharana, P. and D. Murrell (1994). A role for irradiation in the control of foodborne pathogens. *Trends in Food Science and Technology* 5: 190-195.
Lucca, P.A. and B.J. Tepper (1994). Fat replacers and the functionality of fat in foods. *Trends in Food Science and Technology* 5: 12-19.
Manufuture (2007). The European Technology Platform on Manufacturing technologies. www.manufuture.com
Marquez, V.O., G.S. Mittal and M.W. Griffiths (1997). Destruction and inhibition of bacterial spores by high-voltage pulsed electric field. *Journal of Food Science* 62: 399-401, 409.
McClements, D.J. (1995). Advances in the application of ultrasound in food analysis and processing. *Trends in Food Science and Technology* 6: 293-299.
Mertens, B. and D. Knorr (1992). Developments of nonthermal processes for food preservation. *Food Technology* 46(5): 124-133.
Messens, W., J. van Camp and A. Huyghebaert (1997). The use of high pressure to modify the functionality of food proteins. *Trends in Food Science and Technology* 8: 107-112.
Murrano, E.A. (1995). Irradiation of fresh meats. *Food Technology* 49(12): 52-54.
Napper, D. (2006). *Hygiene in food factories*. In: Food Factory of the Future 3, Gothenburg.
Nijdam, D.S., Wilting, H.C. (2003). Milieudruk consumptie in Beeld, RIVM report 771404004/2003. Bilthoven, the Netherlands.
Niranjan, K. (1994). Chemical engineering principles and food processing. *Trends in Food Science and Technology* 5: 20-23.
NovelQ (2006). Integrated Project on Novel processing methods for the production and distribution of high-quality and safe foods. www.novelq.org
Ohlsson, Th. (1994). Minimal processing-preservation methods of the future: an overview. *Trends in Food Science and Technology* 5, 341-344.
Ohlsson, T. (2007). *Concepts for the food factory of the future*. Presentation for the European Commission at "Perspectives for food 2030".
Oshima, T., H. Ushio and C. Koizumi (1993). High pressure processing of fish and fish products. *Trends in Food Science and Technology* 4: 371-375.
O'Sullivan, M.G. (1992). Probiotic bacteria: myth or reality. *Trends in Food Science and Technology* 3: 309-313.
Palmer, M.V. and S.S.T. Ting (1995). Applications for supercritical fluid technology in food processing. *Food Chemistry* 52: 345-352.
Parrot, D.L. (1992). Use of Ohmic heating for aseptic processing of food particulates. *Food Technology* 46(12): 68-72.
Peppelenbos, H.W. (1996). *The use of gas exchange characteristics to optimize CA storage and MA packaging of fruits and vegetables*. PhD thesis. Wageningen Agricultural University, Wageningen.
Pires, M.J., M.R. Aires-Barros and J.M.S. Cabral (1996). Liquid-liquid extraction of proteins with reversed micelles. *Biotechnology Progress* 12: 290-301.
Plug, H. and P. Haring (1993). The role of ingredient-flavour interactions in the development of fat-free foods. *Trends in Food Science and Technology* 4: 150-152.
Popplewell, L.M., J.M. Black, L.M. Norris and M. Porzio (1995). Encapsulation system for flavors and colors. *Food Technology* 49(5): 76-82.
Porter, M. (1996). *On competition*. Harvard Business School Publishing.
Pothakamury, U.R. and G.V. Barbosa-Cánovas (1995). Fundamental aspects of controlled release in foods. *Trends in Food Science and Technology* 6: 397-406.
Prazeres, D.M.F. and J.M.S. Cabral (1994). Enzymatic membrane bioreactors and their applications. *Enzyme and Microbial Technology* 16: 738-750.
Prisma & partners, MinacNed (2006). Roadmap Microsystem & Nanotechnology in Food & Nutrition.
PROFETAS-project: www.profetas.nl
Qin, B.L., U.R. Pothakamury, H. Vega, O. Martín, G.V. Barbosa-Cánovas and B.G. Swanson (1995). Food

pasteurization using high-intensity pulsed electric fields. *Food Technology* 49(12): 55-60.
Raoult-Wack, A.L. (1994) Recent advances in the osmotic dehydration of foods. *Trends in Food Science and Technology* 5: 255-260
Reineccius, G. (1989). Flavor encapsulation. *Food Reviews International* 5: 147-176.
REPRO (2007). www.repro-food.net
Rizvi, S.S.H. and A.R. Bhaskar (1995). Supercritical fluid processing of milk fat: fractionation, scale-up, and economics. *Food Technology* 49(2): 90-97, 100.
Rizvi, S.S.H., S.J. Mulvaney and A.S. Sokhey (1995). The combined application of supercritical fluid and extrusion technology. *Trends in Food Science and Technology* 6: 232-240.
Roos, Y.H., M. Karel and J.L. Kokini (1996). Glass transitions in low moisture and frozen foods: effects on shelf life and quality. *Food Technology* 50(12): 95-108.
Roser, B. (1991). Threhalose, a new approach to premium dried foods. *Trends in Food Science and Technology* 3: 166-169.
Sakai, N. and T. Hanzawa (1994). Applications and advances in far-infrared heating in Japan. *Trends in Food Science and Technology* 5: 357-362.
Schellekens, W. (1996). New research issues in sous-vide cooking. *Trends in Food Science and Technology* 7: 256-262
Scher, M. (1993). Biotech food – and no controversy. Trehalose to find more food functions as cost falls. *Food Processing* April issue: 95-96.
Schuchmann, H., S. Hogekamp and H. Schubert (1993). Jet agglomeration processes for instant foods. *Trends in Food Science and Technology* 4(6): 179-183.
Sebok, A. (2007). *Future Food Processing*. Brussels 180407.
Singh, P.C. and R.K. Singh (1996). Choosing an appropriate bioseparation technique. *Trends in Food Science and Technology* 7: 49-58.
Slade, L. and H. Levine (1991). Beyond water activity: recent advances based on an alternative approach to the assessment of food quality and safety. *CRC Critical Reviews in Food Science and Nutrition* 30: 115-360.
Smeets, P. (2006). Wageningen UR, The Netherlands, personal communication about Agro-Green Parc.
SMES-NET (2006). Vision paper. Ten theses on Food and Drink SMEs and Innovation in Europe.
Stankiewicz, A.I., Moulijn, J.A. (2000). Process intensification: transforming chemical engineering. *Chemical Engineering Progress* 96, 22-23
Stegeman, D. and V. Immink (2000). *European Technology Study; identification of new technologies in Europe for the agri-food industry*. Nr 00/038/310700 Wageningen UR report.
Swienteck (1992). Frozen foods with "fresh" qualities. *Food Processing* October Issue: 55.
Thakur, B.R. and R.K. Singh (1995). Combination processes in food irradiation. *Trends in Food Science and Technology* 6: 7-11.
Tolstoguzov, V.B. (1995). Some physico-chemical aspects of protein processing in foods: multicomponent gels. *Food Hydrocolloids* 9: 317-332.
Van den Berg, C. (1991). *Food-water relations: progress and integration, comments and thoughts*. In: Water relations in foods. Levine, H, and L. Slade (eds). Plenum Press, New York. pp. 21-28.
Van Mil, P.J.J.M. and S. Bouman (1990). Freeze concentration of dairy products. *Netherlands Milk and Dairy Journal* 44: 21-32.m
Vega-Mercado, H., O. Martín-Belloso, B.L. Qin, F.J. Chang, M.M. Góngora-Nieto, G.V. Barbosa-Cánovas and B.G. Swanson (1997). Non-thermal food preservation: pulsed electric fields. *Trends in Food Science and Technology* 8: 151-157.
Voedingsmiddelenindustrie (2002). Water usage in the food industry.
Vulfson, E.N. (1993). Enzymatic synthesis of food ingredients in low-water media. *Trends in Food Science and Technology* 4: 209-215.
Walstra, P. (1983). *Formation of Emulsions*. In: Encyclopedia of Emulsion Technology, Vol. 1. Becher, P. (ed.). Marcel Dekker, New York. p. 57-128.
Walstra, P. (1996). *Emulsion Stability*. In: Encyclopedia of Emulsion Technology, Vol. 4. Becher, P. (ed.). Marcel Dekker, New York. p. 1-62.
Water supply and sanitation technology platform: http://www.wsstp.org/default.aspx
Wijnands, J., B. van der Meulen and K. Poppe (2007). *The competitiveness of the European Food Industry; an economic and legal assessment*. ENTR/05/75
Yano, T., R. Matsumo and K. Nakamura (1994). *Developments in Food Engineering*. Parts 1 & 2. Blackie Academic & Professional, London.

4.3 Current trends in distribution and packaging

4.3.1 Introduction

This background paper describes a set of food system activities at the European level, within the framework of the ESF/COST Forward Look "European Food Systems in a Changing World", with respect to the distribution and packaging of food.

The paper addresses current and future developments for this set of food system activities, guided by the following key questions identified in a First Workshop of the ESF/COST Forward Look in October 2006:

- How will geographical shifts in food production impact the EU food processing and distribution industry and its competitiveness?
- What will be the sustainability issues that most affect the processing/distribution [and packaging] industry and how?

The key questions serve as the entry point to the discussion. Each section links to the others to provide a coherent narrative and analytical frame. The paper is closely linked to the parallel paper on the food processing industry. It is also cross-referenced to the other papers in this series, i.e., food production, and food retailing and consumption.

The paper is split into two sections:

Part A looks at the current situation and summarises how these have led to changes in distribution and packing. It then goes on to assess the sustainability issues for these activities, followed by a discussion of the key choices facing society today.

Part B looks at future developments up to the period 2020 to 2030 and identifies future research priorities for the next five to ten years for consideration by EU and national agencies.

Part A: Current situation

4.3.2 How will geographical shifts in food production impact the EU food processing anddistribution industry and its competitiveness?

4.3.2.1 Introduction

All food is transported from producer to consumer. However, the transport distance, the transport mode, and the number of transportation steps (i.e., the distribution of food) are often very different, and are determined by the characteristics of the individual supply chain. As a result, extremely large differences in food distribution do exist. To illustrate:

- Food that is produced "locally", i.e., sold directly at nearby markets or other local routes, is likely to involve only one or two distribution steps from producer to consumer, involving a small transport distance, typically less than 50 km.
- Food that is sourced by the major retailers from global supply chains can be imported from many thousands of kilometres away. As an example, food from New Zealand travels some 18 000 km to reach Europe (Saunders et al., 2006). In addition to the straight line origin to destination distance, major retailers often add additional distribution steps in the country of origin and/or destination to optimise logistics and stock control. These further increase distribution steps and transport distance, even for food sourced domestically or within Europe.

It is clear that over the past few decades, the geographical shifts that have occurred in food production have influenced food distribution or, more accurately, geographical production shifts have required different distribution systems. However, these production trends are only one driver of many. There are also major changes that have occurred in food processing (see Section 4.2), the influence of retailers across the supply chain and changing consumer demand (see Section 4.4) and in distribution patterns and logistical operations, that led to the current situation.

4.3.2.2 Geographical shifts and other drivers affecting food distribution

Over the past few decades, there have been very significant changes in the geographical production of food in Europe (see Section 4.1), but also from further away. There have also been dramatic changes with the emergence of the major retailers and also changing consumer demand (see Section 4.4). All of these have led to far-reaching changes to food supply chains and to the way that food is distributed.

This section briefly discusses the following drivers and their impact on distribution:

- The changes in the geographical production and distribution of food within Europe, particularly considering European trade, integration and accession;
- The changes in the geographical production and distribution of food from outside Europe and the higher levels of global trade, particularly with the emergence of the new food exporters of the developing world;
- The emergence of major retailers and their supply chains, which have responded to the changes above as well as actually driving these changes, particularly with moves to wider sourcing through global supply chains, and a greater influence of major retailers down

the supply chain (to include distribution);
- The changes in retailer sales/consumer demand towards year-round supply of certain foods, replacing seasonal produce;
- The change in consumer demand towards a different food balance, e.g. proportion of meat in the diet, and towards more processed and packaged foods (convenience).

Changes in the geographical distribution of food production within Europe

Within the EU there are close food-trading relationships between member states, and considerable levels of cross-border distribution of food. The first paper (Section 4.1) in this chapter has outlined the production status in Europe. The increasing encouragement of trade within the EU, combined with liberalisation of the internal market, the removal of constraints on cross-border movements, and reduction in other barriers, has led to greater levels of trade for a much wider basket of food products. This has led to a growing trade in primary food products, either agricultural commodities, or primary products such as fruit, vegetables and meats, with complex trading networks, partly put in place to exploit differentials in labour cost. There has also been the emergence of trade in regional-specific produce or branded products as well as processed foods (tied in with changing retailer/consumer changes discussed below). All of these reflect a trend towards specialisation, either of food types or of production processes.

These changes have, of course, increased the distances between production and final consumer and led to highly evolved distributional networks. With accession (the EU-10 plus 2), the geographical borders across Europe have widened, and this is already leading to changing trade flows across Europe (from East to West, from EU-10 to EU-15), necessitating longer food supply chains and greater distribution. In most EU-15 countries agriculture is a low share of GDP, and the drive towards economic growth has led to a move away from agricultural production and exports (as a low-value sector) and also lessened the reliance on domestic food security (especially given the greater security offered through the EU).

Changes in the geographical production and distribution of food from outside Europe

In Europe, the past few decades have also seen a growing international trade in food, consistent with the development of a global market.

Whilst Europe has always had a number of long-distance trading partners, USA and New Zealand, for example, in recent years a growing proportion of food trade has arisen with developing countries. This trade now occurs with all continents and regions, and has seen the emergence of new trading partners across Asia, South America and Africa. Food exports have become a major source of income for many of the countries in these regions, and this can lead to substantial economical gains. However, there is a growing awareness that the current levels of trade barriers, subsidies and practices can lead to detrimental effects from this trade, to the local environment, to communities and to the economies of developing countries. These pitfalls (e.g., commodity traps) are recognised even by those that advocate much greater free trade (e.g. see Trade and the Global Economy – HMT, 2004).

It is not possible to discuss the reasons for these changes here. This would require a much more comprehensive discussion of agricultural subsidies and reforms, labour and production costs, global price changes, production improvements, changing consumer demand, etc. What is clear is that these changes are largely being driven by trade liberalisation and advanced through the role of the World Trade Organisation in relation to agricultural subsidy, tariffs, import quotas and trade disputes. In turn this has led to growing levels of both imports into, and exports from, the EU. Indeed, the EU is now the world's top food importer (followed at some distance by the USA and Japan), and is a net importer of agricultural products (European Commission, 2007b).

Overall EU food trade is rising, as shown by the Eurostat data below. These changes are leading to a different balance of global production, and also changing import to export ratios (discussed in the box next page).

Table 4.16. EU-27 Imports and exports (Food, category 0+1), Value (Bn ECU/euro) (Source: Eurostat, 2007)

EU-27	2002	2003	2004	2005	2006
Imports	58.1	57.3	58.9	63.0	67.8
Exports	50.5	49.2	49.1	52.8	59.1

It is highlighted that some of these trade flows may appear bizarre to those outside the agricultural sector (though also often to those inside!). Why should the EU produce beef which it sells to Russia, when at the same time it is importing beef from Brazil? This trade, two-way traffic, is perhaps even more pronounced in the case of processed or branded goods: for example, last year, Britain imported 14 000 tonnes of chocolate-covered waffles from all its trading partners and exported 15 000 tonnes, and the UK exported 20 tonnes of mineral water to Australia, and imported 21 tonnes (NEF, 2007). The answer is simple – the presence of international markets –, though in truth there is much more complexity.

The changing pattern of international trade

There are a number of changes that are occurring with international production.

1) The growth in agricultural production is coming largely from developing countries. Take as an example the production of poultry meat below. While there are lots of factors in production (not least bird disease in recent years), European production has remained broadly static over the last seven years whilst production has significantly increased in India, Brazil, Russia, and China (partly in response to internal demand but also for export).

2) There is a changing import:export balance. This can be illustrated with beef. Since 2003 the European Community has become a net importer of beef.

- In 2004, the EU exported around 396 000 tonnes of beef (meat and live animals), though this fell to 285 000 tonnes in 2005 (due to tight supplies on the Community market, the strong competitive position of third country suppliers [especially South America] on the world market and the unfavourable euro-dollar exchange rate). The majority of exports were destined for the Russian market (52%, mainly beef) as well as the Lebanon (14%, mainly live animals).
- At the same time, the EU imported around 507 000 tonnes of beef in 2004 (and 528 000 tonnes in 2005) primarily from Brazil (64% of the total imports), Argentina (21%) and Uruguay (5%).
- Total beef imports exceeded total Community exports by around 111 000 tonnes in 2004 and 242 000 in 2005.

(Source: The Agricultural Situation in the EU Report, 2005)

	United States	Brazil	China	Japan	Russia	India	Thailand	EU-15	EU-25	World
1998	15 178	4 969	11 349	1 212	690	710	1 210	8 823		62 400
1999	16 039	5 647	11 951	1 213	748	820	1 180	9 148		65 333
2000	16 416	6 125	12 873	1 195	754	1 081	1 194	8 939		69 156
2001	16 761	6 380	12 866	1 216	861	1 250	1 336	9 381		71 643
2002	17 268	7 239	13 262	1 229	937	1 401	1 414	9 383	11 109	74 377
2003	17 468	7 967	13 687	1 218	1 034	1 600	1 191	9 066	10 880	75 823
2004	18 007	8 895	14 170	1 237	1 030	1 715	964	9 098	11 037	78 559
2005e	–	–	–	–	–	–	–	–	11047	–
%TAV 2004/99	**12.2**	**57.5**	**18.5**	**1.9**	**37.7**	**109**	**–19**	**–0.5**	**–**	**20.2**

Source: FAO, European Union

All of these changes mean a rise in international trade, and a greater level of food distribution in relation to European imports and exports (i.e., for European supply chains, which now extend globally). This raises new challenges for transporting food. World trade involves much greater transportation distances and introduces potentially important transportation costs, as well as issues in relation to preserving food quality, minimising damage which links to packaging, etc. Global transport also requires different transport modes when compared to most EU food transport (which is by road), with the use of shipping to transport goods over seas and oceans, or for some high value/perishable goods, air transport.

The emergence of the major retailers

As the following paper (Section 4.4) presents, a growing share of the food sold in Europe is through the major retailers, and this has greatly influenced overall food supply chains and, in turn, distribution. Indeed, the move to wider food sourcing (above) is strongly linked to the increasing dominance of retailers in the supply chain. Global sourcing offers a way to source lower cost food from countries with lower labour and production costs. It also offers a route to access large-scale suppliers rather than dealing with numerous smaller suppliers, and therefore offering efficiency of scale, as well as the advantages of central purchasing policies. These trends have led to a concentration of the supplier base. There has also been a change in the types of food sold across the year, in terms of the basket of products, driven by a concentration of sales in major retailer outlets; in the 1960s an average European grocery had 2 000 product lines. A modern supermarket has more than 15 000 (INCPEN, 2003).

A related consequence has been a move away from seasonal produce towards year-round supply. This is also related to consumer trends (see below). There remains a debate whether consumers influence retailer behaviour (i.e., retailers narrowly follow consumer demand), or whether retailers themselves determine consumer demand through their product selection and marketing. Global sourcing removes seasonal restrictions on locally-grown food, as well as increasing diversity of food available.

These changes to global supply and year-round sourcing have necessitated more food distribution (greater distances, improved logistics), but also have led to a change in the distribution network, centred around the needs of the major retailer (see discussion in section below).

Changes in consumer demand

There has also been a change in the balance of foods consumed, which partly influences these supply chains. The consumption of potatoes, milk, and red meat in the EU-15 has decreased over the last decade while at the same time the consumption of fruit, vegetables, pork meat, poultry meat, fish and seafood has increased (EEA, based on FAO data, 2005). Changes are already occurring within the diet of the EU-10, with increasing consumption of meat.

There are also wider socioeconomic trends which have driven food choice changes, with overall increases in working hours for employed people, increases in women at work, increased ownership of freezers and fridges, and changes in lifestyle and demographics. These trends explain the rise in pre-cut and washed products (convenience foods) and towards pre-prepared foods or meals (frozen or chilled, for example), both at the expense of fresh produce. Michaelis and Lorek (2004), for instance, report that consumption of already-prepared meals increased by 9% from 1996 to 2001 in the EU-15. These changes have, in turn, led to major changes in the packaging of food (see later section) as well as influencing food distribution.

Processed and convenience food, even pre-cut vegetables, have a larger number of steps in the food supply chain, and so usually more distribution steps. As examples, this can involve widespread sourcing and distribution of primary products, usually with a focus on securing these at least cost, to the processing point. This is followed by subsequent onward distribution into the supplier chain. The ready-meal market differs strongly across EU member states. It is more pronounced in the UK and Germany, but it is also growing in other countries (e.g., Greece and Spain), with a particular rise in chilled products and note the additional energy requirements for such products in their supply chain.

As well as the changes in primary food production towards a concentrated supplier base, food processing companies have also been concentrating their production capacity in fewer locations to take advantage of economies of scale. Others have adopted a “focused production” strategy, retaining the same number of plants but concentrating the manufacture of particular items in particular locations. Both of these switches lead to more distribution, at least generally in terms of average transport distance.

The EEA (2005b) expects these trends regarding convenience food to continue, driven by demographics (e.g., smaller households), employment changes (double income households), and social changes (e.g., individualism). The key issue is that these changes influence transport movements, as well as transport distances. An increase in the processing and packaging of food has led to more links in the food supply chain, and longer transport distances.

One additional point that is often overlooked is that these changes, and the emergence of major retailers, have altered the way that consumers shop for their food, and affected personal travel habits. There is an increasing move to consolidated (e.g., weekly) shopping for food items, usually by car, particularly in some countries such as the UK: Smith et al. (2005), for example, estimate that the use of car food shopping trips increased from 10.6 billion vkm to 14.3 billion vkm between 1992 and 2002.

There are other trends that are important, particularly with consumers in relation to organic produce, animal welfare, and ethical (fair) trade, discussed in the following paper. As these differentiated lines have a relatively low share of sales (though they are increasing), they have not significantly influenced distribution at the national scale. Their influence can also be complex – for example, the sourcing of organic food is often associated with local produce (which would imply fewer distribution steps and shorter distances), but in the UK, as an example, rising consumer demand has led to major retailers offering imported organic produce, due to low levels of domestic supply.

Finally, out-of-home consumption also accounts for a significant and growing proportion of European food intake. Around 25% of total household food expenditures in the EU-15 go to out-of-home food sources (Michaelis and Lorek, 2004), and out-of-home consumption accounts for a significant and growing proportion of European food intake. The implications of these changes on transport distribution, or environment, are unclear.

4.3.2.3 The effects on food distribution

The drivers above have influenced the systems needed to distribute food. These changes have been complex, and are highly interrelated with respect to different logistical and supply chain trends. Some of these are mutually reinforcing and others counteracting. Nonetheless, the clear trend over the last few decades has been an increase in distribution of food, in terms of numbers of distribution steps and also longer distances, as set out below.

These trends appear to be happening across Europe, but the drivers and changes in distribution are particularly pronounced in some member states. The data collated by Eurostat shows an overall rise in freight transport levels in Europe, of which food transport is an important driver. Total freight transport (in tonne km) in the EU increased by 55 % between 1980 and 1998, an average of 2.5 % per year. Freight transport demand grew between 1980 and 1999 at an average of 2.5 % per year, outstripping GDP growth (2.2 % per year) (EEA TERM, 2001).

The rate of change can be demonstrated with detailed member state data. In Great Britain, since 1978, the annual amount of food moved by heavy goods vehicles (HGVs) has increased by 23%, and the average distance for each trip has increased by over 50% (Department for Transport, 2003); these data include food, drink and tobacco. Food transport now accounts for over 20% of all road freight by tonnes moved and 27% by tonne kilometres (DfT, 2007). This is due to an increasing average number of links in the food supply chain, as well as increased average length, resulting in a large increase in tonne kms (McKinnon and Woodburn, 1996). However, note that vehicle kms grew by a significantly smaller margin because average payload weight has also increased.

However, these statistics (on food moved in any member state or across Europe) are only part of the story. To understand these changes fully, it is necessary to assess the impact of European supply chains globally and the additional distribution outside the EU. These data are not collated by Eurostat. Luckily, some of these data are available at the member state level, for example as undertaken on behalf of a member state Government as in the UK (Smith et al., 2005). These show a pattern of rising total food transport, as measured by total tonne km transported, and to a lesser extent the rise in vehicle km (see box for metrics). They also show a changing use of different transport modes, with a dramatic increase in the use of aviation for food transport.

Food transport metrics

Food tonne km relate to the total weight of food transported over a distance, and as a functional unit can be interpreted as the transport of 1 tonne of food over 1 km. This gives an indication of the total amount of food being transported, but does not take into account the mode, efficiency of transport, or allow a direct analysis of the burdens of transportation.

Food vehicle km relate to the actual vehicles transporting food, rather than the weight. They allow an analysis of the actual burdens (e.g. emissions) of transport, as these burdens are associated with the vehicle, not the commodity itself. As an example, a heavy goods vehicle can be carrying 1 tonne or 2 tonnes of food, but will pretty much emit the same level of greenhouse gas emissions for either. This metric therefore takes load factors into account. It also allows differentiation by mode, which is important, as for example the burdens from transporting food by ship are completely different to transporting by aircraft.

The two metrics attach different relative importance to different parts of the supply chain. For example, the use of food tonne km gives a much higher weighting to bulk commodity shipping in relation to total food transport, whilst the use of vehicle km attaches more weight to road transport distribution. Related to this, even if tonne km are increasing, the changes in vehicle km will change at a different rate, depending on whether load factors are increasing or decreasing. It is therefore good practice to consider both metrics.

The recent growth is summarised for the UK next page (Table 4.17). This shows the rise in both domestic and non-UK food transport, consistent with changes outlined above. Note that while food transport (as measured by tonne km and vehicle km) are increasing, the greatest increase was found for air freight, which has increased by 40% over the past decade. Further discussion of the implications of these statistics, and the associated sustainability debate (including greenhouse gas emissions), are presented in Section 4.3.3.

Table 4.17. The growth in food transport associated with the UK Food Supply Chain (UK and Overseas), including exports and consumers shopping for food (Source: Smith et al., 2005)

	1992	1997	2002
Total billion tonne kilometres			
UK	39	49	50
Overseas	164	173	183
Total	203	222	234
Total billion vehicle kilometres			
UK	21	23	25
Overseas	5.7	5.5	5.3
Total	27	29	30
Aviation million vehicle km	11	22	27

It is highlighted that the UK is probably exceptional in the rate of this change, due to a dominant large retail sector and a faster move to global year-round supply chains than most other European countries. Nonetheless, similar changes are happening across Europe. In Germany, the amount of food consumed has not grown much in the last three decades, but food transport (in tonne km per capita) has almost doubled, again due to customer preferences for food from other countries, transport policies, the location and production patterns of the food industry and the policies and location of retailers (FAW, 2000). Further work is needed (see Section 4.3.6) to identify the changes across all countries in Europe, and to see whether these trends are already reaching the new EU-10.

One aspect that is highlighted is that the share of rail food freight is extremely low. In the UK, it is insignificant (i.e., below the 0.1% level). This is because rail is more suited to large-scale heavy bulk commodities, not to light, high volume foods, and it does not offer the flexibility needed for the Just-in-Time (JIT) delivery systems at the end of the retail supply chain. Nonetheless, rail has advantages over road in terms of security and low accident rates, good reliability especially over long distances, and environmental advantages.

The changing nature of distribution

The increases in food transport above have been possible because transport is relatively cheap compared to the costs of production (including costs of labour) and because international transport has become much quicker. The distribution industry has therefore been able to increase the number of movements, and the length of movements, and still provide efficiency gains/cost savings in the wider food supply chain. This has led to some fundamental changes in the distribution system, and in the way that food progresses through the food chain, which are heightened in the case of the supply chains associated with the major retailers. Examples (Smith et al., 2005) are:

- It has been possible for efficiency gains to be made by reducing the number of stockholding points in production and distribution systems. This allows companies to cut the amount of inventory (stock) required to maintain a given level of customer service. The associated transport cost penalty is usually quite small relative to the savings in inventory and storage costs. By increasing the average distance between the point of production and the final consumer, centralisation generates additional tonne kms. However, it can result in a less than proportional increase in vehicle kms, where centralisation is accompanied by an increase in vehicle load factors.
- These potential efficiencies have led to a move into "secondary distribution" by many large retailers (away from suppliers). Supplies are routed through retailers' own regional distribution centres (RDCs) – effectively warehouses – which allow consolidation of deliveries to large shops. This has diverted flows of food products from producers' or manufacturers' distribution depots (and wholesale warehouses) to retailers' RDCs. The benefits are potential efficiencies through larger-scale sourcing away from multiple local production. This has been one of the drivers of the changing geographical production sourcing above, with retailers seeking out year-round supplies at low prices, which leads to a greater proportion of global food sourcing.
- Similar issues have driven the move to JIT delivery [often known as "Quick Response" (QR) in food retail], which minimises inventory by sourcing supplies in small quantities at frequent intervals, and maximises the ratio of total sales to inventory. Note that since JIT increases numbers of trips, it has the potential to increase vehicle km, but this has not happened due to the parallel move to secondary distribution above, which has led to payloads with very high load factors.
- New distribution systems such as local break-bulk operations, hub-satellite networks and primary consolidation also have the effect of increasing tonne kms but improving the speed and efficiency of centralised sorting. They provide high vehicle load factors (so the effect on vehicle kms is less pronounced).
- Information and communication technologies (ICT) have played a part in improving logistics and supply-chain planning (computerised vehicle routing and scheduling – CVRS). Route planning with ICT can reduce the number of vehicle-kilometres (though may increase JIT delivery).
- Availability of more efficient packaging and mobile refrigeration technologies has allowed longer transport of fresh produce.

- There have been major changes in vehicle size, weight and type. This is particularly important in the road transport sector, with the emergence of larger and larger vehicles (up to 44 tonne vehicles), which can potentially achieve very high efficiencies of distribution (provided load factors are good).
- The volume of primary and secondary packaging has also been increasing, affecting vehicle space requirements, but allowing much greater efficiencies in loading and delivery systems.

Most of the trends above increase the distance of transport, but also increase the load factors, and so whilst there are high increases in food tonne km, the increase in food vehicle km is much less (than might otherwise be). The use of larger vehicles, routing of produce via regional distribution centres to allow consolidation of loads and use of logistics software has allowed food freight operations to achieve typical load factors of around 70%, and empty running of only 23% (Smith et al., 2005).

Interestingly, these changes have led to both positive and negative effects for local suppliers. Small or local suppliers can potentially access large retail chains (towards national and international supply) from these systems. However, and of course, the same chains have allowed others (regional, wider EU, global suppliers) to also penetrate these same markets and so opened up greater competition. In such conditions, large-scale operators have tended to win out. A related trend is that the large, highly-centralised retail logistics systems make it virtually impossible for local suppliers to deliver directly to local large stores, which has led to some bizarre examples of food moving round a country. One consequence of these systems is that it is now almost impossible for all but a few product lines to penetrate the retailer's supply chain anywhere but the RDC in the UK, which are set up to receive large consolidated loads from articulated vehicles. This has led to examples of seemingly bizarre food supply chains, e.g., where a sandwich company in Derbyshire supplies its products to a major supermarket chain and has a plant within a few hundred metres of one of their shops, but where the sandwiches on the shop's shelves have been routed through one of the retailer's RDCs on a round-trip of over 100 km. This occurs because at an aggregate level, the centralised systems are more efficient and achieve higher levels of vehicle utilisation. As the RDCs are much more centralised and serve wider areas, this considerably lengthens the link in the chain from warehouse to shop, and increased food tonne kms, though the consolidation of retailer-controlled deliveries in much larger vehicles may well have reduced total vehicle kms.

The scale of these changes varies by individual member states, and is determined by the strength of major retailers and the level of fragmentation in the retail and wholesale sectors.

- In countries which have gone heavily down this path (as in the UK, where 85% of food is sold in large retail chains), the move to overseas sourcing has been dramatic. As an example, half of all vegetables and 95% of all fruit consumed in the UK now come from overseas (FAO, 2003). When large retailers dominate, the move towards large-scale supply chains reduces the interface between major and local retailing. It can lead to a dramatic decline in local food sales and outlets. This is now leading to the sale of local food via farm shops, farmers' markets or box schemes, in part as a response against the dominance of the major retailers and their supply chains.
- In countries which have a more fragmented retail market, or where a more local or regional food supply system exists (e.g., associated with regional provenance), the trends are less pronounced. Such countries usually have small to medium suppliers that sell their produce either to wholesalers (who sell on to local shops, markets or caterers), local shops, caterers, or direct to consumers via markets. Transport is mainly in smaller vehicles and load factors are lower. Importers have more logistical and distributional constraints.

It is interesting to consider which system the new EU-10 will go towards. In these countries, the emergence of the major retailers is already starting, driven by expansion plans of the large EU-15 players. As an example, Tesco, UK's largest retailer with 1988 stores countrywide, has already built 280 stores in Poland, 101 stores in Hungary, 84 stores in the Czech Republic, 48 in Slovakia and even 30 in Turkey, as well as having 636 stores across Asia (Tesco, 2007). In the short term there is likely to be competition between the two systems, in that smaller shops compete against large superstores, wholesalers are potentially displaced by supermarket regional distribution centres, and smaller suppliers are affected by the reduced numbers of small independent shops and wholesalers. In the longer term, one system is likely to dominate, and this will be determined by the drivers outlined above.

The changing nature of packaging

The increases in pre-prepared and convenience food have led to a rise in packaging (EEA, 2005a). At the same time the changes in supply chain have required more general shifts in both primary and secondary packaging, to enable the new distribution and other steps. Packaging is clearly needed for the transport of convenience food, but is also being used more for primary food types as well (i.e., for fresh goods). Increased packaging has helped to reduce damage and spoilage (e.g., during transport), but it has dramatically increased the use of plastics, card, etc., which are non-organic materials that were not as widely used previously for food. It has, of course, led to a rise in packaging waste.

Total packaging waste in the EU-15 amounts to more than 160 kg per person per year – almost one-third of total waste from daily household activities – and it is estimated that more than two-thirds of total packaging waste is related to the consumption of food (INCPEN, 2001). A recent study found that in the UK, an average of 5% of the total weight of the products bought from major retailers was made up of packaging (War on Waste, 2007).

Although recycling rates for many packaging materials have increased, wastes from household food consumption are among the least affected by these trends. Indeed, without action, EEA projections (EEA, 2005b) show that packaging waste volumes are likely to continue to increase by about 50 % between 2000 and 2020 in the EU-15 (though note this is at a slightly slower rate than GDP).

The changes that have increased the use of packaging materials are partly a response to the change in products, for example, chilled and convenience foods, but they also reflect a growing multi-functionality for packaging. These include:

- **Distribution and supply chain functionality.** Packaging is now used to standardise many product lines and facilitate their easy handling in the supply chains that have emerged (e.g., as well as primary packaging, this includes secondary packaging to enable the easy transportation and movement in palletised loads).
- **Protection.** Packaging helps minimise the damage of transported goods and minimise wastage, and so with the rise in food distribution, there has been a need to increase protection. Packaging does have an important role therefore in minimising waste. In fact, the industry cites that packaging prevents far more waste than it generates (INCPEN, 2005).
- **Safety and contamination.** Packaging does improve food safety by containing food and protecting from biological and other contamination. This is important in relation to more stringent food safety standards and the protection of the health of consumers, and has led to legislation with respect to food contact materials (Europa, 2004).
- **Lifetime (durability).** Packaging extends product lifetime. While historically the use of cans and glass was the main long-term packaging used, more recently, packaging has been applied to a range of fresh as well as processed foods, using plastics. Some of these changes are sophisticated, for example, many consumers will not be aware that bagged lettuce or other fresh produces are likely to be packaged with a controlled air mix (modified atmosphere packaging) to extend lifetime and preserve structure.
- **Marketing and branding.** Clearly packaging has a major role in trying to increase the attractiveness of products. There has also been a more recent move to use controlled packaging atmospheres to enhance product appearance. As an example, some meats are packed in certain controlled atmospheres to maintain the redness of the meat.
- **Functionality/Consumer demand.** Packaging can be used to reduce cooking or preparation time for consumers, particularly in relation to microwave-ready (or oven-ready) food products.
- **Information.** Packaging is also used in relation to consumer communication, for example in relation to nutritional information, cooking times, product origin, etc. Most recently there are linkages here with distribution, with some UK retailers actually putting additional labels on fresh products that are air freighted, as with the recent introduction of aircraft logos on air-freighted Marks & Spencer and Tesco products. The current debate is now moving to discussion of carbon labels (see later discussion).

There are some competing elements above. There is a general view of the need to reduce packaging, but at the same time, health protection legislation is increasing, consumers want more information on products, the increase in convenience food is changing packaging requirements, etc. Most of these drivers are leading to more packaging. While there are many technological issues (i.e., types of materials, performance enhancement, etc.), these are not discussed here. Instead, the discussion moves to the issues of sustainability, and the choices facing society (see Sections 4.3.3 and 4.3.4).

4.3.2.4 Competitiveness

One of the elements of this ESF/COST Forward Look, and the entry questions, is competitiveness. Competitiveness can be viewed at different scales – individual enterprise, parent company, sectoral – as well as different geographic scales (domestic and international).

However, the term “competitiveness” does not have a universally accepted definition, and can capture many aspects of economic or financial performance. The broadest definition of competitiveness, such as in the European Commission’s competitiveness report, states that “Competitiveness is understood to mean high and rising standards of living of a nation with the lowest possible level of involuntary unemployment, on a sustainable basis” (European Commission, 2002). The

World Economic Forum (WEF) definition of competitiveness at a national or European level is "the ability of a country to achieve sustained high rates of growth in GDP per capita". For the impact on individual enterprises and industry (e.g., distribution), a more appropriate definition is the ability of an enterprise – and by aggregation a parent company and industry or sector – to sell its goods and services in both domestic and international markets, i.e., its ability to stay in the market at competitive prices. Competitiveness can also be defined as the ability of a business to constantly improve its productivity in generating differentiated goods to meet market demand, and to efficiently deliver those goods to the market, while simultaneously developing a customer base, or the ability of a business to maintain production and distribution costs to customers that are comparable to the cost of rival businesses, both in domestic and export markets. In addition, being competitive means having access to capital at a cost that is lower or, at worst, comparable to rival businesses.

The assessment of agricultural competitiveness is complicated by the subsidies, tariffs, etc. in place in Europe and in exporting countries. It is not possible to discuss these here. Instead a brief discussion of some of the issues affecting distribution is made below.

In relation to European distribution and logistics, the most important issue is in relation to transport costs. Transport costs include the cost of vehicles (which has been increased slightly by European environmental legislation), by fuel prices (again influenced by environmental legislation, but more recently due to rises in world oil prices), and by European transport policy. The major changes likely to occur in the future (see also Section 4.4) are in relation to carbon pricing and wider transport pricing, e.g., road user charging reflecting congestion costs as well as environmental external costs.

Any rises in prices could be passed on in the form of higher final prices (transferring costs to consumers) or absorbed by the distributor, thereby reducing profit margins. The economic consequences of an increase of such costs depend on the magnitude of the cost increase in relation to the total production costs, and the price-elasticity of the demand for the produced good. However, transport costs are a relatively small proportion of overall food costs, with the exception of a few denser "value" own brands, such as for example low-cost imported orange juice, and it is unlikely that competitiveness issues in the distribution sector will be the factor that changes the choice of supply chains.

4.3.3 What will be the sustainability issues that most affect the processing/distribution and packaging industry, and how?

4.3.3.1 Distribution

The previous section outlined how food transport has increased in Europe, and for European food supply chains. This has already led to a debate over the sustainability of food distribution, particularly in relation to global sourcing, often termed the "food miles" debate (see box below).

Food miles

The rise in food transport has led to increases in the environmental, social and economic burdens associated with transport. Concerns over these effects have in turn led to a debate on the sustainability of global food supply chains and distribution, captured broadly through the term "food miles". The term was first used around ten years ago in a report by the SAFE Alliance (now Sustain), which highlighted concerns over the negative environmental and socioeconomic impacts of increasing transport of food (SAFE Alliance, 1994). Food miles are simply the distance travelled by food from farm gate to consumer. They are generally measured as tonne kilometres, i.e., the distance travelled in kilometres multiplied by the weight in tonnes for each foodstuff. However, as outlined above, to actually capture the impacts of food miles, it is necessary to also consider vehicle kilometres, i.e., the sum of the distances travelled by each vehicle carrying food, as it is vehicles that actually generate environmental and social impacts.

While "food miles" primarily relate to transport, they have taken on a much wider definition in the debate on food chains and sustainability. The term is often used to reflect a wider set of social, environmental and economic issues associated with the change across the whole supply chain from agricultural production through to retail. This involves issues of downward pressure on farm-gate prices, the disappearance of local shops and detrimental effects on rural economies and farming communities, the increase in transport burdens, and the increasing dominance of major retailers. While food miles are not responsible for these changes, they are a potential indicator of these trends, i.e., the move towards more global sourcing is reflected in increasing food miles. A strong (NGO) movement therefore advocates that there is a need to increase the demand for food produced closer to the point of sale, often termed "local food", to strengthen the position of local suppliers and retailers, arguing that this would reduce food miles, as well as leading to other potential sustainability benefits to the local economy.

However, there are also many who disagree with this perspective. They typically argue that the current food supply system is tailored to meeting the needs of today's consumer, and that centralisation and consolidation of food production and retailing operations, and global sourcing, have led to lower prices that meet consumer expectations for a year-round supply. They also argue that improved transport logistics have largely offset the rise in vehicle kilometres, and that modern logistics operations are highly optimised. With respect to wider sustainability issues, this group advocates that local food production is unlikely to be as efficient (or as productive), that it could raise prices (or constrain choice) and would be counter to policy on a more liberal international trading system, having negative social and economic effects through reducing agricultural exports from developing countries.

Clearly the rise in food distribution will increase transport activity, and so increase the major environmental, social and economic burdens of transport. These are:

- Congestion;
- Accidents;
- Damage to infrastructure;
- Emissions, including greenhouse gas emissions (particularly CO_2) and air pollutants;
- Noise.

The combined effect of these effects is significant. As an example, the work in the UK estimated that the external costs associated with current food supply chains for the transport burdens above was £9 billion/year (Smith et al., 2005). In the UK, the concerns over food miles has led to the Government adopting a set of "food mile" sustainability indicators, and the UK Government tracks 1) urban food vehicle km, 2) HGV food tonne km, 3) air freight, and 4) CO_2 emissions from food transport (Defra, sa). Pretty et al. (2005) estimate that transport externalities (and other subsidies) would add some 12% to the costs of the current UK food basket.

However, it is also highlighted that the transport burdens vary with:

- The number of vehicle km (impacts above are caused by vehicles, not the food that is transported).
- The load factor, i.e., the efficiency of transport. The same effective impact will occur from one vehicle whether carrying 5 or 10 tonnes of food (per km), and so higher load factors (especially bulk commodity travel) can have low impacts, even though distances are great. This is why international shipping, which carries extremely large weights over very large distances, has relatively low impacts per tonne of food carried compared to other modes.
- Different vehicles and modes have different impacts. Due to European emissions legislation for example, a modern road vehicle will have lower emissions than an older one. Note that air transport has disproportionately large CO_2 emissions per tonne carried.
- Different steps in the food supply chain use different vehicles, with different load factors, and will be associated with different levels of impacts and even different types of impacts.

Thus, while a major food supply chain will have much longer transport distances involved, it will run with larger, more efficient and modern vehicles and have very high load factors. In contrast, local distribution networks are likely to be based on smaller light goods vehicles (less efficient for freight), running with lower load factors (and more empty running) and using generally older vehicles. While clearly a global supply chain will have a much higher total transport burden, the relative performance is at least partly mitigated by the above factors. The 2002 UK Transport Key Performance Indicator survey provides some evidence for this. "Tertiary" distribution (mainly local food service and wholesale delivery in small rigid vehicles) had roughly twice the energy-intensity of primary and secondary distribution in articulated lorries. The differential would be even wider for vans (under 3.5 tonnes). A move to local distribution is therefore likely to increase local food transport kilometres (and impacts), though it will reduce non-local transport. Additionally a move to lots of local producers using vans is likely to be made up of an older fleet, as these operators run less miles and so keep vehicles over longer lifetimes. There are other issues here as well. Does local food require less refrigeration, less wastage, higher on-shelf availability, etc.? If so, this could mean additional benefits; however, given that the major retailers operate on JIT, this may not be the case.

With respect to environmental issues, air quality has historically been of greatest concern in Europe due to the problems associated with acid rain. However, for road transport, a series of successive rounds of legislation, the Euro standards, have dramatically reduced the air pollution emissions from road transport vehicles. There do remain important air emissions from ships (notably sulphur emissions), though these look set to be tackled in the next round of European air quality legislation. Ambient noise is an increasing issue, with the EU Noise Directive now in place, but again noise levels have been reduced from goods vehicles in Europe. The key environmental issue is therefore greenhouse gas (GHG) emissions and climate change.

Carbon emissions

The fuel efficiency of goods vehicles has improved only modestly in recent years. As a result the rise in freight transport has led to a continued year-on-year increase in CO_2 emissions from the freight sector, and from food transport. In the UK, the Government (Defra) has a sustainability indicator of food transport CO_2 for the UK food supply chain and this reports that food transport-related CO_2 emissions increased by 19% between 1992 and 2004.

The rise in aviation for freight is a particular concern here. Aircraft have disproportionately large CO_2 emissions per kilometre travelled and there are also potential additional concerns over emissions at altitude. As an example, in the UK food supply chain, aviation is responsible for only 0.1% of the total food vehicle km, and 1% of tonne kilometres, but 13% of total food supply chain CO_2 emissions. Transport of goods by air produces between 40 and 200 times the CO_2 of shipping goods (FSA, 2004).

At the same time, the importance of tackling climate change has risen up the political agenda, notably through European proposals for a 20% reduction in EU GHG by 2020 (agreed at the Council Meeting on 8-9 March 2007) and proposals from the EC towards 2050 that "global emissions must be reduced by up to 50% compared to 1990, implying reductions in developed countries of 60-80%" (European Commission, 2007a). This is broadly consistent with the EU (Council of the European Union, 1996; 2004) aims to limit global temperature increase to 2 °C above pre-industrial levels to avoid severe impacts globally.

At an aggregate level, the CO_2 emissions from food transport are significant. Again using the UK data, the total CO_2 associated with food transport in the UK and overseas, associated with UK food supply, is just under 20 million tonnes a year. This is around 3-4% of total UK CO_2 emissions (though a slightly lower % of total GHG emissions).

Is this significant? Many have commentated that this number is low in relation to the total from food supply chains. Total emissions associated with UK agricultural production were around 7% in 2005. Emissions of methane and N_20 were around 44 Mt CO_2 equivalent. Total UK CO_2 emissions were 554 million tonnes and all GHG 654 million tonnes (NAEI, 2007). In addition to the emissions from agricultural production, there are also emissions from the food processing industry, the use of energy by consumers, etc., with many studies estimating the total food chain to be around 15% of emissions.

The important question is whether these emissions are sustainable, given EU emission reduction commitments. Allocated per capita, UK food transport chain emissions are some 0.3 tonnes CO_2 per person per year. This is ~ 3% of average per capita carbon emissions in the UK. However, compared to the long-term ambition, which requires us to achieve a long-term goal of 2-3 t CO_2/ per capita to achieve the 60-80% reduction, it quickly becomes apparent that this level of emissions might be a luxury, or require emission reductions in other activities as compensation. At the very least it would seem prudent not to further increase food transport CO_2 emissions through exacerbating the current trends towards greater import:export flows, increased use of aviation for food freight, etc.

However, in balancing the drive to address transport CO_2, it is important to recognise that GHG emissions also occur from the rest of the food supply chain. While it is often assumed that food transport is the dominant GHG impact of the food supply chain for exports, several studies have shown that this is not necessarily the case.

It is clear that there is complexity according to type of food and the location where it is produced. Food transport is only one consideration, and it is not always (or even usually) the largest. Food that is produced "locally" does not have lower GHG emissions per se, even though it involves less transport. As an example, it seems that growing food "locally" out of season can lead to GHG impacts that can offset the potential benefits of lower food transport on a life-cycle basis. Smith et al. (2005) considered the energy balance of UK tomatoes produced out of season in glasshouses vs. imported Spanish tomatoes. Producing food out of season in UK heated glasshouses had higher energy (and so CO_2 emissions) than growing and transport of imports from Spain (though note this can be reversed through use of Combined Heat and Power-CHP). Thus a move merely to replace imports with locally-produced food, without addressing seasonal production issues, might be counter-productive. In practice there is considerable variability and different studies can produce conflicting results. The results can be influenced by the choice of assumptions and according to system boundaries and GHG included. The better studies now recognise that there can be very strong variation between the same product lines, according to the exact production, the exact location, the variation across the season, etc. Milà i Canals et al. (2006), for instance, found that consumption of an EU-grown apple (in Europe) requires less energy than a New Zealand-grown apple, but that there is strong seasonal variation to this. In practice the difference varies according to when the apples are produced and when they are eaten.

These discussions have led through to a new and recent debate about the possibility of food carbon labelling[6]. Carbon (or more accurately GHG) foot-printing has an immediate role for companies in looking at their product portfolio and supply chains and helping them to reduce their GHG emissions. The same data might also lead to policy proposals, e.g., extending sectors into GHG trading, or ensuring a carbon price is internalised for food production and supply. It could also be used to inform consumer choice, though there is a debate whether a carbon label for consumers should be broadly based, i.e., to show differences between high and low carbon products (meat vs. vegetables), or product based (apple X is better than apple Y).

Finally, it is highlighted that over the past two or three years, the food miles debate has changed from a consideration of a broad set of environmental and social issues to the single issue of carbon. This means that other burdens are given less attention and that there is a risk that policy is likely to be directed towards a single goal, rather than considering a multi-attribute framework of sustainability. This is investigated more in the next section.

Sustainability

While the change in distribution has increased transport burdens, the issue of what this really means for sustainability is much more complex. In like-for-like systems, sourcing food from further away implies lower sustainability because of the additional transport burden. However, food systems are rarely like-for-like, and there are differences in terms of transport (mode, efficiency, etc.), but also wider issues in relation to other environmental, social and economic aspects across the entire food supply system. There is therefore a question about what to do with the information obtained on food distribution in shaping appropriate policy responses, and the overall sustainability of food chains.

Local production is not more environmentally friendly per se. Food that is produced close to final consumers will have a lower transport footprint. However, it does not automatically have any advantage over food produced elsewhere with respect to the rest of the food supply chain. Indeed, in some cases, large-scale production has arisen exactly because the local area is optimal for growing with respect to climate or soil type. The impact of food transport can therefore be offset if food imported to an area has been produced more sustainably than the food available locally. There is also a wider set of issues, beyond environment, that also alter the sustainability of a supply chain.

This means there can be systems with greater food transport that are more sustainable, just as there can also be local systems that are more sustainable. The reality is “it depends”. For example, local European production can lead to benefits to the local economy, particularly to rural economies from local production and direct multiplier effects. However, these must be contrasted against the potentially large development benefits, like poverty alleviation and attainment of millennium goals, from global trade for developing countries, providing commodity traps can be avoided, or local environment unsustainably degraded. Clearly a €that goes to a poor developing country farmer has much greater benefit than when it goes to a European farmer.

Global supply chains do allow lower prices for consumers, at least in theory. They also allow greater consumer choice. Both are potentially important in relation to the availability of fresh fruit and vegetables, which are important in relation to health objectives, especially relevant in the context of rising obesity levels in Europe. However, in turn, these price/health benefits must be balanced against the potential loss of freshness/nutritional value associated with shipping goods over long distances, i.e., over longer time periods.

What is “best”, i.e., what is most sustainable, is really determined by personal perspective. Because competing systems involve trade-offs, the “best system” is as much a moral and ethical view as a scientific one. As an illustration of this, take two extreme perspectives.

- Someone from a weak sustainability perspective, or a strong economic perspective, believes it is acceptable to fully substitute the trade-offs between environment, social and economic effects, and may well prioritise the development of international trade and associated developing country benefits, plus the lower prices this leads to, as the most beneficial option, perhaps with the caveat that environmental burdens from transport, e.g., externalities, are internalised. They are also likely to be highly critical of the current subsidies in place in Europe.
- Someone from a strong sustainability or precautionary perspective, i.e. someone who does not believe environment is a substitute for economic development, will take a different view. They are likely to take a strong precautionary stance on the issue of climate change, and prioritise this above all other aspects, advocating local production.

6. See the Oxford Symposium – http://www.ukerc.ac.uk/TheMeetingPlace/Activities/Activities2007/0705UKERCTescoCLSymposium.aspx

Interestingly, this is now leading to conflicts between groups that would have historically been closely aligned. Take the example of the UK NGOs. An intense debate has arisen, started by the Soil Association, an organisation with a strong environmental perspective, which launched a consultation on removing the organic certification from air-freighted food. This triggered a strong criticism from the development groups, e.g., Oxfam, which have a strong social perspective, and which argue that this trade is linked to livelihoods in Africa, and that removing the certification would lead to real impacts on very vulnerable groups. In practice these debates are even more complex. Taking the example above, there are wider sustainability issues with developing country production: for example, whether it is advisable to produce water-intensive crops in areas of drought; whether intensive agriculture for exports leads to soil degradation or impacts upon local biodiversity or essentially ecological services; or whether economic growth and development are sustainable, etc.

Similar conflicts can be seen in Government too. On one hand, most Government treasury departments advocate greater trade, not least because in the EU-15 agriculture is a low value-added sector, with high labour demands, and resources can be more usefully directed towards economic growth in other areas. At the same time, most European countries, and the EU as a whole, are setting ambitious GHG reduction targets. Greater levels of imports from developing countries will of course mean higher transport CO_2 emissions.

The discussion indicates that these wider environmental, social and economic issues are complex and very system-specific. Consideration of these effects does not lead to an absolutely clear case for a move to either higher or lower food miles systems.

The choices facing society are therefore extremely complex.

4.3.3.2 Packaging

The sustainability issues of packaging are simpler and less contentious than for distribution, though there are some conflicting areas. The use of increased packaging leads to an increase in resource use and associated environmental burdens, and also generates additional waste, again with associated environmental burdens.

The historic concerns over the rise of packaging across society, and on the waste hierarchy (minimisation, re-use, recycling, and improving final disposal), meant that in 1992 the Commission came forward with a Proposal for a Council Directive on Packaging and Packaging Waste. This was adopted in 2004 (European Parliament and Council, 1994). The Directive aims to harmonise national measures in order to prevent or reduce the impact of packaging and packaging waste on the environment and to ensure the functioning of the Internal Market. It contains provisions on the prevention of packaging waste, on the re-use of packaging and on the recovery and recycling of packaging waste.

Through innovation, there has been some reduction in the weight of individual items of packaging with the result that most bottles, jars, cans and plastic containers are now lighter than they were before 2000. As an example, in the UK, since the introduction of the packaging regulations, and their recovery and recycling targets, there has been a significant increase in the level of packaging waste recovery, some 20% since 1999. In 2006, the recycling rate for packaging waste stood at 56% (Defra, 2007).

More recently, the issues of packaging and waste have resurfaced in relation to sustainability. The area of sustainability and resource use is very broad, and includes a number of different elements. The area can be split into two broad categories:

- Natural resource protection, i.e., preventing damage to the natural resource base. This recognises that the natural environment is key to the functioning of the planet, and that the quality of air, water and soil is key to the health of both the natural and human environment. It also recognises that economies depend (directly and indirectly) on ecosystems. Damage to the natural environment, as can arise when natural tolerance levels are exceeded, has wide ranging impacts. These effects occur from the pollution burden associated with all activities.
- Sustainable consumption and production. This is a broad term that aspires to change the way we design, produce, use and dispose of the products and services, so as to live within the resources available, to achieve more with less. It recognises that historic economic growth has not considered the long-term sustainability in relation to natural resource scarcity, or the potential limits to growth that this may have. It can refer to the over-use of resources, with scarcity concerns, e.g., fossil fuels, minerals, water, land, natural resources and the potential physical impacts this can have, as well as the wider health and economic impacts. Note that the issues relate both to renewable (e.g., natural ecosystems) and non-renewable (e.g., fossil fuel and mineral) resources.

In 2005, the EC proposed its Thematic Strategy on the Sustainable Use of Natural Resources (European Commission, 2005). The objective of the strategy is to reduce the environmental impacts associated with resource use and to do so in a growing economy. This recognises that the sustainable use of resources, involving sustainable production and consumption is hence a key ingredient of long-term prosperity, alongside improved resource efficiency. The aim is for Europe to develop a long-term strategy that integrates the environmental impacts of using natural resources, including their external dimension, i.e., impacts outside the EU, including on developing countries, in policy making, and is part of the wider EU Sustainable Development Strategy (SDS). The overall objective is to reduce the negative environmental impacts generated by the use of natural resources in a growing economy. There are also individual policies in specific areas.

One of the major elements of the SDS is the identification of Sustainable Consumption and Production (SCP) as one of the key challenges, and the SDS sets the aim to "promote sustainable consumption and production by addressing social and economic development within the carrying capacity of ecosystems and decoupling economic growth from environmental degradation". In relation to food packaging this does involve some issues with respect to the balance of primary and secondary packaging, and some trade-offs against the competing functions of packaging, i.e. the list above, for example, in relation to the need to ensure food safety whilst reducing packaging, or ensuring that food wastage rates do not rise as packaging is reduced or lightened. In some cases, packaging may reduce environmental impacts elsewhere in the food chain, and can lead to lower waste than unpackaged food (INCPEN, 1996).

For packaging, the sustainability issues relate to the need to be more efficient and reduce burdens. This includes moving to minimise resource use, improve recycling or reuse, or use smarter materials like recyclable or degradable material, and to improve waste management. Progress has been made here, but more can be done.

4.3.4 Choices facing society at large

4.3.4.1 Geographical production and distribution

There are many competing priorities that will shape the future geographical production and distribution of food, including economic, environmental, social and political aspects. These are outlined in relation to future trends in Part B. However, it is clear that society does face a serious, and complex, choice in relation to distribution, as part of the wider debate about production and supply chains.

The previous discussion points to a situation where the current food distribution system has emerged to meet a changing supplier network with more influential retailers, to meet changing consumer demands towards convenience foods and to react to a changing global market in respect of the trade of food, particularly with the emergence of new large players.

The relationship of food transport to sustainability is complex. It is established that the transport of food has significant direct environmental, economic and social impacts. Therefore, in like-for-like systems, where food supply chains are identical except for transport distance, reducing food transport will improve sustainability. However, food chains are rarely similar and there are usually differences between food supply systems which often involve trade-offs between various environmental, social and economic effects. These must be taken into account when considering sustainability.

In some ways, the difficult choices facing society in Europe today might be outside our control, i.e., the removal of global trade barriers will change production and distribution whether we like it or not. Nonetheless, consumers can shape the degree of future trends, for example, through their purchasing decisions, especially if these are accompanied by consumer choice as advanced by retailers. In this context, society should include business as well as individuals.

However, it is by no means clear what the optimal choice is for consumers or society more generally. It depends on the perspective that is taken, and whatever is chosen will involve compromise. If the aim is towards narrow European or domestic producer self-interest, then systems that move away from the current global supply trends might seem appropriate. If the aim is merely the consideration of a precautionary approach to global climate change, the ultimate aim might appear similar. The convergence of these two perspectives has already led to an alliance of environmentally-concerned NGOs and domestic producers in the UK, advocating a return to regional or domestic production. However, a closer examination reveals that these groups actually have competing objectives. The NGOs are concerned with environment, the producers are concerned with protecting/increasing market share and, some have argued, looking towards protectionism. Ultimately their goals must conflict. Taken to its logical extreme, localised sourcing will be counter-productive for larger local producers, who are currently advocating local food, as it will reduce patterns of inter-regional and international trade. Local producers will therefore lose sales to more distant customers/exports, who in turn are more local to their local markets. This will often not be offset by the growth in local demand, in which case the level of production will decline.

If the aim is to more global social equity and development, e.g., achievement of millennium goals, then the optimal choice might be to encourage good trade with developing countries. Ideally, development in developing countries should be advanced through growth and exports that do not rely on the overexploitation of natural resources, and that do not lead to potential conflicts between domestic needs and the potential for export revenue. This would mean alternatives to agriculture for advancing development. However, the reality is that agricultural production is a relatively easy way for developing countries to produce an export stream. As outlined earlier, there are, however, many potential pitfalls in such reliance.

The questions facing society are therefore associated with the most complex and difficult challenges facing the world today – the issue of climate change – and the issue of global development and equity. Not surprisingly, consumers often find conflicting messages and while there is an increasing mood to use consumerism as a means for change, there is an emerging view that in many cases apparently "ethical" or "environmental" choices can lead to detrimental outcomes (The Economist, 2006).

Is it possible to reduce these issues to a simple message for consumers? Some commentators have suggested sustainability check lists for food. Some of these are overtly biased, for example, from domestic trade organisations. All of them are dictated by the perspective of the organisation that collates them. One of the better examples is included below, based around a strong environmental perspective associated with CO_2 reduction. Someone who had a strong social perspective would draw up a very different list, with competing priorities, reflecting their trade-offs. Anyone who says they know "what is best" is merely expressing their own personal perspective.

Consumer guides. An example for eating to reduce your carbon footprint.

1. Change the balance of what you eat (less meat and dairy, "lower down" on the food chain).
2. Choose seasonal field-grown foods (require less storage, heating & transport).
3. Do not eat or purchase certain foods (including foods that are hot-housed or those that are air-freighted).
4. Reduce your dependence on the "cold chain" (get rid of the second freezer, choose less processed robust foods and do more frequent non car-based shopping).
5. Waste less food (improve your "food turnover" to eat what you buy sooner and reduce wastage).
6. Cook more efficiently (cook for more people and for several days at a time, use the oven less frequently).
7. Redefine your ideal for quality (be willing to accept variability in quality and supply).

(Source: Tara Garnett from the Food Climate Research Network. Presented at 2007 GreenPower conference. http://www.climateresponseblog.com/index.php/page/2/)

Further examples of the trade-offs are included in Appendix 1.

In conclusion the key choices facing society are:

1. What should the priority be? Is environment more important than development? The current priority seems to be swinging dramatically towards climate change, i.e., that reducing GHG from food should be prioritised above all other sustainability issues. However, it is also important to recognise that CO_2 from transport is only one part of the overall food supply chain and that shorter supply chains do not always lead to lower GHG across the food life-cycle, and are not always more sustainable.
2. Whether to advocate reduced distribution and supply chains as a result? This would effectively mean a move back to more local food, less global trade and shorter supply chains. It is doubtful if this is really possible given the state of international trade, and it would be controversial if achieved through protectionism though it might be justified on the basis of carbon. As an example, it could be legitimate to argue that imported goods should "pay" the price of the embodied carbon emissions associated with production and transport, and it is possible to see routes (e.g., through trading schemes) where imports

could be made to pay effective carbon tariffs. As an alternative, can society initiate this change through purchasing decisions? What would a large-scale move to local sourcing actually mean for consumer choice, prices, etc.? Note there is also a potential choice for retailers here, in respect to their position of power over society and their corporate responsibility.

3. Whether to move away from year-round supply? Much of the move towards global sourcing has arisen because of this trend. However, what are the effects on consumer choice when products are no longer available year round, or the health effects in relation to availability of fresh fruit and health benefits? Are consumers prepared to accept this trade-off?
4. Whether such a move is acceptable, given the likely impacts on international trade with developing countries, particularly where that trade can be demonstrably linked to other sustainability benefits, e.g., through ethical systems of trade? What does local food mean for developing importers? Is it legitimate or ethical for the EU to reduce potential export revenues and growth opportunities? Is it equitable for someone in the EU, with a per capita carbon footprint of almost 11 tonnes CO_{2eq} per year, to avoid African imports because of food transport CO_2, when the average sub-Saharan African has per capita emissions well under half this (WRI, 2008)? Where international trade does take place, there is an additional issue on how to stop unsustainable resource use and environmental damage.
5. Whether to simply let the market decide, with the caveat that there should be appropriate price signals to internalise external costs such as CO_2, but also economic ones such as congestion?
6. How much, and what sort of information, to provide to consumers? Whether to recognise the complexity, or just provide an over-simplistic message, and if so, what should the message be? If this information is to be provided by labelling, what form should this take?
7. Whether consumers are best placed to make these complex decisions anyway? The issues here involve complex inter-generational and intra-generational equity with inequality between regions in the case of development, and between regions and generations in the case of climate change. Individuals are notoriously bad at making these types of trade-offs due to narrow self-interest and these sorts of decisions might be better handled by Government.
8. What are the real implications for local producers and production in the EU? As mentioned earlier, taken to its logical extreme, localised sourcing is likely to be counter-productive to many (producers) as it reduces patterns of inter-regional and international trade. Local producers will therefore lose sales (exports). European producers would be more susceptible to these changes, given the major export opportunities are going to be in the developing countries, especially China and India due to population size and development. Would it not be contradictory and hypocritical to prevent imports on the grounds of environmental concerns, at the same time that European producers target major emerging export opportunities overseas?

None of these are simple choices.

There are also inter-related issues on food cultures and provenance, as discussed in the following paper, strongly linked to the issues around convenience food and choices.

4.3.4.2 Packaging

For packaging there are some choices for society, which involve trade-offs. Many of these are linked to the drivers on food supply chains above, i.e., longer food chains require more packaging, to minimise damage and to extend product life. The key choices facing society are:

1. Whether society is prepared to accept the trade-offs that are likely to arise from less packaging? This might involve, for example, potential compromise on food safety standards, or reduced product life-time. It could also involve a move to less convenience food. The latter point is perhaps the most difficult issue facing modern European society in relation to packaging. Other drivers (as outlined above) are leading to a rise in convenience foods (demographics, lifestyle changes, etc.). With better information, consumers could make more sustainable and healthier choices with more fresh food, which would have potentially important links with EU health policy and the aims to reduce obesity. Are consumers prepared to make this change? Is it the role of Governments to try and force this change, or is this interfering with personal choice?
2. There are some potential trade-offs that could potentially arise with less packaging. Packaging does have an important role in minimising damage to food in the supply chain, and less packaging may actually lead to greater damage rates. Similarly, moves to reduce packaging could reduce product life-time, which again could lead to greater wastage rates for food. The issue here is that there is a need to consider outcomes across the entire food cycle from production through to consumer, to avoid potential perverse effects.

3. There are some issues in relation to waste disposal. These are linked with wider issues of waste management and the waste hierarchy, e.g., whether consumers are prepared to accept greater incineration use, whether they might be prepared to accept waste charging and fiscal instruments as incentives, to accept greater levels of recycling activity, etc.

Part B: Future developments and research priorities

4.3.5 Future developments

The second part of this paper has considered the likely future developments for packaging and distribution. It has considered the potential changes likely to be important. It has also used the project scenarios to investigate the possible different outcomes.

The distribution of food will be affected by European production and trade, which in turn is related to European agricultural reform. European agriculture (in the EU-15) is characterised by high productivity levels, i.e., a relatively high production level per production factor unit, and this is expected to transfer to the EU-10, along with structural changes which will increase the competitiveness of this region. A growing influence of the EU-10 would mean greater potential flows across Europe, i.e., a greater or at least different pattern of distribution. The paper on production (Section 4.1) includes a discussion of the issues affecting European production and so these are not repeated here.

However, food distribution will also be affected by international production and trade, and international agreements. There are forward-looking assessments of agricultural commodity markets (EC, 2006). These predict dramatic changes, for example, because of changing reforms, but also changes in the world's three big agricultural players, namely Brazil, India and China. Brazil has seen the most significant agricultural market developments, with dramatic growth in soybean, beef, pork, poultry, and sugar, though there remain questions whether it can maintain this growth and if not, how world market prices may change. China has increased its imports for these same commodities. With future increases predicted in Chinese demand, can these be met, and in turn how this might affect world prices? The future trends in India are less certain, but demand is growing very rapidly and therefore India may not remain a net exporter for long.

There have already been major changes in world food prices from climate change mitigation, and the drive towards biofuels. These have the potential to have far-reaching consequences on agricultural production. It is also important to stress that distribution of agricultural fuel products, e.g., biofuels, will itself lead to very important issues. While production will increase in Europe, the strongest growth in overall biofuel production is expected in Brazil and the US, though there are also good prospects in Asia. EU imports are set to increase following the implementation of the biofuel legislation.

Climate change itself will also affect production. The IPCC 4th Assessment Report has recently been published (IPCC, 2007). Up to relatively modest levels of climate change, perhaps 3-4 °C, global production is affected mostly through the distribution of production, rather than the total production. There is a strong pattern of agricultural winners and losers. Taking Europe as an example, greater stresses will become apparent in southern European (Mediterranean) and southerly eastern European countries with a changing climate, due to the larger climate signals that these areas receive, with higher than average increases in temperature for Europe, and also greater reductions in summer water availability, as well as likely increases in drought (Alcamo et al., 2007). This will reduce yields. In contrast, the agricultural systems in Western Europe are considered to have lower sensitivity to climate change, and the modelling predictions show likely opportunities, like yield increases and wider agricultural crops, for Northern Europe, at least initially. However, as climate change continues, negative impacts are likely to outweigh its benefits.

It should be highlighted that the ability to adapt to climate change is strongly related to income. Therefore adaptation, which can be defined as policies, practices, and projects with the effect of moderating damages and/or realising opportunities associated with climate change (EEA, 2006), is strongly dependent on development. Countries that are at lower levels of development will be more affected by the impacts of climate change, and have less capacity to adapt. The implication of this is that it is possible to exacerbate climate change impacts by reducing development opportunities.

There are other issues in relation to consumer choice, relating to emerging differentiation by organic, ethical, welfare concerns, but these are discussed in the next paper.

It is worth reporting on recent projections for Europe in 2020 that have an influence on distribution and packaging (Scenar, 2007). Demographics such as income, double-income households, and household size will continue along the same trends, influencing food consumption towards convenience, pre-prepared and processed food, and quality/luxury products. There are, however, likely to be strong differentials between different groups, both in relation to age and socioeconomic circumstances.

4.3 Current trends in distribution and packaging

The ageing population is contributing strongly to the trend in healthy products, for older adults have higher concerns for health and well-being and are looking for healthier options. With more time available, they prefer buying fresh ingredients that they then cook. The socially deprived are likely to be more interested in the price of food. These scenarios also predict lifestyle forces will continue in the same directions: reduced time budget, more individualised behaviour, increasing flexi-eating and snacking, and strong social influences such as the popularity of eating out/trying new foods. These factors will continue the trend towards convenience food. They are likely to increase the trends towards more distribution and potentially also more packaging. EEA projections (2005b) show that packaging waste volumes are likely to continue to increase by about 50% between 2000 and 2020 in the EU-15, though at a slightly slower rate than GDP. However, it is unclear how food packaging trends might be reflected in this overall total.

As for distribution itself, the most important changes are likely to come from a focus on "getting the prices right". This recognises the external costs of transport, and seeks to internalise these through appropriate pricing signals. This is already leading to the emergence of road pricing/congestion charging in many member states. It is also likely to see the internalisation of the price of carbon, either through direct taxation, through entry into emission trading schemes, or through other actions, even direct legislative action, for example through emission limits for vehicles. The most important effect is likely to be an increase in transport costs.

There are already trends towards cleaner vehicles in Europe with successive rounds of legislation on environmental (air quality) emissions. There has also been a more general move to modal switch, though for food transport in Europe this is likely to be much more limited. A range of logistical improvements will occur, which should all help to improve efficiency.

Finally, the study has considered the ESF/COST Forward Look scenarios, and the potential for distribution and packaging, shown below.

Forward Look Scenario Assessment

Fast Forward	**Pause**
Continued economic globalisation increases food trade and the trend towards global supply chains. Distribution and packaging increase as with recent trends (more of each). Some adjustments may occur as a result of carbon pricing (i.e., towards greater transport efficiency) but is unlikely to influence trends significantly, especially under a global trading scheme (carbon reductions in the transport sector are expensive, so as long as emission reductions can be bought in other sectors, then transport costs should not rise prohibitively).	Concerns initially reduce global supply chains, at least until global verification comes in. There are increases in distribution, though much less pronounced than for fast forward. A focus on safe food could likely increase packaging.
Play	**Rewind**
The drive towards sustainability and the "Tuscany agriculture" reduces global supply chains, and global distribution, as well as packaging, though less severe than rewind.	Heavy tax penalties on long distance supply chains penalises global food distribution. The focus moves to safe, fresh foods, locally grown and appropriate for the season. Packaging likely to reduce heavily, driven by the same sustainability concerns.

4.3.6 Research priorities

The information in the previous sections highlights the importance of this ESF/COST Forward Look, particularly the questions facing society outlined in Section 4.4, and the possible outcomes that will arise from these choices. Indeed, the research undertaken in the next few years could dramatically shape the direction that society will move towards in the future. To reflect this, a number of the most important research needs are identified, including:

- Research to measure and monitor local and global food supply chains, including the distributional systems and activity levels split by mode, import and export flows, etc. The important issue is to move from a data system that focuses only on Europe, to one that looks at how Europe influences global production and distribution in supply chains, i.e., to non-EU data. This is essential to understand and act on these issues. Some additional analysis is needed in areas typically omitted at present, i.e., in exact energy use in refrigeration in transport. As a general statement, the information on shipping and its impacts remains poor. There is a need for improved estimates of average vehicle loads for air and sea transport. Estimates of transport overseas are very crude and could be refined.
- Research to look at the environmental, economic and social trade-offs between different local and global supply chains. There is lots of anecdotal information that highlights concerns, but in many cases, the evidence that does exist is limited, for example, only considering environment issues but not potential social trade-offs. A comprehensive analysis, and most importantly an independent assessment, of the potential trade-offs is needed, assessing and balancing European and global effects, across environmental, social and economic areas. This should be advanced through practical research work and case studies, as well as top-down analysis.
- By combining the two areas above, to look at the policy implications and appropriate responses in this area, through robust and transparent policy/scenario appraisal. The research could investigate the effect of a switch to more local or regional sourcing. A study of potential policies to reduce the impacts of food transport would help to examine the advantages and disadvantages of different policies, and design a suitable integrated framework. This could include areas such as improving logistics, internalising the social costs of transport, consumer awareness, and policies to improve the wider sustainability of the food chain.
- Further work to reduce household food and packaging waste through light weighting, innovative designs to reduce packaging and more reusable packaging seem sensible priorities, as well as analysis about the implications of changes in primary and secondary packaging across different supply chains (though of course, very large reductions can also be made by reducing food waste from the household).
- Further work to investigate the trade-offs involved in action to reduce packaging. This would involve the potential issues in relation to food safety, product life-time, etc. to ensure that any policy leads to the desired policy outcomes rather than leading to other waste arising in other parts of the supply chain, for example from greater levels of food damage.

Acknowledgements

This paper draws on previous collaborative work undertaken, particularly the Food Miles study undertaken for Defra (see Smith et al., 2005). I highlight the excellent contribution of Professor Alan McKinnon of Heriot Watt University as part of this Defra work, and Alan's original input has been invaluable in collating this rapid Forward Look. Any errors or inaccuracies are, however, my responsibility.

References

Alcamo, J., J.M. Moreno, B. Nováky, M. Bindi, R. Corobov, R.J.N. Devoy, C. Giannakopoulos, E. Martin, J.E. Olesen, A. Shvidenko (2007). *Europe*. Climate change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (Eds). Cambridge University Press, Cambridge, UK. pp. 541-580.

Council of the European Union (1996). 1939th Council Meeting. Luxembourg. 25 June 1996.

Council of the European Union (2004). 2632nd Council Meeting. Brussels. 20 December 2004.

Defra (sa). *Sustainable farming and food strategy – indicator data sheet*. http://statistics.defra.gov.uk/esg/indicators/d410_data.htm.

Defra (2007). *Waste strategy*. http://www.defra.gov.uk/environment/waste/strategy/strategy07/pdf/waste07-strategy.pdf

Department for Transport (2003). *Transport of goods by road in Great Britain 2002, a national statistics publication*. http://www.transtat.dft.gov.uk/tables/2003/csrgt/csrgt.htm.

Department for Transport (2001). *Focus on personal travel*. www.dft.gov.uk.

DfT (2007). *Transport statistics bulletin*. Road Freight Statistics 2006. http://www.dft.gov.uk/162259/162469/221412/221522/222944/285840/01_Road_Freight_Stats_2006_1.pdf

EC (2006). *Agricultural commodity markets past developments and outlook February 2006*. http://ec.europa.eu/agriculture/publi/commodity/rep2006_en.pdf. Also note the OECD-FAO Outlooks.

The Economist (2006). "*Good food?*" 381 (8507): 71-73.

EEA (2005a). *Effectiveness of packaging waste management systems in selected countries: an EEA pilot study*. Copenhagen, Denmark.

EEA (2005b). *Household consumption and the environment*. Copenhagen, Denmark. http://reports.eea.europa.eu/eea_report_2005_11/en.

EEA (2006). *Vulnerability and adaptation to climate change in Europe*. EEA Technical report No 7/2005. ISSN 1725-2237.

EEA TERM (2001). http://themes.eea.europa.eu/Sectors_and_activities/transport/indicators/demand/TERM13,2001/Freight_transport___TERM_2001.pdf.

Europa (2004). *Food contact materials – EU legislation*. http://ec.europa.eu/food/food/chemicalsafety/foodcontact/eu_legisl_en.htm.

European Commission (2002). *European Commission's competitiveness report*. http://www.tescocorporate.com/images/annual_review_and_sfs_2007_0.pdf.

European Commission (2005). *Thematic strategy on the sustainable use of natural resources* (COM(2005) 670 final). http://ec.europa.eu/environment/natres/pdf/com_natres_en.pdf

European Commission (2007a). *Limiting global climate change to 2 degrees Celsius: the way ahead for 2020 and beyond*. COM (2007) 2.

European Commission (2007b). *The agricultural situation in the EU Report 2005*. http://ec.europa.eu/agriculture/publi/agrep2005/agrep2005_en.pdf

European Parliament and Council (1994). *Directive 94/62/EC of 20 December 1994 on packaging and packaging waste*.

Eurostat (2007). *External and intra-European Union trade monthly statistics*. Issue number 10/2007.
http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-AR-07-010/EN/KS-AR-07-010-EN.PDF

FAW (2000). *Lifestyles, future technologies and sustainable development*. Schauer, T. Research Institute for Applied Knowledge Processing. Ulm, Germany.

FAO (2003). FAOSTAT database. Food balance datasheet for the UK for the year 2000, see http://apps.fao.org.

FAO (2005). FAOSTAT Agriculture tables on food supply. http://faostat.fao.org/faostat/collections?subset=agriculture.

Food Standards Agency (2004). *Consumer committee: sustainable development*. http://www.food.gov.uk/multimedia/pdfs/conscommd03604.pdf

HMT (2004). *Trade and the global economy: the role of international trade in productivity, economic reform and growth*. Her Majesty's Treasury. http://www.hm-treasury.gov.uk./media/5/1/17B2B51A-BCDC-D4B3-1A234C0A43505CFC.pdf

INCPEN (1996). *Environmental impact of packaging in the UK food supply system*. http://www.incpen.org/pages/data/Foodsupply.

INCPEN (2001). *Towards greener households — products, packaging and energy*. INCPEN, London, UK.

INCPEN (2003). *Packaging reduction — doing more with less*. London. http://www.incpen.org/resource/userdata/ipu/PackagingReduction2003.pdf.

INCPEN (2005). *Waste management – the facts*. http://www.incpen.org/pages/userdata/incp/wastemanFS.pdf

IPCC (2007). *Climate change 2007: impacts, adaptation and vulnerability. Summary for policymakers*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Summary approved at the 8th Session of Working Group II of the IPCC, Brussels.

McKinnon, A.C. and A. Woodburn (1996). Logistical restructuring and freight traffic growth: an empirical assessment. *Transportation* 23: 2.

Michaelis L. and S. Lorek (2004). *Consumption and the environment in Europe – trends and futures*. Danish Environmental Protection Agency, Environmental Project No. 904 2004, Copenhagen, Denmark. http://www2.mst.dk/common/Udgivramme/Frame.asp?pg=http://www2.mst.dk/Udgiv/publications/2004/87-7614-193-4/html/kap08_eng.htm

Milà i Canals, L., G.M. Burnip and S.J. Cowell (2006). Evaluation of the environmental impacts of apple production using Life Cycle Assessment (LCA): case study in New Zealand. *Agriculture, Ecosystems & Environment* 114: 226-238.

NAEI (2007). *UK emissions of air pollutants 1970 to 2005*. UK Emissions Inventory Team, AEA Energy & Environment: C.J. Dore, J.D. Watterson, T.P. Murrells, N.R. Passant, M.M. Hobson, S.L. Choudrie, G. Thistlethwaite, A. Wagner, J. Jackson,

Y. Li, T. Bush, K.R. King, J. Norris, P.J. Coleman, C. Walker, R.A. Stewart, J.W.L. Goodwin, I. Tsagatakis, C. Conolly, M.K. Downes, N. Brophy and M.R. Hann
http://www.airquality.co.uk/archive/reports/cat07/0801140937_2005_Report_FINAL.pdf

NEF (2007). *Chinadependence*. The second UK Interdependence Report. New Economics Foundation.
http://www.neweconomics.org/gen/uploads/fmq2gmn5w2dn2qemwoor0m4505102007192709.pdf

Pretty, J.N., A.S. Ball, T. Lang and J.I.L. Morison (2005). Farm costs and food miles: An assessment of the full cost of the UK weekly food basket. *Food Policy* 30: 1-19.

SAFE Alliance (1994). *The Food Miles Report: The dangers of long distance food transport*.

Saunders, C., A. Barber and G. Taylor (2006). *Food Miles – Comparative Energy/Emissions Performance of New Zealand's Agriculture Industry*. Research Report No. 285. July 2006. Agribusiness & Economics Research Unit. Lincoln University.

Scenar (2007). *Scenar 2020 – Scenario study on agriculture and the rural world*.
http://ec.europa.eu/agriculture/publi/reports/scenar2020/index_en.htm

Smith. A., P. Watkiss, G. Tweedle, A. McKinnon M. Browne, A. Hunt, C. Treleven, C. Naish and S. Cross (2005). *The validity of food miles as an indicator of sustainable development. Report for Defra*.
http://statistics.defra.gov.uk/esg/reports/foodmiles/default.asp.

Tesco (2007). *Annual report*.

War on Waste (2007). Local Government Association.
http://www.lga.gov.uk/Documents/foodpackagingstudy%20full%20report%20wave%201.pdf

WRI (2008). *Climate Analysis Indicators Tool (CAIT)*.
http://cait.wri.org/Also available at:
http://en.wikipedia.org/wiki/List_of_countries_by_greenhouse_gas_emissions_per_capita

Appendix 1.

Examples of trade-offs between UK local and non-local food

ECONOMIC ISSUES	
Benefit of local food	**Potential trade-off**
Initiatives to promote local food can have important benefits for rural communities. For example, farmers' markets enable closer links between producers and their markets, bring life to town centres, and provide a bigger share of the retail price for producers. Local food also offers a potential for farmers to increase the value added of operations, building on the public's enthusiasm for locally-produced food or food with a clear regional provenance. Potential benefits could be further enhanced through local processing. More of the money spent in local shops or directly by local farmers is passed to the local community than via supermarkets (i.e. reduced "leakage"), e.g. with studies showing local multiplier effects from local organic "box scheme" 2.5 times greater for the local area than for supermarkets. Studies show locally-produced food has a higher labour requirement than mass-produced food. In the UK, farms under 100 acres provide five times more jobs per acre than those over 500 acres. Another study showed farms producing food which is sold locally employ an average of one additional employee per farm. Although many rural communities are prosperous, there are serious problems in some communities. Eight out of the 10 counties in England with the lowest GDP per capita are rural, indicating the potential for significant distributional benefits.	Taken to its extreme, localised sourcing could be counter-productive, as it will reduce patterns of inter-regional and international trade. Local producers will therefore lose sales further away (outside the local area) to more distant customers who are nearer to their local markets. This will not necessarily be offset by the growth in local demand, in which case the level of output could decline. For local food to succeed, the sector needs to be able to add market value with minimal inputs at maximum efficiency. Agriculture is a low value-added sector. There may be local rural benefits from increasing local food, but this may not represent a good use of local resources, especially for production methods such as organic which have high labour intensity. Moreover, these jobs are usually low wages (total income from farming per full time equivalent worker in 2002 was £11 000, compared to a national average per capita income of £23 000). Some of these communities may have surplus labour, but others may have tight labour markets – in fact rural areas generally have a lower level of unemployment than urban areas.

ENVIRONMENTAL ISSUES	
Benefit of local food	**Potential trade-off**
Local food producers are more likely to be certified organic, make more use of local suppliers, make more use of waste reduction practices and introduce more traditional breeds and varieties than non-local enterprises. Interest in local food has been fuelled by growing awareness of some of the potential negative impacts of mass-produced food. Some consumers are now becoming more interested in tracing the origin of their food, and place increased confidence in local foods which can be traced to a specific farm – leading to increased consumer confidence.	There is no reason, per se, why local food should be better than non-local food. It may be that the balance of environmental impacts differs between large and small farms (e.g. use of intensive farming techniques) but the evidence is unclear. To illustrate, large-scale agricultural production is optimised, with producers growing in areas that are most suitable in terms of climate, land type, etc., using large-scale production techniques. Local production may be more resource-intensive. Local food grown out of season can have higher environmental burdens, e.g., growing tomatoes in glasshouses out of season and associated energy use.
Local supply offers the potential to reduce packaging, reducing waste arising from the food supply chain.	Local processing may lead to greater impacts because of the smaller scale of production and resource inefficiencies. Larger processors are more likely to be captured by emissions legislation relating to GHG, air pollutants, waste production, and have greater drivers for energy efficiency improvements. Local box schemes do not always offer consumer choice, and there have been issues raised about the amount of wastage at the home.
Local food supply chains can reduce the food transport km (food miles) associated with the food distribution chain. By avoiding the wider sourcing distance, plus routing via RDCs, it is possible for a much more direct food distribution route. This has benefits in reducing the environmental and social impacts of food transport (greenhouse gas emissions, air pollutants, noise, congestion, accidents and infrastructure damage). A shorter supply line and order lead time also means less need for temperature-control in transit. Overall, if lead times are shorter for locally-produced food, there should be less inventory, less refrigeration, less wastage, higher on-shelf availability, etc. Given the supermarket retailers' quick response/JIT replenishment systems, this hypothesis may not hold.	A very large proportion of "food miles", as measured by vehicle km, is undertaken by consumers travelling by car (47% of UK food vehicle kilometres, and 13% of total CO_2 from food transport). A move to greater sourcing of local food could alter the distance consumers travel to buy food – in some cases it could increase distance, e.g., for travelling out to rural farmers' markets. Also trips to buy local produce will often be in addition to trips to the supermarket as grocery purchases will be displaced by local produce. Supermarkets run extremely efficient logistical operations, with very high load factors, which transport large bulk deliveries of multiple goods to retail outlets. A move to more local sourcing will increase the food transport km by smaller, less efficient vehicles (e.g., local van deliveries). This will increase local vehicle km – and so could increase congestion. The 2002 Transport KPI survey found "tertiary" distribution (mainly local food service and wholesale delivery in small rigid vehicles) had twice the energy-intensity of primary and secondary distribution in articulated vehicles. The differential would be even wider for vans (under 3.5 tonnes). Moreover, supermarkets continually update fleets, using modern vehicles of recent Euro standards – a move to lots of local producers using vans is likely to comprise an older fleet.

SOCIAL and CONSUMER ISSUES	
Benefit of local food	**Potential trade-off**
Local food is associated with freshness and greater nutritional value, due to minimal loss during storage and transport. Several vitamins and minerals are depleted during storage and transport of food, especially vitamins C and A. Long transport times (e.g., when shipping produce from New Zealand) may require use of chemical coatings to preserve the produce. There is a growing interest in the local preparation of local ready meals as an alternative to supermarket food, due to the long supply chains of ingredients and concerns over the nutritional value. Overdependence on processed food has nutritional implications as such food is generally higher in salt, sugar and fat compared to fresh produce (with some exceptions, e.g., frozen peas). Locally-produced food can enhance food culture and the local food heritage, providing consumers with opportunities to experience local varieties of produce, and improving knowledge of the seasonality of produce and the origins of food. Local food avoids many costs with food transport (transport fuel, warehousing and logistics; cost of retail operations). Packaging and processing costs will generally also be lower, due to a reduced need to preserve food quality during transport.	While there may be benefits from local food in terms of freshness (and nutritional value), global sourcing of food contributes to improved consumer choice, e.g. out-of-season and exotic produce. This may have a beneficial impact on nutrition. Current government policy promotes increased consumption of fruit and vegetables for health reasons (5-a-day policy). Consumption of fruit has increased significantly since availability of non-indigenous fruit such as oranges and bananas (typically transported by sea) and makes a significant contribution to nutrition and health. It is not clear that local fresh produce would displace purchases of more processed food, as many consumers who choose processed food do so for reasons of convenience. Although many local food initiatives have captured niche markets, strong demand for local food has yet to penetrate the mass market. Consumers still value low prices. However, production costs overall are generally higher from local food, due to imports having cheaper labour and/or favourable climatic conditions.

4.4 Current trends in food retailing and consumption and key choices facing society

4.4.1 Introduction

This paper describes a set of food system activities at the European level, within the framework of the ESF/COST Forward Look "European Food Systems in a Changing World", i.e. the set of activities on retailing and consuming food. It reviews the present situation regarding the respective set of food system activities which are discussed in the context of key choices facing society at large. The key questions outlined serve as the entry point to frame the discussions, i.e.:

- Will "food transparency" (i.e., the level of information available and readily accessible to consumers) increase, and how will this change consumption patterns?
- Will "big retailing" reduce – or even disappear – and what are the implications for supply chain relationships (i.e., the how, where and what type of food is supplied)?
- Will steering (via regulation or intervention) increase, and how will this affect food markets and food systems (i.e., to the benefit of consumers, food quality, public health)?

The structure of this paper is set around the three questions. In each case the questions are used as an entry point to present the current trends in consumption and retailing in Europe and regulation and other interventions. Each section seeks to link to the next to provide a coherent narrative and analytical frame. The final section summarises some of the key choices facing society today that arise from the paper.

4.4.2 Will food transparency increase and how will this change consumption patterns?

4.4.2.1 Introduction

Information and public knowledge about food have been subject to substantial change over several decades in Europe. Some changes have been derived from specific, highly publicised, food safety problems, some related to changing patterns of trust and concepts of risk, particularly in relation to new food technologies, and some are related to rising levels of diet-related illness, in particular obesity. This section will examine:

- The pressure for transparency;
- Analysis drawn from academic and public sector research on consumers and transparency;
- Analysis drawn from commercial marketing studies on shaping factors which "push" or "limit" transparency;
- The impact on consumption patterns.

4.4.2.2 The pressure for transparency

The link between information on food and consumer belief and behaviour is complex. For most of human history, food transparency has meant substantive information about food drawn from sight, smell, touch, or from knowledge of the producer. In modern society, by contrast, information about foods has increasingly become symbolic, communicated in words or pictures (sell-by-date, nutritional information, etc.), a process which is stimulated through continuous iteration between supply chain, consumers and state.

Supply chain: An increasing proportion of foods are packaged, processed or pre-prepared, with visual presentations of packages showing the product in future state of preparation. Even for some fresh foods touch is discouraged as a source of spoilage or infection risk while considerations of visual appeal have been driven through rigorous crop selection and use of chemicals or pesticides. An increasing proportion of foods are sourced through lengthening supply chains. Traceability and transparency are therefore central issues of the commodity sourcing and supply chain management.

Public: Perceptions of price, quality, availability and convenience remain central to consumer food choice perceptions, but these are filtered through personal background in the context of local and national food cultures, perceptions of pleasure or risk, concerns about health, and trust or confidence in suppliers and products. Food "knowledge" has been increasingly influenced by marketing, in the case of some products (e.g., soft drinks, confectioneries) reinforced over the lifetime and the media. The purpose of marketing is to build trust. However, trust has been lost or disrupted by multiple incidents or factors, ranging from BSE in cattle through to GMOs. While food safety concerns became prominent from the 1980s to 1990s, these have been supplemented by broader issues, ranging from the health consequences of food to environmental consequences of food production. For example, Eurobarometer survey data indicate that most Europeans (85%) feel public authorities should play a stronger role in fighting obesity, while nine out of ten Europeans feel that marketing and advertising influence children in their food and drink choices (Health and Consumer Protection Directorate General, 2006a). While this implies that Europeans hold consistent views on such matters of marketing, in fact it is likely that trust means different things in different places (Kjaernes et al., 2007).

State: Food safety concerns have been a major driver for enhanced food transparency. While in the first instance this has been an issue for individual EU states, the growing integration of the European food supply chain has led to the strengthening of EU com-

petence in this area, with the European Commission increasing its focus on food safety, traceability and transparency (see Section 4.4.3.2), and more latterly, action around diet-related chronic diseases. Survey evidence from Eurobarometer suggests nearly half of the European public surveyed agree that public authorities in the EU are doing enough with respect to food safety risks, while one-third of the public would like to see them do more. New policy making initiatives at the EU level are not solely driven by disruptions of the food chain or failures of food safety, but by increased consumer antipathy to new food technologies. In the case of GMOs, for example, Eurobarometer indicates that 66% of Europeans would not buy GM fruit even if it tasted better, nor would they eat eggs from hens fed on GM maize (Health and Consumer Protection Directorate General, 2002). Accordingly, and as an indication of the importance of transparency issues, the DG Health and Consumer Protection of the EU noted that biotechnology and GMO products (Byrne, 2003):
"could only prosper in an environment:

- where GMOs are safe;
- where proper information and dialogue of all stakeholders takes place;
- where the consumer is fully recognised as a legitimate stakeholder;
- where the consumer is given a free choice;
- where risk/benefit assessments are fully transparent;
- where traceability and monitoring are organised;
- where authorisations are time-limited;
- where all consumer concerns are addressed and taken into account."

Actions at the level of individual EU member states may, if proven effective, enhance pressure for EU action, one example being Denmark's ban on the use of trans-fats or the UK's promotion of "traffic lights" labelling to warn of the obesogenic properties of some foods.

4.4.2.3 The roots of consumer belief and behaviour

The pressure for food transparency now appears unrelenting, and it might be thought that public perceptions are the critical element spurring food chain and state into action. However, survey evidence suggests that health issues or food risk concerns may not be ever-present in the public mind – or may only be so during "food scares". Evidence from Eurobarometer indicates that when consumers (from all 25 member states) were asked what comes to mind in thinking about food, only one out of five mentioned health and that possible risks or disease were hardly mentioned at all spontaneously (Health and Consumer Protection Directorate General, 2006b). Asked to rank the importance of the statement that "the food you eat is damaging your health", this obtained fourth position behind environmental pollution, car accidents, and serious illness and on par with the risks to health posed by consumer goods (see Figure 4.22). When consumers were asked specifically to cite any possible problems or risks associated with food, no single issue emerged for the majority of respondents. Food would not appear a dramatic form of perceived risk, although it is likely that it would have achieved much greater prominence if the survey had been undertaken when food safety issues were a major theme in the media.

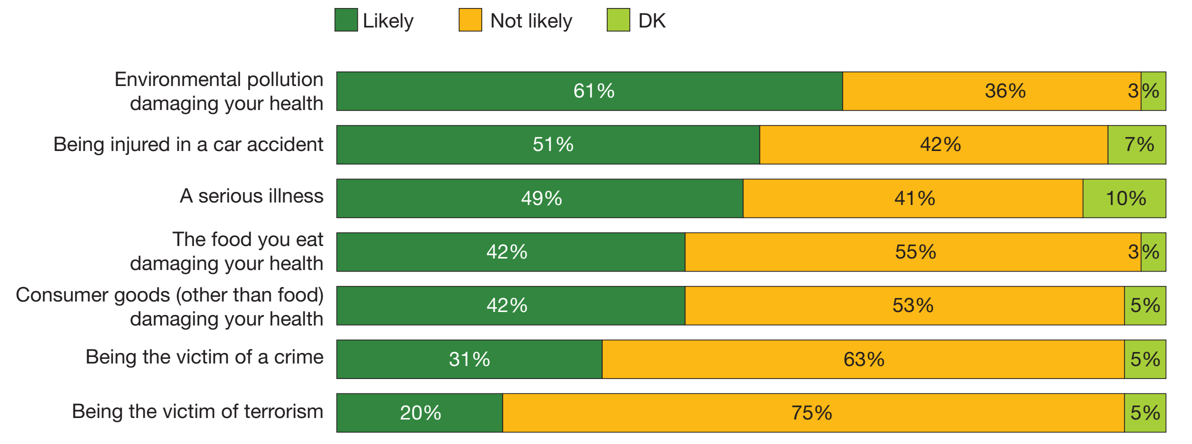

Figure 4.22. Relative ranking of risks (% EU) based on consumers' response to the question: "I will read out a list of potential risks. For each of them please tell me how likely you think they are to happen to you personally"
(Source: Health and Consumer Protection Directorate General, 2006b)

When consumers were confronted with a list of possible risks associated with food, however, concerns appeared to be more widespread. One finds at the top end of the "worry" scale (over 60% of respondents) concerns regarding: pesticide residues, new viruses (such as Avian Influenza), and residues in meats, food hygiene (outside the home) and contamination of food by bacteria. Consumers appear to be less worried about possible risks associated with their own behaviour or practices and to worry most about risks caused by external factors over which they have little or no control. The question could be posed therefore that consumers believe that potential problems are being dealt with. Certainly, a significant proportion of consumers interviewed (61%) were aware of EU regulations on food safety, which in terms of awareness ranked third after smoking (85%) and consumers' rights (66%). A majority (54%) agreed that public authorities took citizens' concerns about health risks very seriously although some scepticism existed regarding the prioritisation of consumer health with respect to commercial interests. Almost six out of ten considered that public authorities take into account the most recent scientific evidence when taking decisions related to food risks and nearly one in two commend their role in informing citizens about food-related risks. Public opinion remained divided on whether food safety had improved over the previous decade: 38% of respondents state that the situation has improved, 29% that it has stayed the same and 28% that we are now worse off than before. Nearly one in two people considered that public authorities' actions with regard to food safety risks were appropriate.

The implications are that perceptions of risk and the drive for transparency are not just complex but that consumers also approach food from a different direction other than that of risk. This point is supported by a qualitative study of the King Baudouin Foundation (KBF) across 15 European countries (Debomy, 2006).[7] When asked to give their spontaneous responses to food, the words which came to mind among those interviewed ranged from taste and pleasure (most responses) to disease (fewest responses). The KBF suggest that three core attributes, or types of approach, guide all Europeans in the selection of food products:

- Food as first and foremost a source of pleasure and sensations (the epicurean or affective approach). Products are judged by taste, sight, smell, point of origin, trustworthiness of producer/retailer, etc.;
- Food as first and foremost a matter of price, convenience or ease of use (the rational or functional approach);
- Food as first and foremost a consideration for health (the dietetic approach).

These conclusions appear consistent with the Eurobarometer data, shown in Figure 4.23.

These divergent approaches to food, they suggest, may be found differentially in different countries or even co-exist within the same individual who will exhibit one or another approach depending on circumstances. The blend of attributes at the national level may vary according to societal features (food cultures), demographic features (social class, gender, ethnicity) and economic factors (level of disposable income). Within families or groups influences include personal or family history, position in life cycle, family status, and receptivity to the diffusion of new influences and new food choices or retail settings, potentially the most rapid changes in Europe being in the transition countries.

The KBF study suggests that the pleasure/sensation criteria is more pronounced in those countries with a strong culinary tradition – France, Belgium, Italy, Spain, Greece, Germany – and/or still close to traditional agriculture – countries of Central and Eastern Europe, the

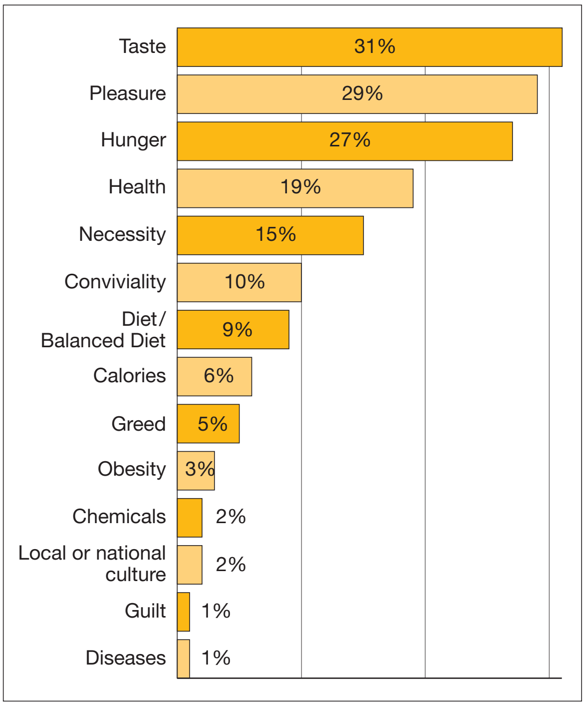

Figure 4.23. Thinking of European consumers about food (% EU), based on consumers' response to the question: "When thinking about food, what words first come to mind?" (Multiple answers possible) (Source: Health and Consumer Protection Directorate General, 2006b)

7. Baudouin Foundation report countries: Belgium, France, Germany, Sweden, UK, Ireland; Spain, Italy, Greece; Hungary, Czech, Poland, Estonia; Romania & Bulgaria.

"dietetic" approach is present in all countries, but it is especially emphasised in Northern Europe – in the United Kingdom, Sweden, and Ireland, particularly as regards women. It is more widely present in countries where consumers seek to have a balanced diet – for instance in Spain where concerns about weight problems have increased, while the price criterion is much more present in lower-middle social groups, as well as in Eastern European countries.

The interplay between these consumer perspectives does not mean that transparency issues are not important, rather that they emerge from different concerns. For example, in regard to displayed food information this suggested that there was "no great dissatisfaction" as regards information on food products and a large number of respondents said that they barely read the labels apart from sell-by dates. Where food information failed, it was because these did not address issues which were pertinent to consumers. In this regard improvements were proposed in the following areas:

- Increased clarity and simplification of labelling (legibility, comprehensibility);
- Precise mention of origin;
- Mention of treatments used (for fruit and vegetables in particular);
- Presence or otherwise of GMOs.

Although the KBF study suggests that there is diversity in traditions around food across Europe, other studies of what people are actually eating – rather than what they say about their eating – show signs of considerable convergence. In 1961 the proportion of energy derived from sugar varied considerably across Europe, and over the next forty years sugar energy shares began to narrow. A similar story is told of fatty acid dietary composition and vegetables and fruit, albeit with still qualitative differences between type of fatty acid and level of fruit and vegetable consumption. While the main focus on greater similarity in EU diets – in the light of concerns around obesity – is the increased intake in Mediterranean countries of saturated fats, cholesterol and sugar, there has also been a lessening of saturated fat and sugar consumption in some Northern European countries (Schmidhuber and Traill, 2006). Dietary transition appears therefore to be as consistent a trend as that of transparency.

Such dietary transition and convergence may be shaped by trade, urbanisation, common marketing campaigns, improved infrastructure and the dominance of supermarkets in the food supply chain – some of which apply broad product ranges irrespective of country of operation.

4.4.2.4 Critical factors increasing the push for transparency

Market researchers have sought to understand how consumer trends interact with media, market and institutional factors in order chiefly to inform the food industry about the changing market environment. Using their studies, and other sources, it may be useful to bring together a number of generalisations on recent trends:

- The continuous attention given to food in the media ranging from problem consumption (the obesity epidemic), food scares (food standards and health protection), even enjoyable consumption (restaurant reviews) which means that food is an ever-present societal narrative, albeit with peaks and troughs linked to food scares, health evidence, etc.;
- Disruptions in public trust in food – even as the food protection focus strengthens – is evoking new sensibilities and language around food: "junk food", Frankenstein food, slow food, healthy food;
- Risk awareness has risen alongside social anxieties associated with problem consumption (body weight/energy imbalance, habitual eating, dietary imbalance);
- Market restrictions (including export blockades) which suppress demand for products directly or indirectly associated with food protection problems;
- An increase in the incidence of or perception of food allergies and intolerances, leading to "free from" product markets, including wheat, lactose-free, preservative-free or nut-free foods;
- High sensitivity among European consumers towards GMOs and, less significantly, hormone-treated beef;
- Publicity given to the environment, unethical practices (including animal welfare, employee work conditions, terms of trade), making consumers more aware of the origins of their food and leading to growing demand for organic, vegetarian, additive-free, and fair trade foods;
- The development of symbols of personal identity around food choices e.g. vegetarianism;
- Linked to the publicity given to obesity, concern around the quality of school meals or food marketing to children, which has generated concerns among parents about processed foods and their ingredients and institutional catering;
- Greater sophistication among some consumers with regard to salt, fat or sugar content of foods, with evidence that diets are improving for some groups and declining for others;
- The growing link between broader environmental issues (climate change, sustainability) filtering into patterns of demand;
- The widening employment of signposting sys-

tems to impart health or environmental qualities to foods (attention to food miles, traffic light labelling schemes);
- The attempt to win market share by publicity to "healthy foods", plus criticism that early offerings lack identifiable health benefits;
- The pressure for adoption of transparency on "second movers" as early leaders among manufacturers and retailers develop new environmental, fair trade or food quality commitments.

4.4.2.5 Countertendencies which limit pressures to increase food transparency

There are practical and technological limits to increasing food transparency and industry resistance to some forms of food transparency which might have the effect of exposing the position of some food groups (e.g. the potential impact of traffic light schemes on the confectionary industry). Other limiting factors include:

- Technological innovation in product formulation and marketing;
- Rising disposable incomes in many parts of Europe which have led to greater eating out in settings (or advertised menus) containing aspirational or experiential qualities (themed with marketing, films, television, celebrity culture) rather than nutritional attributes;
- The growth of snacking, resulting in a widening of the type of food outlet, particularly impulse channels, going beyond convenience stores and kiosks to include service stations and vending machines;
- "Healthy" or "better for you" food ranges, being marketed as premium goods, lend support to the notion that eating healthily also requires large disposable incomes;
- The decomposition of the family meal and children making food choices drawing upon targeted food marketing;
- The marketing of products linked to commercial diet plans (dietary faddism) undermines the (potentially) timeless concept of a "healthy balanced diet". Many premium foods (including functional foods) carry no additional transparency over non-premium products;
- Fears over the effects of pesticide residue in foods have bolstered sales of products made from organic grains aimed at children. Organic products, however, remain a limited fraction of the market and some organic labelling lacks full transparency. Even so, insufficiency of supply means that many organic products are sourced in foreign markets meaning that "personal health" perceptions may have advanced over "environmental" perceptions, at least for the moment.

4.4.2.6 Impact on consumption patterns

As the KBF study showed, the national culture of food does make a difference. Individual choices are made up from a relation of personal identity to such cultures filtered through a composite of three basic approaches: epicurean, functional and dietetic. However, it was also noted earlier that Europe has been engaged in a process of diet and nutrition transition with Southern countries moving closer, in dietary terms, to Northern countries. As part of this trend some consumers in Northern countries were adopting diets with higher levels of fruit and vegetables, while Southern countries (and particularly younger age groups) were adopting some of the less beneficial aspects of Northern European diets, in particular more energy-dense food choices. In some respects therefore, the commercial and social processes producing greater pan-European similarity may also be linked with the fragmentation of consumption trends at the level of EU member states. The vulnerability of children to the marketing of energy-dense foods is, as we saw, a concern of many European citizens.

How does the drive towards greater transparency feature within these two processes? In part, the selection of more healthy diets may be a result of some social groups (by social class, education, etc.) being in a position to appreciate and adopt the critical content of new societal narratives around food (in particular, the need for a high mix of fruit and vegetables and the restriction in foods with high levels of salt, sugar and saturated fats), while at the same time being less vulnerable than others (children in particular, but also those disadvantaged by income and education). The next question would be whether simpler signposting systems, such as nutritional "traffic lights", as opposed to complex, generally unread information on product composition, would make a substantial difference to the more vulnerable. The evidence might be that such information might only make a difference in the context of other changes, such as blockades on advertising and marketing to certain groups, price discrimination of such products or restrictions on availability in some settings.

4.4.3 Will "big retailing" reduce – or even disappear – and what are the implications for supply chain relationships?

4.4.3.1 Introduction

The growth of big retailing has been widely identified as a dominant trend in the last two to three decades or more within the food system. The term "big retailing" is interpreted as meaning corporate retailers that operate across multiple sites to sell groceries and are predominant in the formats of: hypermarkets, supermarkets and discounter superstores. This classification is based on the Euromonitor International classification for grocery retailing formats, which is: hypermarkets, supermarkets, discounters, convenience stores, independent grocers, food/drink/tobacco specialists, other grocery retailers. This definition also includes: companies with branded fascia and franchised stores which may be independently owned but with central buying and supply operations (such as Spar); and, cooperative retailers who are very large players in some national markets in Europe. The growth of big retailing has been marked within the EU member states and North America and Australasia. From the 1990s, supermarkets have spread rapidly through to Latin America, Asia, and parts of the Middle East and Africa (e.g., Reardon et al., 2003). The result is that developing countries, including more advanced ones in Eastern Europe, are experiencing supermarketisation and hypermarketisation even more rapidly and over a shorter period than North America and Western Europe before them. The focus here is on big grocery retailing in Europe. Firstly, the growth of big grocery retailing across Western and Eastern Europe, respectively, will be explained and illustrated[8].

There is an increasing concentration of corporate ownership within grocery retailing. The big retailers who dominate in the supermarket category are also are major players in hypermarkets (e.g., Carrefour and Tesco). A more recent feature of this concentration of ownership is that supermarkets are spreading out into discounting superstore formats in some instances (e.g., Auchan in France) and into convenience stores in others (e.g., Tesco and J. Sainsbury in the UK). Amongst the discounters, the German-owned Lidl (part of the Schwarz Group) and Aldi lead the way. In the early to mid 2000s, the discounters showed notable growth (although still relatively smaller compared to supermarkets and hypermarkets as part of overall retail value share), suggesting that there is still further growth potential in the European market for aggressive lowering of prices to consumers.

4.4.3.2 Supermarkets and grocery retailing in Europe: Growth of retail value

By the mid 2000s the big retailers, in the form of hypermarkets, supermarkets and discounters, dominated the Western European grocery retail markets and were taking an increasing share of the rapidly-growing Eastern European markets. The leading European retailer (in terms of value) was Carrefour, followed by Tesco.

Grocery retail has continued to grow in value in the 2000s. From 1999-2006, in Western Europe the grocery retail value grew by about 20% and in Eastern Europe it doubled in value, as illustrated in Table 4.18.

Big retailing continued its dominance in the West and it doubled its value share in Eastern Europe, as illustrated in Table 4.19.

Table 4.18. Growth in value of grocery retailing in Western and Eastern Europe (adapted from Euromonitor International 2007a, b).

	1999	2006
Western Europe		
Retail value (M€)	890 496.4	1 064 287.9
Eastern Europe		
Retail value (M€)	87 331.9	179 863

Table 4.19. Western and Eastern Europe: Big retail value and percentage share of total grocery retail value 1999-2006 (adapted from Euromonitor International, 2007a, b)

	1999	2006
Western Europe		
Retail value (M€)	603 663.9	765 018.1
Percentage of total value	68	72
Eastern Europe		
Big Retail value (M€)	20 619.3	80 766
Percentage of total value	23.6	44.9

8. This section of the paper draws, in part, on Euromonitor International's reports and data. Euromonitor groups its data by country and within Europe regionally by Western and Eastern Europe respectively.
Western Europe comprises: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom.
Eastern Europe: Bulgaria, Czech Republic, Hungary, Poland, Romania, Russia, Slovakia, Ukraine.
Other Western Europe (these figures are obtained by mathematical modelling, rather than acquired through in-depth country research, and hence these are less reliable) Andorra, Cyprus, Gibraltar, Iceland, Liechtenstein, Luxembourg, Malta, Monaco.
Other Eastern Europe (again, these are modelled): Albania, Belarus, Bosnia-Herzegovina, Croatia, Estonia, Georgia, Latvia, Lithuania, Macedonia, Moldova, Serbia and Montenegro, Slovenia.

4.4.3.3 Market leaders in European grocery retailing

Within big retailing there are market leaders in terms of retail sales across Western and Eastern Europe, respectively. The top retail companies in Western Europe and Eastern Europe with percentage market share are given below. Many of the key retail companies increasingly dominate in both Western and Eastern Europe.

Market leaders in Western Europe (Table 4.20)

Carrefour and Tesco, who are both large players in both the supermarket and hypermarket formats, came first and second, respectively, with the discounters Aldi and the Schwarz Group (Lidl) third and fourth, respectively.

Market leaders in Eastern Europe (Table 4.21)

In 1999 the top ten retailers controlled 13.2% of the market; in 2006 the top ten retailers controlled just over 30% of the market. During this period Eastern Europe was seen as the fastest-growing region for grocery retailers. In an earlier analysis covering the period from 1999-2003, Bulgaria was identified as the fastest-growing national market in the world (Euromonitor, 2005a). This degree of dominance will expand further over the next decade or more. For example, the Rewe Group, currently the third-largest player, has identified that for their business growth: "Expansion will come above all from the fast-paced growth markets of Eastern Europe. The foreign share of REWE's total turnover is to be increased to over 50% by 2015" (www.rewe-group.ch).

At the lower end of the table are Eastern European and Russian businesses, reflecting the inclusion of Russia in the market ana lysis. Tander ZAO (Russia) owns the Magnit fascia, and Pyaterochka Holding NV are now called X5 Retail group NV.

National variation of market concentration: the case of Western Europe

The cross-European picture is more differentiated when we look at national markets. In the case of national market concentration by grocery retailers some earlier figures (from 2002) presented in a report by the consultants Cap-Gemini show that the degree of concentration varies from country to country in Western Europe. Using a concentration ratio (CR) of 3 (CR3), i.e. the concentration of the market within the trading of the top three grocery retailers, a more varied national picture emerges (Table 4.22). The highest CR3 is found in the Northern parts of Europe with Sweden (95%) and thereafter the Netherlands (83%) and Denmark (83%). Lower CR3s are found in the southern European countries of Greece (32%), Italy (32%) and Spain (44%).

Table 4.20. Top ten largest grocery retailers in Western Europe 2006 (Source: Euromonitor International, 2007c)

Grocery retailer	Retail value (M$)	Retail value share (%)
Carrefour SA (France)	80263.3	6.1
Tesco Plc (UK)	56083.4	4.2
Aldi Group (Germany)	45040.3	3.4
Schwarz Beteiligungs GmbH (Germany)	44028.0	3.3
Auchan Group (France)	36430.6	2.8
Edeka Zentrale AG & Co KG (Germany)	35436.0	2.7
Rewe Group (Germany)	34385.0	2.6
J. Sainsbury (UK)	27362.8	2.1
Internationale Spar Centrale BV (Netherlands)	26091.7	2.0
E. Leclerc (France)	25915.8	2.0

Table 4.21. Top ten largest grocery retailers in Eastern Europe 2006 (Source: Euromonitor International, 2007d)

Grocery retailer	Retail value (M$)	Retail value share (%)
Tesco Plc (UK)	6033.8	2.7
Royal Ahold NV (Netherlands)	3552.7	1.6
Rewe Group (Germany)	3368.3	1.5
Auchan Group (France)	3324.3	1.5
Schwarz Beteiligungs GmbH (Germany)	3245.4	1.5
Internationale Spar Centrale BV (Netherlands)	2711.0	1.2
Carrefour SA (France)	2374.6	1.1
Pyaterochka Holding NV (Russia)	2300.0	1.0
Tander ZAO (Russia)	2148.0	1.0
CBA Kereskedelmi Kft (Hungary)	2085.9	0.9

Table 4.22. Food retail top 3 market share (by fascia) in selected Western European countries 2002 (Source: Grievink, 2003)

Country	No.1	No.2	No.3	Combined market share (%)
Sweden	ICA	OF	Axfood	95
Netherlands	Ahold	Laurus	Su	83
Denmark	FDB	Dansk Supermarkt	Supergros	78
France	Carrefour	Leclerc/SysU	Intermarché	64
UK	Tesco	J. Sainsbury	Asda	58
Germany	Edeka	Rewe	Aldi	57
Portugal	Sonae	JMR	Intermarché	52
Spain	Carrefour	Eroski Group	Auchan	44
Italy	Coop	Conad	Carrefour	32
Greece	Carrefour	Alfa Beta	Veropoulos	32

The global spread of the big grocery retailers

The larger European retailers also have been spreading their stores into other continents beyond Europe. For example, when Carrefour merged with Promodés in 1999, it became the largest retailer in France, Spain, Belgium, Portugal, Greece, Brazil, Argentina, Taiwan and Indonesia with stores in 26 countries (Hollinger, 1999). It had spread its stores to Asia-Pacific, Africa and the Middle East and Latin America by 2003. Carrefour and Auchan are the largest supermarket chains in China. Carrefour has been careful to adapt its offering in national markets to meet local tastes. The bulk of supermarket retail offerings are sourced within national and regional markets particularly with processed and manufactured foods. For example, the Carrefour distribution centre in Sao Paulo, Brazil may serve 50 million consumers in three different states; and the Ahold centre in Costa Rica can serve all their Central American retail market. Indeed, according to figures for 2002, sales of processed foods worldwide were almost 80% of total world food sales in value (about $3.2 trillion). However, only 6% of processed food sales were traded internationally, compared with 16% of major bulk agricultural commodities (Regmi and Gehlhar, 2005a, b).

Table 4.23. Top 10 world grocery retailers 2005 (Source: IGD. www.igd.com)

Rank	Retailer	Turnover (M$)
1	Wal-Mart (USA)	256 329
2	Carrefour (France)	79 625
3	Ahold (Netherlands)	63 337
4	Metro Group (Germany)	60 510
5	Kroger (USA)	53 791
6	Tesco (UK)	50 336
7	Costco (USA)	48 107
8	Rewe (Germany)	44 260
9	Aldi (Germany)	39 798
10	Intermarché (France)	36 206

The world's top ten grocery retailers in 2005 included seven European firms (Table 4.23).

In sum, it is clear that currently (2006) the big European grocery retailers are very entrenched in Western Europe and are increasing their market share in Eastern Europe, and are amongst the leading movers in expanding beyond Europe to have a global presence.

4.4.3.4 Some key features in the growth of supermarkets

The growth of supermarkets has changed the face of food and grocery retail over the past three decades. A number of features are now dominant in the grocery retail market. The main companies in grocery retail combine these features in differing ways but the smaller stores are also following some of these features. The overall picture is one of increasing retail concentration and control by fewer retail companies. This is not likely to change in the near future. Some of the key factors that explain the continued growth of the big retail supermarkets are explained below.

- Service and convenience – supermarkets have focused on continually providing "good service" to customers. In the pursuit of good service, retailers have:
  - Re-shaped perceptions of convenience amongst consumers. As a result, convenience is perceived in terms of the ability to purchase all grocery needs under one roof, often in one shopping trip; and, to be able to drive to, park and transport home all such

goods by car. International supply chains have provided year-round seasonality to Northern European consumers of vegetables and fruits, drawing on export-oriented growers in Sub-Saharan Africa and Latin America, for example.

– Utilised latest technology to improve and utilise, for the benefit of the customer and of the business, enhanced checkout and payment facilities. From the 1970s Electronic Point of Sale equipment (EPoS) has been deployed and used for more and more sophisticated purposes: from stock control and shelf replacement, to "just-in-time" ordering, to customer loyalty schemes, to customer-based data and targeted marketing uses. Similarly, Electronic Funds Transfer at the Point of Sale (EFTPoS) is being deployed to improve the security of transactions at the checkout and the transfer of funds and the speed of customer movement. Once credit card details are stored, customers can be targeted to adopt the retailers' own credit cards. New technologies are continually implemented. For example, Radio Frequency Identification (RFID) tagging methods are being experimented with currently by the big retailers and some of their suppliers (Wal-Mart, Metro and Tesco), and supply chains are waiting to see how the retailers will roll out this technology on a large scale (Euromonitor, 2005c).

– Altered the design and layout of stores to improve the shopping experience and to induce further customer spend, e.g. sites of fruit and vegetable sections at entrances to stores; in-store bakeries; breadth of offerin gs; going beyond groceries to include non-food goods such aselectronics, furnishings and clothing, where there are greater mark-ups in price and so increasing value added. The evolution of supermarkets into larger-format hypermarkets has been accompanied by increased food offerings, bulk purchases and non-food offerings.

- Marketing and shaping of demands:
  - – The design of stores and the display and marketing of products are part of the shaping processes affecting customer choice.
  - – Special offers such as "buy one, get one free" have proliferated. Known value items (KVIs), where consumers are familiar with the price and so use it as a benchmark of how competitive the retailers' prices are, are used as loss-leader products in retailers' offerings, for example some types of milk and bread in the UK market.
  - – EPoS and EFPoST are used as marketing devices (see above).
- Pricing- "every day low costs" is the mantra of Wal-Mart (USA), the global leader in retail and grocery retail. Amongst the leading grocery retailers in Europe, Tesco came to dominate the UK market with its aggressive discounting, a feature of the success of the top discounters such as Aldi and Lidl.
- The supermarket, its fascia and identity, is now itself a "branded presence". As part of this, the development of own-brand products competes against established manufacturers' brands. Own-brand products also increase the retailers' control over supply chains. The UK retailers have been at the forefront of developing own brands – today around 40% of supermarkets' packaged goods are sold as own-brand labels (IGD, 2004). Throughout Europe the supermarkets attempt to link their brand to trust in the consumers' mind. One result is that supermarkets have led the way in traceability and responsiveness to consumers' anxieties and desires and aspirations. For example, the European supermarkets led the way in segregating GMOs and their derivatives in a wide range of their food offerings in response to customer concerns in the late 1990s (ahead of the regulators) (Barling, 2001). Equally, the supermarkets are very quick to respond to customers' desires as with the rapid offering of organic foods in the late 1990s and 2000s, and for fair trade products.
- Supply chain integration and logistics management. The supermarkets have been at the forefront of centralised distribution systems, often located regionally, and of integrating their point-of-sales information with their whole supply chain.
  - – Both the deployment of information technology and logistics management is integrated to provide ever more efficient and responsive supply management.
  - – The advent of internet shopping has been quickly embraced by the supermarkets. The most advanced markets for internet shopping are the USA and, within Europe, the UK (due to the high rate of high-speed internet penetration in UK homes). With the logistics and distribution infrastructures and brand recognition already in place, the established supermarkets have been at the forefront of internet shopping and delivery of groceries. Even alternative direct-to-customer sellers such as organic and farmers' box schemes are being challenged by the large supermarkets offering their own direct-to-door boxes of fresh and seasonal produce.
- Standard setting and capturing value. As buyers at the end of supply chains, supermarkets are in a position to demand and set exacting standards and contract specifications from their suppliers. Given the supermarkets' dominance in the market place, contracts with large supermarkets are valuable to suppliers.

Suppliers, whether they are manufacturers or farmer–growers, find themselves battling for the valued shelf space of the supermarkets. This creates an inequitable relationship where the supermarkets can seek to extract value from the products supplied to capture a larger share of the profit margin. This is occurring with own-brand goods, branded manufactured goods and fresh produce (milk, fruit and vegetables, and meat) alike. Traditionally, the producer and the processor/manufacturer have battled over the capture of value. The contemporary buyer-supplier relationships result in private systems of governance along supply chains, with the retailer increasingly in a dominant position (this is explored more fully in the next section).

To conclude, the current trends are towards the continued ascendancy and domination of big retail over food supply chains. The end of the dominance of big retail is not yet in sight. The next section explores the implications for the food supply chains of this ascendancy more fully.

4.4.3.5 Impacts of supermarkets upon supply chains

The changing locus of power along the food supply chain

Over the past century there has been a gradual shift in the locus of power along food supply chains. In the broadest sense there has been a shift from farmers to manufacturers and ultimately, and in the past three decades or so, to the retailers, with the wholesalers also seeing an erosion of their position in many product supply chains. An interpretation of this relative shift is given in Table 4.24.

In one respect we have seen a shift from producer-driven to buyer-driven supply chains. The concept of the value chain has been used to explain how value has become increasingly captured by the buyer (at the near consumption end) from the primary producer (the farmer/grower). However, there has been a further shift in the buyer-driven aspects in that the dominant position of food manufacturers has given way to the retailers/supermarkets, which have been able to dictate the terms of contracts and act as gatekeepers to the large majority of food consumers, threatening non-compliant suppliers with delisting and the ending of access. The nature of these changing relationships in the supply chain and their impacts on food supply chains are discussed next.

Searching for evidence of the hidden supply chain impacts

It is difficult to find hard evidence of the impacts of supermarket practice upon their suppliers. One attempt began in 1999 when the UK's Office of Fair Trading (OFT) called in the Competition Commission to look at whether or not supermarkets were engaged in "a monopoly situation in relation to the supply in the UK of groceries" – they issued their report in 2000. The investigation focused on: barriers to competition, intensity of price competition and exercise of buyer power in the supply chain (8% or more of groceries' market with resale through stores). The investigation found little clear evidence of monopoly but found evidence of buyer power. Examples of the findings and concerns can be found in sections 2 and 11 of the Commission's report (Competition Commission, 2000). The Commission quoted suppliers as coming under "alarming" pressure from the multiples, due to fear of "delisting". Also, Efficient Consumer Response (ECR) adoption leading to "category management" (privileging certain suppliers) was seen as unfair. The result was a voluntary code of practice for supermarkets in their dealings with suppliers under the Department for Trade and Industry in 2002, in order to provide transparent terms of supply. However, the code is seen as "toothless" by producers as well as suppliers, who admit to being inhibited from complaining, due to fear of losing contracts with the supermarkets.

In 2006, the Competition Commission was charged with conducting a further investigation focusing on the increase in supermarket buyer power and the extent to which this may be distorting competition through practices such as below cost pricing, as well as the supposed accumulation of land-banks, that is land purchased for development or to take potential sites away from supermarket competitors (OFT, 2006). Given the OFT's consumer focus it remained uncertain at that stage if such an investigation would give concern to the wider

Table 4.24. Food industry: power in the value-added chain (adapted from Von Schirach-Szmigiel, 2005)

Period	Farmers	Manufacturers	Wholesalers	Retailers
≤ 1900	Dominant	Minor	Major in a few trades	Very Minor
1900-1950	Declining	Dominant	Major in many trades	Minor
1960-1970	Minor	Dominant	Dominant	Emerging
1980-2000s	Very Minor	Declining	Rapidly Declining	Dominant

social impacts upon farmers and suppliers. However, there was evidence that farmers were providing evidence to the enquiry of unfair practice, not least at the urging of the National Farmers' Union (NFU) (Levitt, 2007). The conclusion that can be drawn from these investigations to date is that it is difficult to get clear evidence of the unfair practices that suppliers are subjected to due to the fear from suppliers that they will lose vital contracts with the retailers.

Private governance of the food system by retailers

There are effectively private forms of governance appearing along supply chains driven by the supermarkets that impact upon the suppliers. These private forms emerge from the combined effects of the dominant market share of the supermarkets allied to their contractual specifications and standard-setting. This is also the case for the suppliers to the food manufacturers, of course, but now the food manufacturers are also at the behest of the retailers' demands in return for the vital shelf space in the supermarkets.

A further development has been the growth of grocery retailer-led buyer groups or alliances in Europe across national boundaries. In 1999, it was estimated that the joint turnover of the members of seven main cross-border buyer alliances accounted for about 40% (or 340 billion €) of total EU supermarket turnover (Dobson et al., 2003). A key feature of buyer groups is that their mass allows them to gain discounted prices from suppliers. Groups often focus on certain product lines thus strengthening their potential presence and potential influence on the supplier market (IGD, 2007). Leading buyer groups (by turnover) in 2007 were:

- *EMD* – ABVassilopoulos (Greece), Axfood (Sweden), Delhaize Group Europe (Belgium), Delvita (Czech Republic), ESD Italia (Italy), Euromadi Eberica (Spain), Markant Central European (Czech Republic), Markant Deutschland (Germany), Markant Slovensko (Slovakia), Mega Image (Romania), Musgrave Group (Eire), Nisa-Today's (UK), Super Gros (Denmark), Superunie (the Netherlands), Système U (France), Tuko Logistics (Finland), ZEV Markant (Austria)
- *COOPERNIC*- Colruyt (Belgium), Conad (Italy), Co-op Schweiz (Switzerland), Leclerc (France), Rewe (Germany).

In terms of aggregate turnover, which is one guide to the potential negotiating power of any buying group, the leading grocery buyers in Europe are given in Figure 4.24.

One business overview of retailer dominance of the supply chain in Europe identified 600 supermarket formats and 110 buying desks acting as mediators for almost 90 million shoppers purchasing for a further 160 million consumers (see Figure 4.25).

The explosion of private standard setting has lead to more cross-national retailer-led initiatives to set standards for suppliers to European members of such retailer initiatives. Two main examples are EUREP(GAP) and GFSI.

- **Euro Retailer Produce Working Group (EUREP)** was set up in 1997 by 13 large European retailers to set minimum standards for Integrated Crop Management production (Van der Grijp, 2003). EUREP's Good Agricultural Practice (GAP) protocol for fruit and vegetables followed, and has evolved from its initial defensive role in trying to set environment-friendly

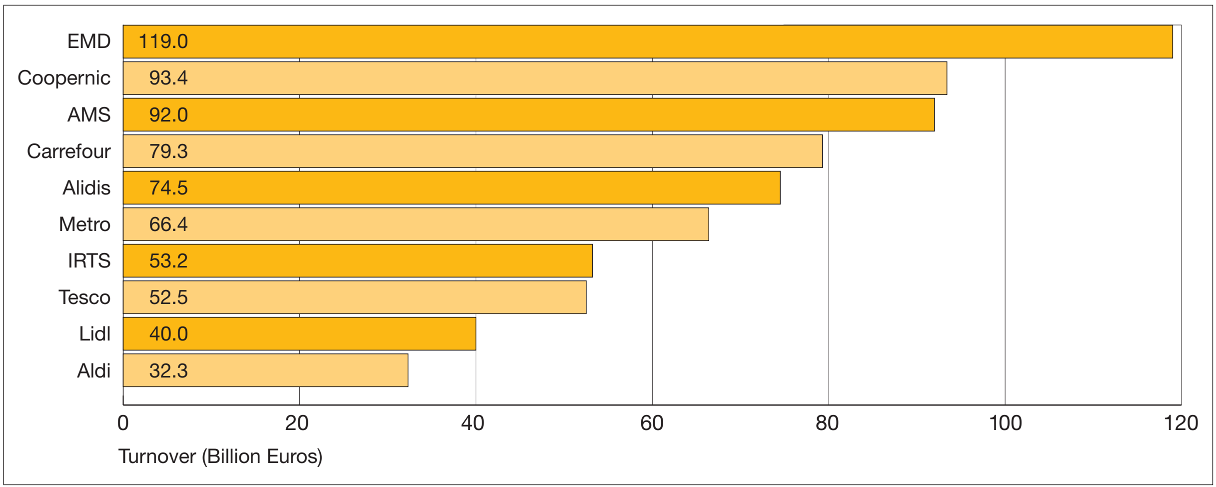

Figure 4.24. Top 10 leading grocery buyers in Europe (Source: IGD, 2007)

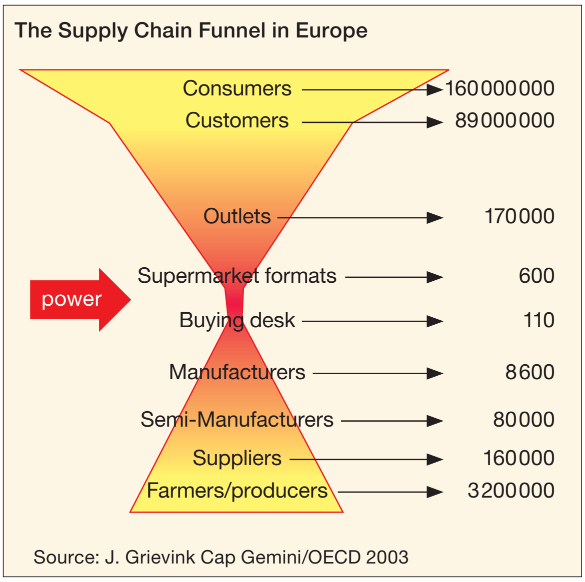

Figure 4.25. Supermarket buyer concentration in the European food supply

pesticide standards, into setting standards for many more characteristics and systems (such as traceability). EUREPGAP sees itself as "in pole position to become the global player in agricultural production standards and verification frameworks for fruits and vegetables" (EUREP, 2003). In 2007 it was renamed as GLOBALGAP.

- The Food Business Forum (CIES) is composed of some 200 leading retailers across 50 different countries. In May 2000 it set up the **Global Food Safety Initiative (GFSI)** composed initially of 50 retail members. The initiative is a global task force that seeks to implement a scheme to benchmark food safety standards world-wide involving cooperation of all sectors, suppliers and stakeholders. The GFSI mission includes: strengthening consumers' confidence in the food they buy in retail outlets; developing a simple set of rules for standards; creating harmony in the use of standards between all countries; and saving money for suppliers. These goals it claims will bring benefits to all stakeholders: for consumers, in ensuring food safety, strengthening confidence and promoting awareness; for suppliers, in reducing the number of audits undertaken and improving overall efficiency; and last but far from least for retailers, in developing simpler, better standards and supporting improved information flow and enforcement. GFSI has implemented a scheme to benchmark food safety standards for private label products, and develop an international information exchange system and a Good Retail Practices guide. The compliance of four standards – the BRC Global Food Standard, the Dutch HACCP Code, the EFSIS Standard and the International Food Standard (IFS) – was announced in January 2003. Subsequently, a fifth standard met compliance, the SQF 2000 standard owned by the US retail association – the Food Marketing Institute (FMI). The accreditation of competent auditors for their standards is now an added priority (Vaxelaire, 2007).

Supermarkets as large corporate concerns are coming under pressure to respond to the external costs that their business generates – particularly in terms of environmental, public health and social costs. Given their role as a key driver of food supply chains and standards, the retailers are coming under the spotlight to take actions to tackle these external costs. They are responding, in some cases ahead of governments. For example, in October 2005 in a landmark speech in the wake of hurricane Katrina, the chief executive, H. Lee Scott Jr., of Wal-Mart (the world's largest grocery retailer) announced that it will start holding its suppliers more accountable for environmental and social standards at foreign factories: "The environment is begging for EDLC [everyday low costs]… for the Wal-Mart business model. And if we do that, everyone will benefit." (Scott, 2005). Subsequently, in October 2006 the head of Wal-Mart's global buying unit said that the retailer wants to work with fewer factories handling larger orders so that it can keep a closer watch on working conditions, quality and costs. The retailers want to build long-term relationships with 900 or 1 000 key manufacturers to produce everything from food to towels. "We're going to focus on consolidating our factory relationships because as we do that, we're able to get our hands around ethical standards, quality and sustainability." (Planet Retail, 2006). And, in February 2007, the chief executive made a further announcement that it had "stepped up the pace in the race to be green with a series of initiatives to cut its own giant carbon footprint – and those of its suppliers, customers and staff" (Finch, 2007). In 2006-7 some of the other largest UK grocery retailers made similar announcements.

In short, the influence of big retailers on food supply chains is immense and the directions these retailers take will have a profound effect on the viability of methods of production and who the producers are who can afford to stay in business. The criteria are changing as the retailers are responsive to shifting consumer moods and social trends (as with the example of Wal-Mart, above). The changing criteria that retailers base their standards and specifications upon impact upon the supply chains and so upon the type of food demanded. Food may be classified according to the processes of production, inputs, externalities created and measured, freshness and authenticity, and a wide array of other factors – as outlined and explained above. A key set of questions that emerge from this exposition of the role and influence of big retailing upon food supply chains is the extent to which, and the ways in which, the public authorities are seeking, and will in the future seek, to intervene to steer and regulate the activities of the supermarkets and the impacts of their large market share. We turn to this question, in part, next.

4.4.4 Will steering via regulation or intervention increase, and how will this affect food markets and food?

4.4.4.1 Introduction

This section identifies some key dimensions of regulation and intervention, and proposes that:

- Food markets and systems operate within clear structures of regulations and policy. These structures are dynamic, not static, and there is increased activity over some issues, and decreased activity in others;
- Actions occur mostly at the national level;
- Despite diversity in European food markets, some common trends and features are visible in the dynamics steering Europe's food system.

4.4.4.2 The existence of market "steering"

All EU member states have traditions of regulation, which partly framed their food systems prior to their EU membership. Famously, Germany had its *Reinheitsgebot*, a law dating from 1516 governing purity of beer and other products. This is often portrayed as a consumers' friend, proposing that beer could only be made with simple and restricted ingredients. No added sugar, for instance, was permitted, but it also restricted market access for rye and wheat beers. Notions of pure food and cultural expectations have been delicate matters for food regulation, as the EU has expanded and deepened, particularly with the creation of the Single Market (Commission of the European Communities, 1987).

Example 1. Food labelling

The creation of the Single Market from 1986 brought to the fore the need for new agreement on labelling. The previous policy attempt had been to win agreement among member states for composition standards. This was both slow and tortuous. The Single Market signalled a change of direction, offering a policy recipe that ensured basic safety of products, open markets and increased flow of information to consumers. Food labelling thus became high profile, but there was some tension over how extensive that labelling might be. Should labels be restricted to ingredients? Already, the EC had introduced additive "E" labels to indicate EC approval, but this led to increased rather than diminished consumer concern about the role of additives. Should ingredients be just listed or be given by weight? In the end, under pressure from consumer organisations, a system of quantitative ingredient declaration (QUID) was adopted.

A more thorny issue has been nutrition labelling. A standard format for EU nutrient labels exists but is only mandatory when a health claim for the food product is made. Most manufacturers and retailers use nutrient labelling but vary in how they present the information. To promote some consistency for health education purposes, some countries have experimented with national systems of nutrition approval. In 1989, for instance, Sweden's National Food Administration introduced its "keyhole" system with strict regulations about when and how a product could receive the "keyhole" as a symbol of health approval (Livsmedelsverkert, 2005, 2007). The UK's Food Standards Agency has introduced a "traffic lights" system, like the Swedish system, to indicate gradations of health approval, but while some suppliers have introduced this, the system has met considerable hostility from others, notably some large manufacturers (e.g. Cadbury Schweppes, Mars/Masterfoods, Danone, Kellogg, Kraft, Nestlé, PepsiCo) and at least one giant food retailer (Tesco), which prefer the system of Guideline Daily Amounts.

This short account of labelling raises an important point about the role of civil society organisations, such as consumer organisations, in shaping food discourse and lobbying for regulation. NGOs can have a voice beyond their actual resources; they may be small and have limited finance but they have totemic influence. They do not speak as one. They bring subtle but divergent positions to the information and policy discourse. Consumerist organisations such as the Bureau Européen des Unions de Consommateurs (BEUC) see openness as key to making markets work; their role is to deliver the consumer side of the European economic vision. Heart health groups, on the other hand, such as the European Heart Network (EHN), are more focused on nutrient labelling as a health promotion tool, citing EU health commitments. Ecologically-inclined consumer organisations focus more on food quality (Harrison, 2005). These different positions become important in shaping where labelling policy might go:

- What do consumers want or need to know?
- Do consumers need to know the processes making foods or just what is in the food?
- How "deep" does this information need to be?

4.4 Current trends in food retailing and consumption and key choices facing society

These questions shape debate about issues such as genetic modification (GM) and residues of agrichemicals (pesticides). After a long policy debate on GM, the EU responded with new labelling regulations for GMO presence in food and feed and ingredients, above a threshold allowing for adventitious contamination. This was seen by the European Commission as an issue of consumer choice (Commission of the European Communities, 2003). However, in the case of pesticide residues it opted not to declare residues but to allow positive declaration of foods supposedly residue-free marshalled by organic labelling rules, run in concert with organic food bodies. In practice, few foods are contaminant free and another principle comes into play: the proportionality of risk.

Thus, labelling, which was presented as a cornerstone of the smooth working of the Single Market, became itself an object of tension about "steering" the market. This is likely to continue.

Example 2. Food retail competition and market share

The degree of grocery retail concentration across Europe, most notably in the more mature markets of Western Europe and within countries in the northern parts was illustrated previously. All EU member states' food markets are regulated at the national and international levels. In some countries, however, the emergence of large food retailers has sparked intense debate about:

- The impact of giant retailers on competitors and supply chain providers (notably food producers and growers);
- Whether state intervention is either effective or desirable;
- The purposes or rationale for such regulatory intervention.

The policy and regulatory response to this emerging market power has mainly been within national borders, although it has been remarked on by academics, NGOs and consumer bodies (Dobson et al., 2001). In practice, European regulatory frameworks have tended to be left to national action and have fallen within particular policy avenues:

- General planning laws, such as stipulating store size restrictions: e.g., France, Italy;
- Support for SME modernisation, such as tax incentives: e.g., Portugal, Belgium, the Netherlands;
- Specific restriction on out-of-town developments: e.g., Denmark, Norway, France, UK;
- Support for town centre retailing: e.g., Sweden, Finland;
- Competition policy, such as merger approval subject to disposal of some stores: e.g., European Commission acting on Rewe take-over of J. Meinl in Austria; also, UK;
- Price controls, such as controls on discounting or selling below price (loss leading): e.g., France, the Netherlands, Spain, Portugal, Ireland.

Draconian action, such as controls on foreign companies owning land, has not been viewed as part of the European way. Romania used to proclaim this but in practice the regulation was circumvented by allowing joint ventures. Debate about the emergence of powerful retailers is widespread. In Portugal, for example, government offered support for small retailers to modernise their outlets in the face of competition. But it is in France that the most overt policy intervention to shape retail food markets has been tried. *La Loi Royer* of 1976 imposed restrictions on the development of large retail outlets, placing a requirement for authorisation for any new stores. In 1996, France introduced *la Loi Rafferin*, which introduced regulatory powers to restrict the opening of large outlets. A *Commission Départementale d'Équipement Commercial (CDEC)* was given powers over any development larger than 300 square metres. In 1997, *la Loi Galland* also created a "threshold" for selling products at a loss (Euromonitor, 2005b).

Competition and anti-monopoly actions in food retail have been few within Europe. This is mainly because EU competition law means that authorities focus not on supply chain relationships but on the consumer interest. The European Commission is more focused on the potential anti-competitive effects of corporate mergers and acquisitions upon markets, and so intervention is more likely when the large grocery retailers seek to merge or acquire competitors (British Institute of International and Comparative Law, 2005). The higher degrees of grocery retail concentration are found within national markets rather than across the EU as a whole. Furthermore, market power is not judged as vital a consumer or public issue as lower prices or expansion of product ranges. The supermarketisation of Europe is thus far judged a consumer gain. However, at the national level, for example in France and the UK, the profile of monopolisation is higher. A comprehensive inquiry by the UK Competition Commission in 2000 found insufficient hard evidence to curb the actions of UK food retailers, but promoted a voluntary code for the retailers, which has been followed by yet another enquiry (see above). In addition, social pressure is growing, not just on market domination but cultural domination, with arguments that retail giants are turning urban diversity into "sameness" (Simms et al., 2005).

The emerging issues for what "steers" food markets and the food system raised by these debates about competition are these:

- How to define what a market is? Is it the consumer's "travel-to-shop" distance, i.e. a local notion? Is a market wider than that: regional or sub-national? Or is it a political boundary set by national borders? Will markets shortly be defined as European rather than national? If so, where will this leave policy and law?
- The terms of reference of competition authorities. The emergence of cultural, environmental, health and supply chain power questions are leading to some expression that competition laws need to include not just economic or market-share criteria but social criteria too. But how can these been expressed in instruments and measures?

4.4.4.3 The diversity of social issues "steering" European food markets

The European food system has been characterised by remarkable change. Agriculture was one of the core elements of the Common Market at its foundation. Today, agriculture accounts for a diminishing element of the food value-added chain and agriculture's system of policy and financial support is subject to considerable change. Whilst there is a Common Agricultural Policy, there is no Common Food Policy. Yet in the half-century since CAP was created, the food system has been subject to remarkable technological innovations and social change.

Over the last two decades, the European food system has witnessed a number of noteworthy sources of change in both what and how it is being "steered". Table 4.25 summarises key issues which affect what consumers are offered, by whom and whence the food comes.

The future shape of European food systems is likely to depend on:

- The balance of power among proponents of various positions shaping these issues;
- The strategic deftness of activists on these issues;
- The nimbleness of policy responses by state institutions – e.g., level of action (European or national) and type of approach, e.g., "carrot and/or stick" approach.

The form, direction, means and level of future regulation and interventions, as attempts to steer the food system, will be a central element of the choices facing society at large over the future of European food systems.

4.4.5 Choices facing society at large

The foregoing presentation and evaluation point to a situation in Europe where there are dynamic and changing food markets, shaped by evolving and interacting economic as well as social, public health and environmental and regulatory-political factors. The future shape of European food systems is likely to be influenced by the directions taken to resolve the issues set out in Table 8. The questions facing society are no longer simply around decisions made about food production and the nature or extent of its subsidy and support. Rather, decisions made around the steering of the retail and consumption stages of the food system are likely to be of equal importance.

The presumption here is that questions of food safety are declining in importance while environmental issues (notably climate change) and general health questions (obesity being the most visible form of these) have risen and will continue to rise in importance. These issues signal a broader public debate over the purpose and function of the European food system. There is currently a shifting debate around land use, as seen in the development of the multi-functional model for European agriculture and the use of agricultural land for biofuel production. Following the Second World War, there was a determination of all states to ensure that no European citizens would ever again face food shortages or be poorly fed. The question of sufficiency – putting aside the potential of acute disruption to food production and trade caused by oil shortages or crop failures (which we return to below) – is therefore not the primary issue at present, although it remains in the background and may well return. What are increasingly the issues are the health of the European diet and the food sectors' role in supplying and promoting a healthy diet, and the environmental impacts and contribution of food and the food system particularly in the context of climate change and natural resource shortage and depletion. So far, these issues have been researched and discussed to varying degrees but actions have been limited and "soft", but as the evidence of problems mount, more robust measures will be called for.

Hence, key choices facing society will occur around:

1. The balance of power among proponents of various positions shaping these issues;
2. The prioritising of these issues on political agendas and their political salience as reflected in the extent of continuing attention given to food issues, and particularly to diet-related diseases, by official and professional bodies, industry, civil society organisations and the media;

4.4 Current trends in food retailing and consumption and key choices facing society

Table 4.25. The diversity of issues "steering" Europe's food system

Issue	Examples
Public health	• Emergence of food safety and hygiene as key issue in late 1980s/1990s. • Slow emergence of public health issues about diet, focusing on ingredients and product formulation from 1970s, heightened by obesity from late 1990s (see international and global-level responses below). • The impact of cross-border (and international) trade on foodborne disease (e.g., avian influenza).
Public goods	• Raising of environmental standards in general since 1970s, e.g., pesticide residues. • "New" issues in the era of climate change such as auditing of embedded carbon and embedded water in food products. • Creation of animal welfare standards following the recognition of animals as "sentient beings". • The impact of labour standards as "hidden" ingredients in food (raised as a positive issue by fair-traded foods, but by implication casting light on all foods).
Branding	• Strong attempts by manufacturers to create brand loyalty and value. • Emergence of food retailers as brands and manufacturers in their own right. • Emergence of Corporate Social Responsibility into niches by manufacturers and retailers. • Creation of international certification and verification schemes.
Product (& process) labelling	• Process-based labelling offered to consumers to win trust, e.g. organic, environmental, GIs, GM. • Nutritional labelling (mandatory only if a health claim is made). • Emergence of national schemes tied to health promotion, e.g., Sweden's "keyhole", UK's "traffic lights" schemes.
Market regulation	• Application of Competition policy to food systems, off the land. • Regulation of marketing and advertising of foods, particularly to children.
Voluntary codes of conduct	• Shift from "top-down" State regulation to State-encouraged and -endorsed codes and voluntary agreements by industry and/or between industry and civil society.
Inspection	• Self-policing of products replaced by process inspection and consciousness, notably via Hazards Analysis Critical Control Points (HACCP systems). • But also some re-emergence of "old"-style product inspection driven by product liability concerns and brand value protection.
Technological infrastructure	• Ubiquity of "just-in-time" order and delivery systems and computerised logistics. • Universality of Electronic Point of Sale (EPoS).
National initiatives and trend setting	• Individual countries take the lead in setting a trend, which other (especially transitional) countries follow. Examples include: Denmark on banning transfats. UK on salt. Finland and Switzerland (Nestlé) on functional foods. Germany on beers – defence of cultural standards. Sweden on eco-food.
International / global level responses	• "Soft" policy initiatives by cross-border European bodies. • WHO and European Commission collaboration in focusing on diet and physical activity as driver of health. • Tripartite (state, civil society, company) collaboration in delivery of pan-EU actions in relation to EU Platform on Diet, Physical Activity and Health.
Cultural designations	• "Niche" food products have been enshrined by the system of designated "local" foods (PDOs and PGIs). The EU de facto thereby regulates some composition standards, having abolished "euro recipes" with the creation of the Single Market in 1986. • Support for "local" foods as expression of cultural identity (PDOs and PGIs).

3. The strategic deftness of contending groups around these issues;
4. The nature of policy responses by state institutions and indeed the role of the state in these processes, e.g.:
   4.1. The level of action – European and/or national incentives and regulations, and the wider international policy agreements (as with the Climate Change protocol and Biodiversity Convention, the WTO's Agreement on Agriculture, and its Sanitary and Phytosanitary Agreement and the extent of further world trade liberalisation agreements more generally);
   4.2 The nature of public policy intervention – in relation to evidence of the abuse of monopoly power, failure of voluntary controls on marketing/advertising, etc., "soft" responses giving way to "hard" responses by the political class, similar to previous actions on food safety. That is the types of policy instruments adopted. Will the response be:
   - regulation or voluntary initiatives;
   - criteria for regulation and action, e.g.,
     – market competition
     – the accounting basis for costing environmental and public health externalities.
5. The continuation of investor confidence in the food and supermarket sectors. Within these contemporary changes, one area of relative continuity is the evolving hold that large corporate retailers have upon food supply chains. The growth of the supermarkets is underpinned by innovation and corporate concentration. Innovation and corporate concentration mean that:
   5.1 Food supply chain effects can be driven from the retailing end. Hence supermarkets can take a lead in mitigating the public health and climate change impacts of supply chains – as is the declared intent, in the case of environmental impact, of Wal-Mart.
   5.2 Yet there lie vulnerabilities herein:
   - Some innovations around food supply chains are based on high levels of integration, just-in-time delivery systems and the squeezing of costs and shifting of increased responsibilities on to suppliers. Such integrated supply chains are vulnerable to disruption, particularly around transportation and oil dependence.
   - Corporate ownership is subject to potential take-over from outside equity funds, which in turn may erode and break up existing businesses to gain maximum short-term profit returns. This has been a feature of food and drink manufacturing sectors in recent years.
6. A final dimension resides in food cultures. Rich food cultures are on the defensive, functional food cultures on the rise. Yet there is residing symbolic support for rich food cultures within Europe. The answers to these dimensions are lodged in social structures, valuations of food in the home, in schools and in society at large. Here choice is continually being shaped and micro-level choices continually made.

4.4.6 Implications for current trends in food retailing and consumption according to the future scenarios developed

This section of the paper provides an assessment of future developments within the respective set of food system activities outlined previously (food retailing and consumption) in the context of the future scenarios developed at the second workshop of this ESF/COST Forward Look. The implications of the customised future scenarios for the retailing and consumption part of the food system are outlined below.

Scenario A: Fast Forward – Continuing 2007 for another 20 years

In this scenario there is a continuation of existing trends in the food system – with dependence on the carbon economy extended into fringe carbon-based energy sources and a maturing carbon trading market. Food production levels are high and international trade underpins an adequate global food supply, although the distribution imbalances remain (800+ million hungry). Genomics is increasingly applied to food cereal production and in food manufacturing and processing is targeted to high-value manufactured food products aimed at growing global middle classes especially in the markets of rapid economic growth (such as Eastern Europe and China). The consumer appeal of these functional food products is individualised and highly targeted. The longer-term public health epidemics and environmental externalities of current contemporary consumption trends remain unanswered. In the case of economic growth areas, such as China, the nutrition transition of rapid increase of diet-related diseases exists side by side with under-nutrition through poverty.

Food retailing concentration continues as the marketing and supply chain efficiencies and controls and product variety are maintained or increased. The interventions towards more transparency around food and its contents, origins and production and processing methods remain, led by the corporate food retailers underpinning their efficient market responses and controls. Social inequalities in food consumption remain but are not adequately addressed by state or regulatory response.

4.4 Current trends in food retailing and consumption and key choices facing society

Scenario B: Pause – Globalising markets and higher perception of risk

Public health crises stemming from diet and consumption are prevalent, increasing pressures on interventions in the food system. The environmental costs of extended supply chains have also come more to the forefront of policy agendas. The trend towards greater intervention continues with private governance and public regulatory interventions, resulting in greater certification, traceability, verification of food authenticity and further regulatory-led quality controls. Both regional and traditional food consumption prosper alongside globally-sourced foods as transparency and quality controls are extended across both local and global food supply. No notable changes in food retailing practice are signified, suggesting continued food retail concentration notably through the exertion of quality controls. The inequities identified in supply chain relationships under the buyer- or retailer-led governance of supply will probably be more embedded and accepted. There are some examples of price increases for food, notably due to costing of environmental externalities. The suggestion is that existing social inequalities around food will continue in this scenario.

Scenario C: Rewind – Global crisis, act local

This scenario sees a further evolution and ascendancy of some newer trends that are appearing at the consumption level in Europe. For example, there is an awareness of provenance of foods and their environmental impacts and their methods of production. Also, it sees the re-awakening of issues such as cultivar variety, locality, freshness and authenticity. The traditional cultural elements in European food choice are also still present in this scenario – with the re-embedding and strengthening of local cultural values. Retailing presents a picture of stronger local markets and diversity although this does not explicitly preclude corporate concentration in retail or cross-country ownership. However, distribution is less centralised and takes place on a smaller scale although there are high levels of co-ordination in the food system in Europe, but with this coordination emanating from a regional level it seems. Supply chain inequities are being addressed as local and/or regional producer cooperatives exert more power in relation to corporate retailers.

Steering and intervention are maintained and indeed increased albeit more through different levels of authority. Environmental externalities are addressed – reflecting the current trends where retailers are taking a lead. The externalities in agricultural production are addressed as well as carbon costs of the supply chain. The public health externalities of diet – a feature of current consumption trends – are not clearly addressed in this scenario, but some elements may have improved – "fewer fizzy drinks".

Scenario D: Play – Regionalised markets and low perception of risk

There is awareness of potential crises, and a market response (presumably) to niche marketing of specialised and value-added foods and a growth in organic and sustainably-produced and delivered foods. The more traditional cultural roots of European consumption seem to be maintained in the face of global brands and fabricated foods. This would seem to suggest that current forms of intervention and steering have worked well in terms of more environmentally-sustainable production techniques – but not in some other ways. In particular, there remain social inequalities around food consumption, with a continuation of the public health diet-related inequalities facing lower-income and less-educated groups. Transparency is maintained but does not seem to have met all of its goals – such as health improvements through better information and labelling. Food will cost consumers more. There is a suggestion that retailer concentration may reverse. The trends associated with retailer concentration seem to be counter to those exhibited in this scenario. Smaller and more specialist shops, smaller scale of distribution may favour more regional concentration. Alternatively, the picture of rural depopulation in Eastern Europe suggests increasing urban population growth, a condition favouring continued corporate expansion and concentration in Central and Eastern Europe evident back in 2007. In terms of the supply chain, the scenario suggests that there is less food imported from outside Europe. The dominance of European production suggests a more locally- to regionally-based food supply is dominant with inter-regional trading. The details presented in this scenario do suggest that locality and sustainable production techniques will be important elements in the future of the European food system, with some geographical localities better situated than others.

4.4.7 Research priorities

From our engagement in this ESF/COST Forward Look process and as a result of the work on the retailing and consumption section, we believe that what is broadly needed is a research agenda that seeks to improve our understanding of how Europe achieves improvements across a range of cross-cutting issues in relation to its food systems, namely: *social justice, environmental sustainability, energy sustainability, public health* and *economic well-being*.

More specifically, four broad areas where better information through research is needed are:

Consumption: Seek to generate more specific and socioeconomic sensitive data on food consumption patterns within different EU member states, in order to produce better aggregate data for the EU than exists currently.

Market power: Conduct case studies of the socioeconomic impact of increasing food retail and food service concentration of market share in different EU member states in order to assess how to generate adequate data on the impacts upon food consumption and its cultural as well as socioeconomic settings.

Energy and life cycle analysis: Improve methodology, scope and boundaries for full life-cycle assessments of food products in order to help quantify environmental costs of the current food systems.

Ecological public health: Develop indicators for the notion of ecological public health[9] as a way of exploring food as a point of linkage between the physical environment and population health and consumer culture.

9. For articulation of the ecological public health model for food policy and food systems see:
Lang, T., D. Barling and M. Caraher (2001). Food, social policy and the environment: towards a new model. *Social Policy and Administration* 35(5): 538-558; Lang, T. and G. Rayner (2007). Overcoming policy cacophony on obesity: an ecological public health framework for policy makers. *Obesity Reviews* 8(s1): 165-181.

References

Barling, D. (2001). Supply chain perspectives-contemporary issues: the case of GM food. in *Food Supply Chain Management: Issues for the Hospitality and Retail Sectors.* Eastham, J. F., Sharples, L. and Ball, S. D. (Eds). Butterworth-Heinemann, Oxford, UK. pp 245-256.

British Institute of International and Comparative Law (2005). *Briefing: EU Competition rules and future developments from the perspective of farmers and small suppliers*, March. UK Food Group, London, UK.

Byrne, D. (2003). *Biotechnology: building consumer acceptance; speech by Commissioner Byrne, European Business Summit*. European Commission, Brussels, Belgium.

Commission of the European Communities (1987). *Single European Act 1986.* Official Journal L.169, 29 June.

Commission of the European Communities (2003). *Regulation (EC) No 1830/2003 of the European Parliament and of the Council of 22 September 2003 concerning the traceability and labelling of genetically modified organisms and the traceability of food and feed products from genetically modified organisms and amending Directive 2001/18/EC.* Official Journal L.268/24.

Competition Commission (2000). *Supermarkets: a report on the supply of groceries from multiple stores in the United Kingdom.* The Stationery Office, London, UK.

Debomy, D. (2006). *The Europeans and Sustainable Food – Qualitative study in 15 European countries – Pan European Report*. King Baudouin Foundation, Brussels, Belgium.

Dobson, P.W., R. Clarke, S.W. Davies and M. Waterson (2001). Buyer power and its impact on competition in the food retail distribution sector of the EU*. Journal of Industry, Competition and Trade* 1(3): 247-281.

Dobson, P.W., M. Waterson and S.W. Davies (2003). The Patterns and Implications of Increasing Concentration in European Food Retailing. *Journal of Agricultural Economics* 54 (1): 111–126.

EUREP (2003). History – Eurepgap Fruits and Vegetables, at http://www.eurep.org/sites/index_e.html (accessed 2 April 2004).

Euromonitor (2005a). *Retailing World March 2005*. Euromonitor International, London, UK. 11.

Euromonitor (2005b). *Retailing World March 2005*. Euromonitor International, London, UK. 58-62.

Euromonitor (2005c). *Retailing World March 2005*. Euromonitor International, London, UK. 75-76.

Euromonitor International (2007a). Western Europe: Grocery Retailing Formats by value. Euromonitor International, London, UK.

Euromonitor International (2007b). Eastern Europe: Grocery Retailing Formats by value. Euromonitor International, London, UK.

Euromonitor International (2007c). Western Europe: Grocery Retailers: Company data (by global brand owner) retail value. Euromonitor International, London, UK.

Euromonitor International (2007d). Eastern Europe Grocery Retailers: Company data (by global brand owner) retail value. Euromonitor International, London, UK.

Finch. J. (2007). Wal-Mart boss says he will press suppliers in race to go green. *The Guardian.* February 2.

Grievink, J.-W. (2003). The Changing Face of the Global Food Supply Chain*. Paper to OECD Conference 6-7 February 2003, The Hague.* In *Changing Dimensions of the Food Economy*. OECD, The Hague, The Netherlands.

Grijp, N. van der (2003). European food industry initiatives reducing pesticide use. In *Pesticides: Problems, Improvements, Alternatives.* Hond, F. den, P. Groenewegen and N.M. van Straalen (Eds). Blackwell Science, Oxford, UK. 204.

Health and Consumer Protection Directorate General (2002). *Europeans and biotechnology in 2002: patterns and trends*. European Commission, Brussels, Belgium.

Health and Consumer Protection Directorate General (2006a). *Health and food. Special Eurobarometer 246*. European Commission, Brussels, Belgium.

Health and Consumer Protection Directorate General (2006b). *Risk Issues: Special Eurobarometer* 238. European Commission, Brussels, Belgium.

IGD (2004). *Retailer own brand*. IGD factsheet, at http://www.igd.com/CIR.asp?menuid=51&cirid=1150 (accessed 11 April 2007).

IGD (2007). *Grocery Buying Groups*. Free Factsheet, 26 Feb, at http://www.igd.com/CIR.asp?menuid=51&cirid=2223 (accessed 12 April 2007).

Harrison, R., T. Newholm and D. Shaw (Eds) (2005). *The ethical consumer*. Sage, London, UK. xviii, 257.

Hollinger, P. (1999). Carrefour's revolutionary. *Financial Times*, 4 December.

Kjaernes, U., M. Harvey and A. Warde (2007). *Trust in food: a comparative and institutional analysis*. Palgrave MacMillan, Basingstoke, UK.

Levitt, T. (2007). More farmers give evidence to competition commission. *Farmers Guardian* April 6: 2.

Livsmedelsverkert (National Food Administration) (2005). *National Food Administration's Regulations on the use of a particular symbol – LIVSFS 2005:9*. National Food Administration: Stockholm.

Livsmedelsverkert (National Food Administration) (2007). *Rules for the keyhole system.* http://www.slv.se/templates/SLV_Page.aspx?id=12237&epslanguage=EN-GB, National Food Administration: Stockholm.

OFT (2006). *Grocery market: proposed decision to make a market investigation reference.* March. Office of Fair Trading London, UK.

Planet Retail (2006). 25 October at http://www.planetretail.net

Reardon T., P. Timmer, C. Barrett and J. Berdegue (2003). The rise of supermarkets in Africa, Asia, and Latin America. *American Journal of Agricultural Economics* 85: 5.

Regmi, A. and M. Gehlhar (2005a). *New directions in global food markets.* USDA/ERS February at http://www.ers.usda.gov/publications/aib794/.

Regmi, A. and M. Gehlhar (2005b). *Market access for high-value foods.* USDA/ERS, at http://www.ers.usda.gov/publications/ae.

Schirach-Szmigiel, C. von (2005). "Who is in Power Today and Tomorrow in the Food System", keynote speech to the *Policy and Competitiveness in a Changing Global Food Industry conference*. USDA Economic Research Service, Washington DC, April 28.

Schmidhuber, J. and B. Traill (2006). The changing structure of diets in the European Union in relation to healthy eating guidelines. *Public Health Nutrition* 9 (5): 584-595.

Scott, L. (2005). Twenty First Century Leadership. *Speech to Associates, Wal-Mart,* at http://www.walmartstores.com/Files/21st%20Century%20Leadership.pdf (accessed June 9 2006).

Simms, A., P. Kjell and R. Potts (2005). *Clone town Britain: The survey results on the bland state of the nation*. New Economics Foundation, London, UK.

Vaxelaire, R. (2007). *GFSI update 2006*, at http://www.ciesnet.com/pfiles/programmes/foodsafety/01-02-07-plenarysession-RV%20for%20website.pdf (accessed 12 April 2007).

www.rewe-group.ch/index.php?id=3062 (accessed 5 April 2007).

5. Outcomes

5. Outcomes

The ESF/COST Forward Look on the future of European Food Systems ended with a conference in Budapest where presentations alternated with lively discussions, and closed with some summarising comments. A keynote presentation was given by Christian Patermann, who presented the viewpoint of the European Commission, based on an international conference "Perspectives for food 2030" held in Brussels, 17-18 April 2007 (http://ec.europa.eu/research/conferences/2007/food2030/index_en.htm). He stressed the importance of the food and drinks industry for Europe and the strength and advanced competitive position of this sector of the European economy. He also underlined the need to consider the whole chain. The mere fact that the various components of food systems, namely production, processing, packaging and distribution, and retail and consumption, were brought together in this ESF/COST Forward Look was in itself already useful. The participants appreciated the interaction and participated enthusiastically in the various discussions. They also were convinced that the total is more than the sum of the parts because it includes the interactions between the parts; and the integrated approach allows for outcomes related to food security, environmental conditions and other social goals to be considered in a structured manner. Therefore, further activities in this field were considered very important. The presence at the conference of participants from very different backgrounds was also stimulating. Researchers from universities and knowledge centres met with people working in the private sector, and employees of consumer organisations and retail companies.

It was clear to the participants of the conference that the dramatic shift in influence and power in the various activities of the food system, from soil to shelf, has had a considerable effect on each of the activities themselves. The role of the primary producers has changed considerably and that has caused radical shifts in their positioning. The papers in Chapter 4 demonstrate that the power has shifted from the primary producers, through the processing industry, to the retail industry. The concentration of power with a limited number of supply chain managers has influenced the role of the primary producers as well as the position of ultimate consumers. The reorientation of all players in the chains is fundamental and requires a good understanding of how food system develops.

The audience at the conference agreed that the two most important food system issues for the future are:

- Health, particularly prevention of diseases that are related to lifestyle and demographic changes;
- Sustainability, including the effects of global warming and of the use of bio-mass for energy/fuel production.

In addition – and in accordance with the outcomes of the ETP Food for Life – trust of the consumers is important. This also includes managing the consumer perception of technology.

Putting these issues up front implies that education remains important, not only for farmers in relation to more sustainable production techniques, but also for consumers with respect to the relation between food and health, technology perception and awareness about sustainability. These issues should be addressed in a global context, taking into account the effects that strongly-emerging markets such as China and India will have on food supply and demand. Furthermore, the effects that changes in European food systems will have in under-developed countries should be taken into account.

In this ESF/COST Forward Look a description of the state of affairs in the various components comprising European food systems is combined with a future-oriented scenario exercise. The exploration of possible futures and the preliminary results of scenarios demonstrate that there is an urgent need for a more comprehensive explorative study specifically designed for food system analyses. Such a study should include consistent and scientifically-sound scenarios that go beyond an analysis of what could happen when food systems get disrupted due to, for example, the occurrence of global food scares or a world-wide energy crisis. Story lines may help to open up the minds for possible futures but do not give insight into trade-offs nor result in consistent and technically-possible future scenarios. They are not predictions but virtual and imaginary futures designed to inspire policy makers and scientists and could help in the formulation of philosophies as a basis for further quantitative scenario studies. In his contribution Patermann used the preliminary results of the SCAR scenarios that were also used in this ESF/COST Forward Look. He made clear that this was just the beginning and that more comprehensive and complete scenario studies are urgently needed.

Scenario studies that take well-defined global objectives as a starting point and confront them with normative and technical constraints as well as with technical possibilities have the advantage that they create possible futures which are consistent and technically feasible. What is more, they may fulfil, in part or fully, well-defined and strongly-accepted and -adopted societal objectives. These objectives may have an economic, a social, an environmental, a spatial, a technological or a cultural background, but are in all cases based on programmes and positions of policy makers at national or European level and accepted in policy documents or even in European regulations or national laws.

Such studies have been done for land use and rural development (see Chapters 3 and 4.1), but they are lacking for European food systems. The storylines used in this ESF/COST Forward Look enabled the opening up of possibilities but have a limited value as explorative studies. They also do not predict or forecast future development and have as such a restricted value; on the other hand they strengthen the debate on desirable or possible futures without giving concrete options. Therefore there is an urgent need to do more comprehensive, advanced and consistent future studies that may fill this gap and answer a need. Such studies require a team effort with participants from the four domains that were distinguished in this ESF/COST Forward Look. The explorative studies on agricultural production of groups in the Netherlands and the studies of the European Technology Platform for the processing industry may help to start this exercise. However, the input of the packaging and distribution sector and that of retail is urgently needed. The report from these domains in Chapter 4 may help to develop such comprehensive scenarios for the European food system.

At the final conference there was consensus regarding the need for extensive scenario studies, particularly for the domains of the food systems. The preliminary studies of the European Commission resulting in the SCAR story lines were considered as a stimulating exercise but need expansion into comprehensive scenario studies as indicated in Chapters 3 and 4.

In addition to scenario studies about the European food system as an entity, there is an urgent need for in-depth studies on technical coefficients and development or adaptation paths within each of the domains. The reliability and accuracy of many of the technical coefficients are still confined. That requires much painstaking research on labour and input requirements for various activities in the four domains and on assessment of what improvement is possible, technically but also economically. It demands a good understanding of the basic physical, chemical, biological processes that occur in these living production systems and the way they may be optimised for various environmental and other societal goals. There is also a pressing need for more technical and socioeconomic research on the interface between the various domains and an investigation of the possibilities to stimulate synergism. Moreover, the change in preferences in consumer behaviour will affect the various components of the chain and that will also require multidisciplinary studies. There are already some typical examples, but they are still very rare.

The societal desire and politically broadly supported view to contribute to sustainable development is already internationalised in many food and drinks industries. In addition, upgrading of supply chains is being implemented in such a way that environmental efficacy and efficiency are substantially increased, social conditions are considerably improved, economic results increased and more space is left for nature and forest development. All these developments and strongly-desired changes are taking place, but in a somewhat disorganised manner. This ESF/COST Forward Look demonstrates that there is a clear need and political will for strengthened collaborations and a clear commitment to comprehensive studies for European food systems that will enable the changes that have to take place in this affluent, but also responsible European society which really wants to contribute to a sustainable world for current and future generations.

6. Research agenda

Based on the outcomes of the ESF/COST Forward Look on the future of European Food Systems, as described in the previous chapter, the following research agenda was formulated:

(1) **Follow-up research activities on the whole food system are urgently needed** for in-depth studies on technical coefficients and development paths within each of the food system activities: production, processing, packaging and distribution, and retail and consumption;

(2) **Comprehensive and explorative scenario studies are called for** to analyse outcomes of different development pathways related to food security, environmental conditions and other social goals in a structured manner;

(3) **Follow-up studies should include all relevant stakeholders**; not only researchers from universities and knowledge centres but also people working in the private sector, and employees of consumer organisations and retail companies;

(4) **Health and sustainability require due attention** in follow-up studies as these are the two most important food system issues for the future;

(5) **Production of safe food for personalised nutrition requires an action plan** to follow-up new discoveries in order to eliminate/reduce threats arising from nutrition patterns and from new contaminants generated by technology and climate change;

(6) **An important element of follow-up studies is education**, as this remains important, not only for farmers in relation to more sustainable production techniques, but also for consumers with respect to the relation between food and health, technology perception and awareness about sustainability;

(7) **Cooperation with ongoing activities is required** to make follow-up studies efficient and effective (e.g., the European Technology Platform) and may support European policy making, notably the reform of the Common Agricultural Policy in 2013.

7. Organising Committee for the Forward Look

Co-chairs:

Professor Rudy Rabbinge, Sustainable Development and Food Security, Wageningen University and Research Centre, The Netherlands

Professor Peter Raspor, Department of Food Science and Technology, University of Ljubljana, Slovenia

Members:

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Professor Kostas Gouliamos, Management and Marketing Department, Cyprus College, Cyprus

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Ms. Bouktje Stol, Science Officer (to June 2008),
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Dr. Arja Kallio, Head of Unit, Life, Earth and Environmental Sciences, European Science Foundation (ESF), France

Annex

European Food Systems in a Changing World – Science Policy Briefing

EUROPEAN SCIENCE FOUNDATION
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SCIENCE POLICY BRIEFING • March 2009 36

European Food Systems in a Changing World

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Foreword

Food is essential to human wellbeing. For millennia, food has been produced, traded and consumed locally, and, while in some regions farmers, pastoralists and fisherfolk generally still sell their products in local markets, the overall picture of local production and consumption has changed radically over the last few decades. This is especially so in Europe and in other parts of the Western world where society has increased food availability by employing industrial production approaches combined with regional and worldwide exchange of food. These changes in producing, in processing, in packaging and distributing, and in exchanging and consuming food (in short, the "food chain"), have already left their mark on the environment with altered landscapes, water cycling and biodiversity, and also contributing to climate change. They have also affected consumer behaviour and increasingly the consequent changes in consumption patterns are having negative and positive effects on health.

Food safety is a major issue nowadays and is a challenge for the production chain. For example, the epidemic of bovine spongiform encephalopathy (BSE) in the 1990's affected seriously Europe's beef production. Likewise the recent production and consumption of tainted milk-powder in China has had serious consequences locally and raised concern elsewhere due to its global export of the product.

Changes in climate, population growth, energy production and economy closely interact with these food chain activities and hence food security at large. The dynamic interactions between these components can have dramatic effects as witnessed by the recent sharp increase in food prices, which led to food riots in many countries. The increase in food prices is a complex matter of a global nature but one principle contributor is the change in the demand for food. The per capita consumption of food in major emerging economies such as India and China continues to rise in particular due to a more meat-based diet. This is paralleled by the Western world's increasing demand for biofuels, which both compete for land and other resources and/or are derived from food crops themselves. Volatile fossil fuel prices also contribute to food price inflation since many stages of the food chain are highly oil-dependent, with the situation being complicated further by export quotas and trade restrictions on internationally-exchanged food. Underlying all is the need to satisfy the increased food demand of a population which is estimated to grow to 9 billion people by 2050 while minimising environmental degradation. New technologies, management methods, policies and institutional arrangements will all be needed to increase both the availability of food – and access by all sections of societies to food – while reducing the environmental impact of the food chain.

Europe's Food Security: Priorities for Science Policy

The rapidly-growing awareness of major global issues such as climate change and shifts in energy policy are raising fundamental concerns about Europe's food security in relation to other needs of society ("competing claims"). This needs the urgent upgrading, renewal and strengthening both of the complementary parts of Europe's food systems, and of the system as a whole. The ESF/COST Forward Look on "European Food Systems in a Changing World" identified critical areas of research to address this need.

These examples illustrate the dynamic nature and complexity of food systems. It is against this background that ESF and COST joined forces to tackle the issue of European Food Systems in a Changing World through a Forward Look. The objective of the Forward Look was to develop medium- to long-term views of future research need around the thematic focus of food security. It was multidisciplinary in nature, involving the ESF Standing Committees for Life, Earth and Environmental Sciences, Medical Research, Humanities, the Social Sciences and the COST Domain Committees for Food and Agriculture, Earth System Science and Environmental Management and Individuals, Societies, Cultures and Health. Both the Science Policy Briefing and the Final Report have been internationally peer-reviewed, and have been approved by the relevant ESF Standing Committees and COST Domain Committees.

This ESF Science Policy Briefing presents the main recommendations of the Forward Look's Final Report, which describes a research agenda and actions to be taken in Europe for this highly timely and important topic. The action plan addresses the complex challenges ahead and aims to contribute to shaping European food policy.

Professor Marja Makarow
ESF Chief Executive

Professor Francesco Fedi
COST President

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The Issues

Recent decades have seen dramatic transformations ("megatrends") which have characterised the development in the food systems which underpin Europe's food security. These include productivity increases per hectare, per man-hour and per kilogram of input; an increased industrial approach, where efficiency and efficacy not only count in economic terms but more and more in environmental and social terms; an increase in the vertical integration in the food chains, where the retailer and consumer have a greater influence on what is grown and how, partly due to a better understanding of the effects of nutrition on human health; and a wider set of objectives for primary production where environmental goals, water- and nutrient-use efficiency, biodiversity and landscape conservation are increasingly important.

In addition to these developments, other aspects of the European food system have also been radically changing due to changes in a number of key "drivers". These relate to changes in mobility and cultural mixing (leading to increased variation in diets), and growing consumer pressures especially in relation to food safety, animal welfare and ethical trade. Other drivers relate to changes in technologies, especially in food processing, packaging and distribution, often driven by the desire for convenience foods. Further drivers relate to increased governmental regulations, and changes in retailing and food prices. As a backdrop to all these drivers are changes in climate and other environmental conditions, a topic of increasing political and scientific importance.

These changes prompt a number of questions:

- What does this mean for Europe's agricultural landscape?
- What does this mean for Europe's food-related industries?
- What does this mean for Europe's competitiveness?
- What does this mean for Europe's food security and the health of the population?

How should Europe's research community best respond? Given the complexity of the issues, it is clear that an innovative approach is needed which encompasses the whole food system, not just agriculture; which includes industry and policy, not just researchers; and which is based on clear guidance on research policy. A food systems approach provides a logical and effective framework within which to develop such a policy.

Food Systems Concepts

Food systems underpin the primary societal goal of food security[1]. Food systems comprise a number of activities. These are (i) producing food; (ii) processing food; (iii) packaging and distributing food; and (iv) retailing and consuming food. These four sets of food system activities are influenced by a range of factors, each of which has an associated research community (*Figure 1*).

In addition to underpinning food security (i.e. food availability, access to food, and utilisation of food), these activities also give rise to a number of other outcomes, many of which contribute to – and influence – other societal goals such as employment, health and social and environmental conditions. Both the activities and the outcomes are influenced by the range of interacting drivers, but they also feed back directly and indirectly to modify the drivers themselves (*Figure 1*).

Societal interest in establishing an equitable and sustainable balance between the range of outcomes related to food systems gives rise to much debate on "tradeoffs" within society in general, as well as amongst those involved in the development and delivery of policy and scientists from all disciplines. It concerns the full range of spatial levels from local to Europe as a whole. The debate is hampered, however, by lack of a clear understanding of the outcome of food systems activities specifically related to food availability, food access and food utilisation. The food system approach provides an analytical lens through which food security, and its links to drivers and other food systems outcomes, can be analysed. Changes in lifestyle related to the growth of convenience foods and the growing problem of obesity are also a matter of wide concern (in addition to genetic and environmental factors, diet has a big influence on the presence of several illnesses). The development of specific functional foods and nutraceutical products aimed at the prevention of these problems could result in a considerable improvement for people's quality of life. It is also highly significant that the widely-heralded advances expected from genetically-modified foods only a few years ago have been largely postponed in Europe as public uneasiness mounted. Food safety is also an increasing issue, triggered by a number of recent concerns around the world.

Future European food systems will be different due to changes in the nature and magnitude of drivers. In addition, further changes in the on-going

[1] Food security is defined as: *when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life* (World Food Summit, 1996).

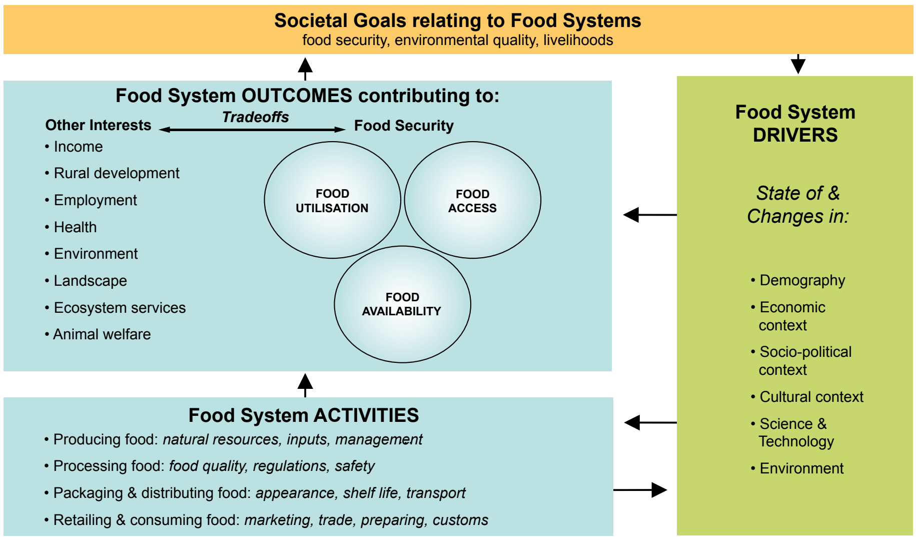

Figure 1: Key Food System Drivers, Activities, Outcomes and Feedbacks. [Derived from Ericksen, P.J. and Ingram, J.S.I. (2005) *IHDP Annual Report 2004-5*, pp. 45-46; and from Ericksen, P.J. (2008) Conceptualizing food systems for global environmental change research. *Global Environmental Change* **18**, 234–245.]

megatrends will be compounded by changes in major uncertainties related to consumer preferences and lobbying (especially related to food safety), reform of the Common Agricultural Policy (CAP) and world trade arrangements, and the shifting influence (power) of big food retailers operating close to the consumer (which are changing the retailers' buying behaviour and which also have the power to set food standards themselves), and global environmental change.

The Need for an Innovative Science Policy Agenda

Much research has been conducted on technical and policy issues for agriculture, fisheries and feed/food in both social and natural sciences. This has generally been of a disciplinary nature, addressing specific aspects of food system activities and sub-components of their outcomes as contributing to food security (*bullet points in Figure 2*). The interactions between key sub-components of food security outcomes (*arrows in Figure 2*) are however insufficiently researched. Improved understanding of these interactions, and how changes in the drivers will affect them, is crucial in being able to address the higher-order issues relating to the food security and the tradeoff debates. This is because many of the sub-components are themselves linked to both drivers and other food system outcomes (*Figure 1*).

Two overarching questions set the scene for integrated European food systems research over the next decade:

1. How will the drivers of the European food system – and the interactions between them – change in the next few decades? Example key issues include changes in CAP, climate, WTO, lifestyle and consumerism. *(cf Figure 1)*
2. How will these changes affect the interactions and conflicts between the food security outcomes of food availability, access to food and food utilisation? *(cf Figure 2)*

These questions were used to set the context for the recently-completed COST/ESF Forward Look "European Food Systems in a Changing World". The Forward Look included a number of distinct, but closely-related, activities. Workshops agreed working questions to guide the development of a set of papers discussing the food system activities.

Papers were drafted for each of the food system activity "sets" (*Figure 1*) which reviewed the current situation and trends in each. Existing European-level scenarios were then reviewed to determine their suitability for food systems analyses. Based

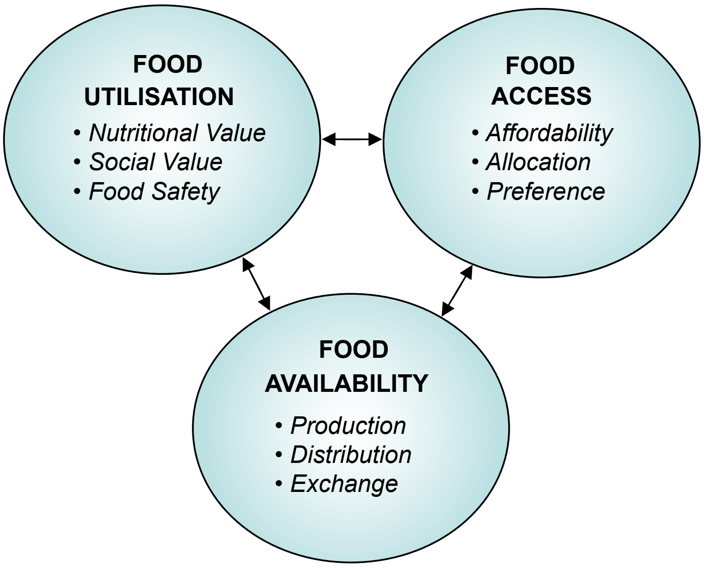

Figure 2: Interactions between food security outcomes. [From: Ingram, J.S.I. (2008) Food System Concepts. In: *ESF/COST Forward Look on European Food Systems in a Changing World.* ESF-COST Final Report.]

on this, a set of new proto-scenarios specifically tailored for food system research were developed. The four papers were then revisited and a final section incorporated in each which discussed possible future trends given each proto-scenario. The systematic approach employed in the Forward Look, and the outcomes and recommendations, were presented in a final conference from which came a set of science policy recommendations.

It is clear from the Forward Look, and supported by earlier scenario studies, that there is ample space for policy choices. There is also an urgent need. A productive, more environmentally-friendly, and internationally more acceptable European food system is possible when the right political choices are made.

- European policy makers should make clear choices based on well-defined objectives and goals. Achievable goals, rather than instruments *per se*, should be the focus of policy discussions.
- European policy should withdraw from policies that undermine the agricultural development in developing countries or that promote unsustainability spirals in terms of land, water and natural resources use.
- European food systems should be considered much more as integrated systems rather than as individual activities.

Setting best policy given the many uncertainties is difficult, and a scenario-based approach would help by analysing implications of policy and management options within a set of coherent, internally-consistent storylines of credible futures at the European scale. Taking a long-term (25-40 year) perspective in addressing European food systems is important, as many key uncertainties are likely to play out strongly over the coming decades – yet responding to these uncertainties already today will reduce future impacts and costs substantially.

Research on Europe's future food systems must be based on the notion of safe foods produced in a sustainable and equitable system. Integrated analyses will need to draw on the many research advances in all the food system drivers listed in *Figure 1*, and while sustainable development takes into account all these aspects, it is not definable in a simple manner, and lacks well-described disciplinary instruments for analysis. This, coupled with the many factors involved, necessitates research in this complex area to be based on a strongly interdisciplinary approach, building on the foundation of disciplinary studies, and guided by the needs of policy formulation and scientific excellence.

Research Priorities

The Forward Look final conference agreed that future research must be geared towards (i) health, particularly prevention of diseases that are related to lifestyle and demographic changes; and (ii) sustainability, including the effects of global warming and of the use of biomass for energy/fuel production. In so doing, follow-up studies need to include all relevant stakeholders, i.e. not only researchers from universities and knowledge centres, but also people working in the food industry, in consumer organisations and in retail companies. Follow-up studies in education are also critical, as this remains important not only for farmers in relation to more sustainable production techniques, but also for consumers with respect to the relation between food and health, technology perception and awareness about sustainability. Cooperation with ongoing activities is required (e.g. the European Technology Platform, and especially on the food chain/food system concepts) to make follow-up studies efficient and effective, and to offer maximum support to European policy making, notably the reform of the CAP in 2013.

The review of earlier scenario exercises and the results of the preliminary scenarios developed in the Forward Look demonstrate the urgent need for a more comprehensive explorative study specifically designed for food system analyses. Comprehensive scenarios would be based on story lines which are not predictions as such but virtual and imaginary futures designed to inspire policy makers and scientists, and to help in the formulation of further quantitative scenario studies. Such a study should therefore include consistent and scientifically-sound scenarios that go beyond analyses of what could happen when food systems are disrupted by individual "shocks" due to, e.g., the occurrence of global food scares or a world-wide energy crisis; they should encompass a comprehensive set of drivers and be designed in close collaboration with intended users.

Based on the outcomes of the Forward Look the following research priorities were identified for consideration by both national and European agencies:

(1) **Comprehensive explorative scenario studies.** These are needed to help guide analyses of the outcomes of food system activities for different development pathways and to analyse the tradeoffs between food security, other social interests and environment goals.

(2) **Research on the key activities related to food security, in the context of the European food system.** This is needed for in-depth studies on technical coefficients and social, economic and environmental aspects of development paths within each of the food system activities.

(3) **Enhanced consideration of food safety and the links between food and human health.** Consumer confidence in food quality and safety is a growing issue and needs to be backed by reputable and transparent studies including behavioural research on consumption patterns.

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