Give Peas a Chance: Transformations in Food Consumption and Production Systems

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Summary

Food production chains can be organised in a variety of ways. Conventional ‘industrial’ agricultural practices are based on advanced breeding techniques and major inputs of chemical fertilisers and pesticides. Food produced in this way is transport-intensive, requires high-energy processing, relies on modern retailing systems and demands high-tech kitchens. Strategies for alternatives are usually contrasted with this system. “Organic” strategies are focused on a system of agriculture that avoids the use of synthetic chemicals and draws on natural systems and cycles. Food processing aims to reduce environmental impacts. Organic farming is often linked to new methods of retailing that seek to cut out supermarkets. Many advocates argue that the industrialised systems should be dismantled and replaced with alternative methods of agriculture, food processing and distribution that emphasise social and environmental sustainability.

Another alternative is the ‘new industrial’ system based on crop management using genomics and other resource productivity enhancing technologies, such as water recycling. This strategy is new because it takes seriously criticisms of conventional industrialised agriculture and aims to bring together the delivery of nutrition and health care - through functional foods and nutraceuticals. This strategy is based on high outputs and global supply chains, but aims to apply new technologies to radically reshape agrofood systems towards sustainability.

This paper looks at the environmental and social sustainability of different strategies by analysing the whole chain of production, processing, distribution and consumption activities of the production of frozen peas, a vegetable that is ‘symbolic’ of modern food systems and the UK diet. It looks at such issues as:

Which technologies are seen as critical for determining sustainability in the pea production chains, and which actors are promoting technological change? What are the implications for technological innovation of different pea production and consumption strategies? To what extent do the different strategies ensure variety from which future technological innovations will emerge?

Introduction

Technological innovation and the changes in supporting economic and social structures that come with it (collectively known as “innovation”), must be central to the achievement of sustainable production and consumption in all areas of human activity. If current systems of production and consumption are unsustainable in terms of their resource usage, ecological impact and long-term environmental effects, then new systems of provision are needed, entailing new processes, new products, new services and new management practices; if these do not exist, they will have to be invented and launched into social and economic use. Conversely, new forms of social relationships that are innovated with environmental improvement as their goal will inevitably use products and processes in new ways. There is thus a strong relationship between innovation in socio-economic arrangements and innovation in the material products and processes in which they are entwined – sociotechnical systems of provision as they might be called.

Consequently, understanding the processes that are likely to underpin these developments is crucial for policy intervention to achieve desirable forms of sustainability. In short, we consider the processes of technological and social innovation and the means of guiding them into sustainable directions.
In this paper, we explore socio-technical systems for the provision of food. We explore the dynamics of the system of food consumption and production and the various alternatives to the current system – represented through ‘advocacy strategies’ by proponents of the alternatives - that are argued as being more 'sustainable' environmentally and/or socially.

As an example, we focus on the system of provision of the frozen pea in the UK. This vegetable is especially important, symbolically if not quantitatively or nutritionally, for the UK diet. It is the green vegetable, the first one to be available in a frozen form in the 1950s and the first to have its consumption, in a ‘fresh’ form, detached from its seasonality. It symbolizes other things as well – as something that might be considered ‘unsustainable’, both in growing it and in freezing and distributing it. We analyse the frozen pea system to identify the sources of technological control and possible innovation solutions in dealing with the systems ‘unsustainabilities’. We might expect that similar analyses could be done on the systems of provision of other types of food – indeed these are the subject of a research project from which this paper is derived.

**PART 1: NOTION OF FOOD SYSTEMS AND ‘TRANSFORMATIONS’**

**1.1 Introduction**

The notion of 'sustainability' in its broadest meaning, as opposed only to the reduction in the environmental impact of individual products or agricultural or industrial processes, requires thinking in 'systemic' terms. Transforming human activities with respect to food implies a focus on the whole system of agricultural, industrial, retailing and household 'sectors' and their interrelationships, with their strongly connecting regional, national and international dimensions. In addition, systemic thinking is concerned with more than the production of food, in agriculture and food processing factories; it also includes distribution and the preparation of final meals whether this be in individual households or in more communal arrangements whether commercial or non-commercial.

We can thus define Food Consumption and Production Systems (FCPSs) to include the whole 'chain' of human-organized activities concerned with the production, processing, transport, selling, cooking and eating of food and the disposal of the wastes of such activities. This includes:

- the inputs to farming (including water, chemicals, seeds and machinery),
- the agricultural sector (including fishing and gathering),
- the food processing industries (and the associated packaging industry)
- food distribution (including wholesaling and retailing and the transport associated with these),
- equipment for food storage and preparation,
- food 'service' (i.e. restaurants/canteens/take-aways),
- the household activities of shopping, cooking and clearing-up, and finally,
- the disposal and recycling of food and packaging wastes.

This ‘systemic’ approach to Food Consumption and Production is illustrated in Figure 1. This shows the ‘flow’ of food materials and some of the major inputs to that flow from agriculture (local or imported) within, say, one country, through the other institutional elements of the system listed above, in food processing, distribution to final consumption in kitchens, canteens and restaurants. At each stage of the flow, there are significant environmental and resource-use impacts, some of which are indicated in the Figure. These include inputs of energy (which has implications, depending on the source of energy, for levels of greenhouse-gas emissions in the burning of carbon fuels for heat or electric power),
water and eco-toxic chemicals (for examples in refrigerants and packaging). An essential environmental impact, one which is the subject of much argument and advocacy of alternatives, is that due to the effects of transport between the elements of the system, whether by road or rail (within continents or regions) or by air and ship (between continents). The Figure is intended to point up the need to consider transformations to sustainability as being about the whole system – ‘from farm to plate’, so to speak – rather than being limited to the certainly important concerns of agricultural sustainability. The large size of the ‘top end’ of the Figure, which show flows of distribution through wholesalers and retailers and on to places in which food is cooked in either private (home kitchens) or public spaces (canteens/restaurants/take-away outlets), is a deliberate distortion to emphasise the importance of the institutions of consumption, rather than just those of food production. Thinking 'systemically' allows a focus on an important, if neglected, aspect of sustainability, namely the intimately connected relationships of production with consumption.

In this paper, we are especially interested in the role of technological innovation in its institutional contexts, in this case with respect to changes taking place in the agricultural and food 'industries', widely conceived. In particular, we explore the notion that there are two factors that are significant disturbers to any notion that there can be 'one' permanent type of sustainability. Firstly, we are keen to emphasise the differing socio-economic structures of the different FCPSs in different regions of the world, something that even trajectories of 'globalisation' will find it difficult to change (the ‘varieties of capitalism’ argument). Secondly, there are the inherent economic and social disturbances caused by the innovative, variety-generating, nature of contemporary capitalist competition (the Schumpeterian ‘creative destruction’ argument). New science, new organisational knowledge, new processes, products and technologies will induce new and continuously changing combinations of production and consumption. Sustainability, regional differences in institutional structures, variety and innovative combinations: these are the concepts with which we try to juggle.

1.2 System strategies

1.2.1 We would claim from the literature on food and sustainability that it is possible to identify four different system 'strategies' for the ‘organisation’ of Food Systems. These are not intended necessarily to be mutually exclusive. Indeed, in any real economy, a combination of some or all of these strategies may well be in operation. We make the assumption that there is no single logic driving the development of FCPSs, and that different societies exhibit a complex and contingent mix of different FCPSs at different levels of definition and development. In this respect, in spite of the ‘uniformity rhetoric’ of globalisation (by its proponents and opponents), we would suggest that there is a great deal of systemic variety. The human-human and human-ecosystems interactions continue to generate comparative advantage and disadvantage between different combinations of strategies, often re-configuring and shifting patterns of inequality between global regions. Consequent patterns of trade and inequalities of exchange continue to differentiate rather than homogenise the world food economy.

In this respect, globalisation is far from having abolished diversity arising from biological properties of foods and their interactions with geographical, climatic and other environmental conditions. Studies of the way that new crops and foods have developed and diverged in all directions around the globe (sugar, tea, coffee, chocolate, potato, tomato) have emphasised how differently they become inserted into the socio-economy (see Mintz, 1985; Diamond, 1997; Dicum and Luttinger, 1999; Zuckermann, 1999; Coe and Coe, 1996; Harvey et al, 2002). Cultures of production and consumption, patterns of land-owning, the organisation of
the household economy and its relation to the market economy, remain critical underpinnings of this variety.

1.2.2 The literature on moving towards more sustainable FCPSs has a strong bias to policies for dealing either with the environmental problems of agriculture or, increasingly, how agriculture might be affected by global environmental changes. Strategies for new systems are usually described in opposition to the supposedly dominant institutional forms of food production, distribution and consumption to be found in the OECD countries and said to be the form that is diffusing most rapidly into developing countries. This 'industrialised/modern' FCPS is based on 'Fordist' principles of seeking high labour productivity and economies of scale in all elements of the system, especially in agriculture and food processing. Fordist principles have been increasingly extended to distribution, with the domination of supermarkets in retailing and mass catering in eating-out. Household consumption is based on a wide variety of mass produced commodities with a historically high consumption of animal products. Agriculture and food processing is the subject of continuous innovation, based on scientific understandings. There is a constant search for innovation in products and agricultural/factory processes.

Within agriculture, there is high energy use (especially in machinery) and a large demand for water, requiring substantial investment in irrigation systems. Crop production relies heavily on synthetic chemicals as fertilisers and pesticides, though chemical use has become more targeted. Since 1960, there has been a dramatic upsurge in the use of 'hybrid' seeds as part of the 'Green Revolution'; in the 1990s, in some countries and for a small number of crops, new seeds have been produced based on methods of Genetic Modification (GM). Animal rearing is similarly industrialised, as meat production soars, with corresponding criticisms of inadequate attention being paid to animal welfare. Farms will typically be large, with low (and reducing) labour inputs, integrated forms of farm and crop management. Applying the classic 'Fordist' model of manufacturing to the primary sector, high-input efficiency and labour productivity of agriculture is matched to the production of uniform products geared for mass markets. High-yield mono-cropping reduces pressure on marginal land and reduces the amount of land needed for agriculture.

Factory processing of raw materials has very high labour productivity through the application of automated flow processing technologies. Production is geared towards mass markets with increasing use of a wide variety of packaging materials in attempts to differentiate new food products. Distribution is based on production-led supply chains that are strongly dependent on the use of modern Information Technologies. As supply chains lengthen, global food trade is increasingly based on carbon-rich fuels for road, sea and, increasingly, air freight transport. Retailing becomes a high capital-intensity industry, with a high dependence on constant innovation in packaging and refrigeration technologies. In most countries, power in the supply chain shifts away from food processors (and certainly away from farmers) to large retailing companies.

Food service increases in volume, as more meals are eaten out or come from take-away establishments. The trend is towards Fordist delivery (pejoratively focused on the production and selling methods of fast-food chains like McDonalds). Within kitchens, food preparation becomes increasingly highly capital- and energy-intensive as does clearing up, with the introduction of ever more electrically-powered pieces of equipment (fridges, freezers, cookers, mixers, microwaves, dishwashers, etc.). There is a rising preference for prepared foods and food shopping is increasingly based on purchase from supermarkets with the attendant use of cars for shop to home transport. Though some recycling for packaging is favoured, it is still limited with any recycling of household food waste limited to composting for gardens.
This form of food production and consumption has been the subject of much analysis, usually to criticise it. Indeed most writing on the application of ‘Fordist’ (often described as ‘mass production’) techniques applied to FCPSs is presented to be critiqued. Ritzer (1998) makes this explicit in his book on the organisation of modern service industries, which have become “McDonaldized” when he says that “in the context of high-end restaurant chains, it is useful to discuss an analogy between Ford and Fordism and McDonald’s and McDonaldization” (p.179). Schlosser (2001) extends Fordist notions to the whole of the agriculture and food processing system. Other writers (such as those in the collection edited by Goodman and Watts, 1997) are less sure of describing the whole food system as Fordist, though they are able to claim that certain foods are mass produced and consumed in Fordist forms in the USA (especially, “wheat, corn, soybeans, beef, hogs, chickens, lettuce, tomatoes and kiwi fruit”, p.228).

Thus, this ‘industrialised/modern’ form FCPS is much caricatured by critics, not just for the quality of the food it provides (with rising concerns about food safety and hygiene) but also for its insensitivity to environmental and animal welfare concerns. Yet, it has been responsible for huge increases in yields, leading to a reduction of food poverty in OECD countries and, through the Green Revolution, in much of Asia and South America. However, critics have probably over-stated the rate of spread of Fordist FCPSs and the degree of global uniformity that it has brought. In fact, there is still a large amount of global diversity, even in superficially similar agricultural, processing and distribution systems. Nevertheless, historically it has proved a pre-condition for the rapid urbanisations of the last 60 years.

### 1.2.3 What alternatives to ‘industrialised/modern’ systems are there?

We would suggest that there are three other ‘strategies’ for achieving more sustainable and food secure food production and consumption that have been advocated.

The first we have called the ‘traditional sustainable’ or ‘agroecological’ strategy. It is an extension of ‘traditional’ methods of production in poorer countries, avoiding the ‘industrialised/modern’ trajectory. The emphasis is on small-scale agricultural production that is culturally- and eco- sensitive. The strategy involves the integration of natural and regenerative processes, with few (but some) chemical inputs and the use of nutrient recycling, natural nitrogen fixation, soil regeneration and the use of natural pests to control other pests. Food wastes would be recycled into agriculture. The use of GM seeds is not ruled out, so long as seed development is locally-based with the ownership of the genomes being communal rather than appropriated by some large international seed company. Diets would not necessarily be vegetarian, but production of meat would be limited. Farms would be small, based on traditional rural community patterns with high labour inputs, making use of the knowledge and skills of local farmers; indeed local skills and knowledge are seen as a resource for innovation that reproduces community cohesion. The strategy would be initially focused on production improvement for local consumption, with limited processing, though local processing for wider sale might be possible. Innovation in rural household management would be focused on better, fuel-saving cooking equipment and food storage.

Though its advocates stress the need for social learning in developing such systems to move away from the downside of traditional agricultural systems, there is plenty of evidence of such systems causing soil erosion, water pollution and diversity loss. This strategy is thus focused on sustainable rural development with limited attention paid to urban issues. The strategy is about increasing food security amongst the rural poor, whilst maintaining environmental stability and allowing for local learning. Such systems however do not necessarily produce surpluses for sale to cities and, while vital for the rural poor, are in global terms a ‘niche’. Other methods of increasing food production would surely be needed to feed
the cities, though successful rural developments could limit the movement to the cities and, indeed, encourage migration back to rural areas.

1.2.4 The second strategy we have labelled 'organic'. This strategy is difficult to characterise precisely, due to the controversy over what constitutes organic food and organic systems of agriculture and how such systems fit into world systems of production and of trade. Advocates of organic systems focus on food production that engages with natural systems and cycles in agriculture and processing. They approve of the proposed dismantling of 'industrialised' systems that are prevalent in rich countries and their replacement with methods of agriculture, food processing and distribution that emphasise social sustainability. Much cultural significance is given to 'natural' products and production methods as a means of ensuring health - of humans, of farm animals and of the eco-system in general. There is a variety of disputing definitions of what 'organic' means; however all focus on the minimisation of agricultural pollution (especially damage to soils and water courses) and maintenance of genetic diversity. This is to be achieved by the avoidance of 'chemical' inputs into agriculture (synthetic fertilisers and pesticides) with the use of closed nutrient cycles (with much waste recycling). The use of GM seeds would be completely ruled out. Animal husbandry methods emphasise the physiological and ethnological needs of animals. Agriculture based on these principles is likely to be more labour intensive than 'industrialised/modern' systems and be associated with smaller farms.

Some advocates of this strategy go further than a concern with agricultural methods; they see it as part of a socially and ecologically responsible approach to the production and distribution of food, with a strong bias to bioregionalism and against large-scale world food trading, though some organic food grown in large farms for international export can be countenanced. There is a focus on the need to maintain high food quality, with the minimal use of synthetic additives. This leads to a strong need for certification throughout the food chain with organic production criteria encompassing waste management, packaging systems and energy-saving systems in processing and transport. The emphasis is thus on overall environmental considerations. In the shorter term there would be growth of specialised (niche) markets for organic products; in the longer term there will be much more local food distribution and thus a reduction in world food trade, restricted to items that can only grow in certain regions. There would thus be a shift to seasonal and regional foods; this would suggest opposition to certain kinds of processed organic food that might be linked to newer food preparation methods (e.g. microwaving of prepared meals, but there is as yet no agreed view about this.

A bioregionalist focus implies opposition to the buying practices of large supermarkets and thus favours more retail diversity. The Internet helps the growth of direct sales from producers – 'from farm gate to dinner plate' – reducing the power of supermarkets. A strong bias to bioregionalism and against world food trading means that in some respects the 'organic' strategy resembles the 'traditional/sustainable' strategy, especially when it is directed to the poorer regions of the world. However, it is intended to be most relevant to those parts of the rich world that have had their FCPSs 'Fordised'. When linked with environmentalist critiques of Fordist food distribution systems, organic strategies have major implications for the structure of existing industrialised FCPSs.

1.2.5 The third strategy we have called 'new industrial': 'new' because it is advocated as a restructuring of the 'industrialised/modern' strategy to take account of a number of scientific and technological developments of the last 20 years. First of all, it takes seriously criticisms of the environmentally-destructive nature of post-1945 methods of high-productivity agriculture. This leads to the introduction of new methods
of crop management, often using IT, and diversification of agriculture into new materials. The strategy could readily incorporate the technical and certification features of the 'organic' strategy, though not the other, more social and bioregionalist aspects of the organic movement. Secondly, the use of genomic knowledge potentially allows a much greater opportunity to develop new seed varieties both through genetic engineering and traditional breeding methods enhanced by a better understanding of a crop’s molecular biology. This is seen as a huge jump from mere 'Monsanto-type' genetic modification, which used genome knowledge linked only to changes in the use of agrichemicals. Though developments in the application of genome knowledge remains reliant upon big firms and their ability to mobilise large resources for innovative developments (This might include the entry of countries of the 'South' - e.g. Brazil, China and India - into world biotechnology knowledge trading). This knowledge also presents the opportunity to improve crop protection technologies, through a better understanding of crop pathogenicity. There are a number of benefits to be gained from better understanding of the full genetic makeup of crop plants and food animals, as part of extending the benefits of the Green Revolution beyond the basic crops of maize, soya and rice. Thirdly, it takes on board the notion of foods as a way of delivering health care, through the development of functional foods and 'nutraceuticals'.

The strategy is still based on high outputs in agriculture and processing within internationally-organised production and trade. It continues the strong 20th century emphasis of the industrial/modern system on high output and low labour agriculture and innovation in agriculture and food processing based upon science. Farms would still be large with high productivity (and low labour inputs) but with new developments in soil and pest management that allow more eco-sensitive approaches to biodiversity. Greater attention would be paid to hygiene and quality, especially in relation to animal products with the development of new non-soil methods of food production (e.g. fungal protein. We would expect continued innovation in food types and processing methods (with an emphasis on processing energy reduction) as well as innovation in packaging with new materials to substitute for plastics. A decline in meat consumption in OECD countries is assumed but there would be a large increase in consumption of processed foods and meat products in industrialising countries with concomitant increases in consumption of all kinds of storage and cooking equipment in retailing and household sectors as urban incomes rise. In OECD countries we might expect an increase in household consumption of ‘intelligent’ kitchen equipment, some directly linked to shopping through internet ordering and home delivery.

The strategy thus continues the focus on producing large quantities of food for rapidly expanding urban populations. It seeks to respond to the undoubted environmental degradation that 20th century agriculture has caused by the application of new technologies, but by the application of further modern technologies – especially in biotechnology – that are considered risky by many environmentalists.

In the next part of the paper, we explore a system of provision of one particular food, seeking to identify the potential for the alternative strategies that are advocated as preferable to Fordist systems. The production of frozen peas can be seen as the example of a Fordist production and consumption system. Sustainable alternatives to it need to be considered to give peas a chance...

PART 2: GIVE PEAS A CHANCE

2.1 Introduction

According to Robert White, ex-President of the US National Academy of Engineering, Industrial Ecology is “the study of the flows of material and energy in industrial and
consumer activities, of the effects of these flows on the environment and of the influences of economic, political, regulatory and social factors on the flow, use and transformation of resources.” (1994, emphasis added) The direction of flow between the ‘physical’/ ‘material’ world and the ‘social/economic/political’ world is, in this definition, one in which the social ‘influences’ the physical. But – as work in innovation studies continues to show – it is possible to see the physical-social relation in a different way, with the process of innovation being ‘embedded’ in structures of social relations (including those that inform consumption patterns and practices), inter-industrial relations, technological relations, and capital/investment relations. A key idea is how we can re-think the link between the flow of materials, a flow which Industrial Ecology is especially skilled at analyzing, with the social, economic, and organizational structures which cause physical flows to be and become ‘clumped’ (concentrated/dispersed) in particular ways. Drawing on Polanyian perspectives (Polanyi, 1957) we can refer to this structuring of flows as instituted processes exhibiting spatial and historical variety. We can also proceed to identify empirically the location(s) of actual innovative change within those structures. We can further identify potential sites for innovation, together with, importantly, constraints to change and reasons for resisting change.

To elaborate, we can conceive four structural domains which together provide organisational logic to the system. They are: the structuring of materials flow; the structuring and organisation of economic activity together with the pecuniary redistributions which arise from the processing of those materials; the social structures and structuring of relations (including power relations) which demarcate classes of agent and, finally, the production of structures and meanings of knowledge including how that knowledge (and its associated symbolic significance, the ways meanings are produced and interpreted) is generated and applied.

2.1 Peas: Industrial Ecology and Innovation

We are trying to bring together notions from Industrial Ecology and Innovation Studies in a study on the technological and social implications of the search for more “sustainable” food systems which is currently exercising many policymakers, industrialists and campaigners, as well as some farmers. This section uses the example of the frozen pea in the UK as an example to illustrate these notions.

Figure 2 presents a “system map” for the frozen pea in the UK. The frozen pea is especially important, symbolically if not quantitatively or nutritionally, for the UK diet. It is the green vegetable, the first one to be available in a frozen form in the 1950s and the first to have its consumption, in a ‘fresh’ form, detached from its seasonality. It symbolizes other things as well – as something that might be considered ‘unsustainable’, both in growing it and in freezing and distributing it. As such it has become the subject of examination by its major processor in UK – Unilever/BirdsEye- through its work, in partnership with the Forum for the Future (FfF, whose guru is Jonathan Porritt, the UK’s leading sustainability campaigner and adviser to Princes and governments), on the Sustainable Pea. The focus of the FfF/Unilever initiative is in making the agricultural methods of pea production more sustainable by, for example, reducing the quantities of chemical inputs suggesting that there are or should be other, and more ‘organic’, methods of agriculture. However, there are other aspects of the frozen pea’s ecological impact which also need to be considered. We need to consider all the resource inputs and ecological impacts before assuming that pea-growing - the agricultural part of the system - is the (only) problem. And we need to identify the sources of technological control and possible innovative solutions in dealing with any of these unsustainabilities; in particular we need to take account of the apparently only fixed point in
the whole pea system map: the continued place of frozen peas, conveniently purchased year-round at a low price, in UK meals.

A food system is thought of here as a sequence of activities, starting with the production of plant seed, that link together to bring food to consumers’ mouths. If we want to analyse the implications of the existence of a certain food system for society, the environment and technology we must start with three questions:

- what characteristics of society, technology and the environment enable the system to exist as it does?
- what are the consequences of its existence?
- what tensions within the system exist between pressures for change and pressures for stasis, and how are these resolved as outcomes/processes of adjustment and co-evolution?

The overall system map included as Figure 2 shows a string of basic activities. However, we have not just drawn a flow diagram of the elements of the pea agricultural, processing and distribution system (something that we would expect from a straightforward IE-type study). We have added those elements that indicate how the system is controlled by a number of “core” organisations, with inputs from and outputs to its socio-economic environment, the “technosphere” and the natural environment. By technosphere we mean the set of human activities which transforms naturally-occurring resources into the forms used in the system under study, and turns wastes from that system back into substances that are released into nature. The catalogue of inputs and outputs is not exhaustive: there would not be space in a graphic representation of this sort for such a listing. We have tried to focus on “critical” inputs and outputs, namely those without which the system could not exist in this form.
2.2.1 The Pea Consumption and Production System: the Materials Flow

Figure 3 shows the chain of basic activities that are the core of this system. The system is centred on growers in the UK. The UK is both the largest grower and consumer of immature, or vining, peas (as distinct from dried, or combining, peas) in Europe. Some 35-40K hectares are dedicated to their cultivation in this country, with this area tending to fall with time. Because of this selected focus, the geographical locations of some of the activities in this sequence are defined or constrained. Such activities are shown in Figure 3 as boxes with no shading. Many activities in the sequence entail transport or motor-powered vehicles: these are denoted by hatched boxes. Boxes with grey shading then denote activities which are static but are not geographically-constrained by virtue of our focus on UK grown peas.

**On the farm:** There are a number of seed suppliers from whom growers can source seed for peas. By definition the chain of activities from planting to harvesting is geographically fixed, but we draw attention to the fact that planting and harvesting are dependent on the use of motorised equipment.

A key aspect of the freezing of immature peas is the time that elapses between picking and freezing. This is portrayed as being a critical factor in determining the taste of the finished product. Indeed, the idea that no pea is packed more than 150 minutes after it has been picked features in the marketing of some brands. (As an old advertising jingle put it: BirdsEye peas are “Fresh as the moment when the pod went pop”.) While other processors have no specific commitment, all apparently aim for similar levels of performance. This has two implications for the system:

- harvesting involves many small vehicles to transfer peas quickly from field to bulk road haulage container, and
- the location of processing plants is geographically constrained to being reasonably close to the farms. We have not done sufficient research to establish a specific radius: however, since the 150 minutes must include time to fill a 40-foot trailer, and time to offload, wash, blanch and freeze the peas as well as actual travelling time, it seems unlikely that this would be greater than 100km.

The harvesting equipment (known as a *viner*) also separates the peas from their pods and the remainder of the plant. These residues are later returned to the soil.

**Into the freezer:** On arrival at the processing plant, peas are cleaned and checked, then blanched (partly cooked by immersion in very hot water – 90°C+) before being frozen and packed. Fluidised bed freezers are used to allow efficient heat transfer from cold air to pea.

**Through the distribution chain:** The activities that follow processing are common to most food ingredients. A proportion will be shipped on to other food businesses that produce prepared foods such as ready meals, soup, etc. A further proportion goes to “food service” businesses – operators of canteens, restaurant chains, commercial caterers, and so on. The remainder is delivered to shops for sale to individual consumers.
It is generally held that supermarkets account for some 80% of all food sales in the UK, so it is assumed that most peas pass through their logistics chains. These start with delivery to a product consolidator (a logistics firm), who feeds goods from a number of suppliers into a distribution centre from which they are sent out to the stores themselves. The last few activities in the sequence, those undertaken by individual consumers, will be familiar to all of us. With the exception of those lost in processing, all the peas that leave the farm pass through these activities, whether they reach the consumer via the supermarket directly, in a prepared food product or via a food-service business.

It is important to note that peas are not grown solely for their food value. Peas, along with other so-called “legume” crops, fix nitrogen and therefore serve to improve the fertility of soil as they grow. These crops therefore have an important place in agricultural systems and recent work on sustainable agricultural systems that include peas has noted the need to take into account the impact on other parts of the rotation of any changes in pea husbandry made in the interests of sustainability. The rotation spans several years (5 to 8) and includes cereal crops and possibly uncultivated years. We suggest that the exact natures of the other steps in the rotation are less important to the further study of the pea system in this project than the fact that they exist, and any influence they may have on the choice of leguminous crop.

2.2.3 The Pea Consumption and Production System: ‘Core Organisations’

Any analysis of the implications of implementing one or another definition of sustainability must consider potential changes in the balance of power between organisations at different points in the “value chain”. One of the contradictions associated with the promotion to business of, earlier, environmental and, more recently, sustainable good practice has been that it offers competitive advantage to all – ‘win-win’. In the case of sustainability, different definitions have different implications for different actors: for example, stressing organic production would appear to favour organic producers and all those involved in moving products to consumers, while stressing local production would appear to provide opportunities for UK farmers and pose a number of threats to the existing food distribution system centred on chains of supermarkets with centralised purchasing.

Figure 4 shows the sections of the chain of basic activities in the pea system that are under the control of three groups. Farmers, or more accurately, “Growers’ Groups” – formal co-operatives bringing together up to 50 farms and controlling cultivation of up to 4000 hectares – control the planting, growing and harvesting activities (pink shading in Figure 4). These Growers’ Groups own the equipment needed for these activities and, for the most part, have in-house agronomy expertise. One large, well-known processor eats into this sphere of control by having its own agronomists work alongside producers contracted to supply its peas. There are reckoned to be some 10-15 of these Grower Groups in the UK now, and the tendency is for them to concentrate further in pursuit of economies of scale.

Moving downstream, the current level of concentration appears to be greater still. There are reported to be only three large pea-freezing operations in the UK, as well as a handful of smaller independents. Their sphere of control is shown by the blue shading in Figure 4. One of the large freezers produces branded peas under its own label, leaving the rest to cover other brands and all supermarket own-brands. (A single cannery also takes in some pea production).

Despite this high level of concentration, power seems to remain with the supermarkets, which control those activities contained within the pale green ellipse in Figure 4: the economic forces that account for this are discussed in Section 6. Supermarkets appear to have greater control over inbound logistics than processors: the latter specify times and dates at which product is to be delivered, leaving choice of haulier and negotiation over haulage rates to the Grower Group. Supermarkets, on the other hand, commonly fix all of these parameters “on behalf of” their suppliers.
Figure 4. Core Organisations
2.2.4 The Pea Consumption and Production System: inputs from the “Technosphere”

We now turn to consideration of the inputs and outputs that are necessary for it to function. The blue boxes in Figure 5 contain those inputs and outputs that are, in our judgement, significant for the purposes of this study. Also shown on Figure 5 are “forced” (i.e. non-rain!) inputs of water to the growing stage: we have not researched the extent of these but have assumed that water used for this purpose is drawn directly from nature rather than from the mains. This unmodified input from nature is distinguished by being shown in a yellow box.

The other inputs shown in Figure 5 all start out as natural resources in some form, but are modified by human intervention. It is convenient to think of these modified natural resources as products of the “Technosphere” whether they take the form of capital equipment or raw materials. The inputs shown do not constitute a comprehensive set: we do not, for example, show fuel inputs to transport activities – although these should not be neglected in future analysis. The inputs have been categorised to some extent according to source and type. Thus, those inputs bought in from the chemical industry are shown in boxes with yellow fill; those from the refrigeration industry in boxes shaded pale blue; those from the energy industry in boxes with orange shading, and those from the packaging industry in a box with shaded pale green. The inputs are described in generic terms because, for most, there is a choice.

**On the farm:** Since peas are planted to enrich the soil they do not, themselves, require inputs of nitrogenous fertilisers. Small quantities only of phosphorous and potassium fertilisers may be used to maintain mineral balances. Selection and application rates of crop protection chemicals (herbicides, fungicides, etc.) is case-specific and is often determined by drawing on suppliers’ expertise.

**Into the freezer:** Clean water is used in large quantities in industrial-scale food processing, both for cooking and for cleaning. It is common practice to treat mains water further to minimise bacterial contamination, either by chlorination or by UV disinfection. The need for, and importance of, heat and electricity in a process which entails first immersion of peas in boiling water followed by freezing is self-evident. Some might argue that disinfectant chemicals are a “sine qua non” for industrial food processing, but we have judged their significance to be somewhat lower in this case, partly in the light of the fact that frozen peas will receive further cooking (which should ensure fitness-for-consumption) and partly in the light of the expected scale of chemical use.

The components of the refrigeration system are clearly critical to the freezing activity. Although the consumables (refrigerants; lubricants) are shown here, we suggest that it is the equipment, enabling the compression-expansion cycle to be driven and harnessed to move heat energy, that is the critical input here. Know-how may therefore be a more important input than materiel, and some such inputs are discussed in the next section.

**Through the distribution chain:** In fact, the refrigeration process is critical to any frozen food system at every stage from initial freezing through to the point at which it is used, so the same inputs are shown to every basic activity (refrigeration is also used in the transport activities, of course, although not shown explicitly).
Figure 5. Inputs from & Outputs to the Technosphere

- **Seed production**
- **Transport**
  - **Planting**
  - **Growing**
    - Peas (pre-ripe)
  - **Harvesting/shelling**
    - Pea specific harvester ("viner")
  - **Transport**
    - Peas & shelling
  - **Clean**
  - **Blanch**
  - **Freezing**
  - **Packing**
- **Intermediate processing to prepared meals etc.**
- **Return to soil**
  - Shells & plant residues
- **Use**
  - Waste management
  - Transport to consumer
- **Cold storage**
- **Transport to point of use**

**Inputs & Outputs:**
- **Electronic control systems**
- **Power generation**
- **Refrigerant & lubricants**
- **Aqueous effluent**
- **Heat**
- **Clean water**
- **Clean**
- **Packaging materials**
- **Engineering & insulating materials**
- **Runoff & solids/contaminants**
- **PK Fertilisers (s.o.)**
- **Herbicide**
- **Agricultural machinery**
- **Production and transport**
- **Production and transport**
- **Forced" water inputs?**
- **Organic solid wastes to disposal/recycling**
- **Electronic control systems**
- **Packaging materials**
- **Transport to s/market DC**
- **Transport to s/market**
- **Intermediates processing to prepared meals etc.**
- **Refrigerant & lubricants**
- **Cold storage (short)**
- **Cold storage**
- **Cold storage**
- **Transport by food service co.
Packaging material inputs are only shown in the system map at the point where peas are packed into their sales packaging, which is most often printed plastic film but may also be waxed board. Secondary packing, such as cardboard cases, and tertiary or transit packing (shrink-wrap, pallets, wheeled cages, etc.) will be used – entering and leaving the system both at the initial packing stage and elsewhere.

**Falling off the sides:** The outputs highlighted in Figure 5 are wastes from the pea processing activity and contaminated runoff from farming (the latter may in fact enter the environment directly, rather than passing through some form of treatment as implied by its representation here as an output to the Technosphere). There are, of course, other commercial and industrial wastes from all the activities shown. These have not been included in the system map – partly for want of space, and also because they are judged to be of less significance to a study of food systems’ particular characteristics.

### 2.2.5 Socio-economic Inputs and Structures

While physical resource flows are needed for the operation of the frozen pea system, a range of economic and societal inputs are also necessary. It is possible to identify a variety of these. Some, such as labour, can be seen as a potentially substitutable input, exhibiting differential mobility and different degrees of fixed/flexible supply, depending on the labour class involved, the levels of skill (and therefore training) involved, and the terms and conditions for hiring labour. The supply of labour does not typically nowadays have significant implications for natural resource consumption. Others are decisions, such as the decision to allocate land to agriculture or the decision to build transport infrastructure. Decisions like the latter obviously lead to natural resource consumption, so that the provision of road transport infrastructure could be represented as an input of built road from the Technosphere to the pea system. However, it is widely acknowledged by workers in the field of life cycle assessment (LCA) that the inclusion of capital goods in product systems makes no significant difference to the results of LCAs, because the impacts associated with the production of these goods is spread so thinly over their lifetime use. On the other hand without decisions to build the transport infrastructure in something like its current form the pea system as shown here could not function. In particular, we suggest that in this case the road network is essential for fulfilment, by a small number of processing centres, of the short time-to-frozen commitments that appear to be common in the industry. Further exploration of this aspect of the system may well be worthwhile as the project moves forward.

Figure 6 shows the chain of basic activities in the system with inputs from and outputs to society shown in green “boxes” and economic “inputs” (forces might be a better term here) in orange circles. Labour inputs at the farming and food-processing stages are shown, because the existence of jobs in rural areas is a significant factor to some parties in the sustainability debate. It seems, however, that labour inputs to pea cultivation are not very different from labour inputs to the cultivation of other crops, although the need for very rapid collection at harvest time requires some additional labour for a short period on any individual farm (Grower Groups stagger planting across the land they operate so that harvesting continues for a period of weeks).

Land allocation is a direct input to the system from nature (denoted in the system map by a yellow “box”) but has been included as a socio-economic input because the decision to allocate the land is seen as a significant factor, as much as the occupancy of land by pea cultivation.
The importance of compressor and pump technology to the refrigeration process has already been mentioned, and is shown here. Consumer mobility is also an important factor, although the penetration of the market for vegetables by the frozen form pre-dates the move of supermarkets to out-of-town and edge-of-town locations, so the car-bound consumer is not judged to be critical.

Only three economic factors are shown, all inputs (support payments, supermarket buying price and the price of imported frozen peas). Clearly the balance between what supermarkets, as buyers, are willing to pay growers for their product and what growers could receive for alternative crops would be expected to be an important factor influencing crop selection. The support payments available to growers for combining peas and field beans amount to some £260 per hectare currently. The selling price of combining peas is in the region of £80 per tonne, with crop yields of the order of 5 tonne/hectare, so that a hectare of this alternative crop may yield some £650 in income, of which 40% is support payment. This alternative might reasonably expected to set some lower limit on the price to which supermarket buyers can drive frozen pea growers down. The price at which imported peas are available imposes an upper limit on the price that growers and processors can obtain from supermarkets, although it has been reported that the supermarkets’ desire to be seen to be supporting UK farming may allow growers in this country a slight premium for peas destined for direct sale to consumers. It should be noted that intermediate processors and food-service businesses, with lower public profiles, have no such sensitivities.

A further crucial economic input (though it is not shown in the Figure) is the availability and access to finance. Modern market economies only exist according to the precondition that there exists a flow of investment capital and credit facility to ‘lubricate’ the productive system, enabling production to take place in the absence of, but in the expectation that, consumption will follow in the future. A working and workable integrated financial system is often taken for granted and rendered invisible in resource-flow models. History shows however that when financial systems enter crisis this can have catastrophic and often amplifying contagious effects across the system.

Economic outputs have not been included in the system map. While they can readily be identified (payments to workers, business profits, taxes), investigating their relative significance (say in terms of which organisations get which proportions of the selling price of a pea, and how much is profit in each case) would require more detailed research than is possible in a preliminary work such as this.

Also not yet the subject of focused research in the particular pea case, but receiving growing attention particularly in the ‘Sociology of Consumption’ literature, are the underpinning structures and meanings that inform consumption as practice (Warde 1996) and which then have an iterative or complicit effect on production. We have already identified that pea consumption has a geographic structure, peas being a ‘staple’ of the UK diet. We can also conjecture social class, age, and ‘occasion’ dimensions of the structuring of pea-eating practices. We have identified the pea as a ‘stand-by’ freezer food, therefore integrated and dependent for its existence and meaning on a whole range and combination of household domestic appliances, notably freezers and cookers. We can also conjecture that peas are eaten primarily as a complement to other, equally taken for granted foods (chips, fish, chicken, burgers) as staples of the UK diet. Perhaps they are more likely to be eaten as a mid-week rather than weekend meal, as a children’s rather than an adult meal, and for everyday occasions rather than special candle-lit dinners. All these ways of appropriating peas into the mundane everyday lives of ordinary people have profound impacts on the way peas have come to be used, understood, bought and stored (and thus produced, and most importantly, transported). Furthermore, producers do not passively accept these structures of consumption, rather, through their marketing ‘segmentation’ and communication strategies they proactively
seek to reinforce stratified consumption patterns (evocative of Bourdieu’s familiar ‘distinction’ theory). Alternatively, producers may use product differentiation and product variety generation strategies to push appeal into new segments and ratchet up total consumption. Thus, although peas have arguably not been subjected to the same variety generation processes as the ‘humble tomato’ (Harvey et al., 2002), we are nevertheless familiar with the distinction, exaggerated by producers, between the ordinary ‘garden pea’ on the one hand and the special ‘petit pois’ on the other.

PART THREE: CONCLUSION

3.1 The system map presented here is intended to provide a basis for further research into the implications for the system and the actors within it of working towards different definitions of sustainability. In drawing up a description and graphic representation that cover all elements of the frozen pea system from seed to consumption but are at the same time reasonably concise, some judgment and selectivity has been essential. This selection process has endeavoured to focus on factors (which we believe can usefully be classified as inputs or outputs) that either enable or constrain the system as it operates now. It has tried to pick out technological knowledge, societal characteristics, resource flows and economic conditions which, if changed significantly or taken away, would cause peas – if they were grown at all – to be handled very differently.

The continued survival and reproduction of the UK frozen pea system we have described depends on a number of conditions that are both social and technological. To present some of these:

1) It is clear that, at the level of system actors, if there is to be one actor with a central structuring role and qualitative asymmetric power it is Unilever. This is especially important when we look at the sources of knowledge in the system. Unilever’s expenditure on R&D and its ability to mobilise knowledge of agriculture, the freezing process and the logistics of pea distribution make it the key location for any innovation within the system (or the breaker of other innovations that might adversely change the system). Unilever is thus the key agent in producing and interpreting knowledge about ‘sustainability’, in the sense that it is Unilever that is the agent that considers what is worth investigating and acting on to bring about more ‘sustainable’ pea production. Unilever’s interest in sustainability is connected with the maintenance of its power in the pea system. So far, this interest in sustainability has been confined to an investigation of agricultural practices of pea-growing. This can be seen either as the ‘first step’ in an examination of the sustainability of the pea system as a whole, or as an attempt to define sustainability as just being about agriculture.

2) As we have sought to show, there are a number of features of the pea system that deserve investigation if we are to think more systemically about sustainability. These could be called the ‘bottlenecks’/‘pinch-points’ for the sustainable reconstruction of the chain:

- the influence on the system of the notion that peas have to be moved from ‘field to frozen’ in a relatively short period of time

- the central position of the pea in the everyday eating habits of the UK populace

- the centrality of the refrigeration process, at numerous sites as well as in transit.
However, if we can identify one element of the system that structures the rest of it, it is the transport infrastructure for the necessary prompt freezing of the pea. This in turn is set by the instituted consumption practice that puts the frozen pea as a cheap, year-round convenient component of green vegetables in the average UK diet. Sustainable reconstruction of the chain might depend on basic changes in some of the current system conditions. These include:

- the possibility of higher prices (necessary if all peas were to be ‘organic’)
- a shift back to **seasonality** for the vegetable (a contrary trend at the moment for virtually **all** fruits and vegetables)
- the assumption that delivery of peas requires long food chains can be altered.

All of these would certainly require some change in the place of the pea in UK diets.

Organic advocates would expect that some of these changes would be necessary throughout UK agriculture and food consumption practices. However, there are other more ‘neo-industrial’ strategies that can also be imagined. In this strategy, you could envisage **new** varieties of peas that travel better, overcoming the transport/prompt freezing bottleneck. This might come from better knowledge of the pea genome and the ability to use that knowledge to create or engineer new varieties. This would then reduce the need for peas to be grown very near to freezing plants thus opening the possibility of changing the economies of scale of the industry, opening up the possibility of local agriculture and local freezing. Such ideas are purely speculative at the moment.

3.2 Any critique of strategies for achieving sustainability in FCPSs in the face of global environmental change and the rise in populations expected for 2030 has to confront the obvious problems of industrialised agriculture and its associated consumption patterns. This applies both in the rich countries and in the developing ones; in the latter, sustainability must mean slowing down, if not reversing, the adoption of the environmentally degrading impacts of such systems in those countries whose living standards are approaching those of the developed world. But it must also recognise the needs for food security of the rural poor and, crucially, the food security of the **urban** people.

Whilst some writers are strong advocates of the strategies they propose (the debate between advocates of organic methods and those put forward by 'new industrial' supporters is especially lively), in our view such strong advocacies are unhelpful when presented without clear indications of how they might fit into a variety of different socio-economic contexts, including their suitability at different geographical scales (i.e. local, regional, global etc.) and their implications for the kinds of technological innovation that is currently being pursued. In global society, uneven development is the norm. It seems reasonable to suggest that within one country there will be different strategies; some foods produced by one, others by another strategy; and there will also be great differences between countries, even for the same foods. In addition, whatever the differences between agricultural systems there will be substantial variety in methods of distribution and food preferences.

Any globally successful FCPS would be a mixture of the various strategies since they are applicable at different levels and to different global and national regions. For example, some of the features of the 'organic strategy' (especially its different views regarding the use of chemical inputs) are compatible with 'new industrial' systems, as the rapid rise in sales of supermarket organics demonstrates. It is quite possible to envisage the co-existence of local, ‘short’, supply chains for some foods (e.g. in the UK, local 'farmhouse' animal products) and global supply chains of foods not locally-available (e.g. in the UK, rice). Similarly, concerns over the maintenance of diversity in seed variety, held by advocates of sustainable-traditional
and organic FCPSs, might be alleviated with the development of genomic databases that improve understanding of the basis for such variety.

The co-existence of alternative FCPSs can have both positive and negative effects. On the one hand, maintaining diversity in technological trajectories allows for unforeseen combinations of technologies in the future. It is also possible that alternative FCPSs are appropriate for different regions at different times. On the negative side, there is the possibility of 'degenerative competition' between alternative strategies. Most notable is the anti-GM stance amongst those advocating organic strategies. In the case of rice, this has contributed to a slowdown in development of knowledge surrounding the possibilities of improving rice production through biotechnological means. Consequently, the development of 'golden rice', enriched with beta-carotene, has been stifled, with uncertainty about regulatory approval and the chances of creating markets for this new variety.

A current manifestation of competition between varieties is the increasing attention paid to the labelling of foodstuffs according to their origin. It is well known that the organic movement is a strong advocate of labelling strategies to differentiate products. It is also increasingly common for those developing biotechnology-based seeds to recognise the need for labelling. The Californian Rice Commission, for example, representing that state’s rice industry, has stated that high-tech rice varieties ‘will be separated every step of the way from conventional crops’, and this extends from growing to marketing and labelling.

But the fact that different strategies might, in principle, be part of a global sustainable FCPS raises a question about the viability of competing systems – can these different strategies ultimately 'co-exist'? No, say the anti-globalisation and anti-GMO movements. Yes, say those can see them as international differences: 'organic' as a rich country strategy; modernising for developing countries.

3.3 To conclude, we have argued that it is important to consider sustainability at the systemic level. For food, this means considering changing economic developments, including increases in the scale and international range of global food trading and, thus, the wider availability of "new" foods and tastes. Globalisation also increases the likelihood of increased dependency in some countries on exported crops and changes price structures, affecting the more vulnerable poor farmers. Changing household consumption patterns are also important, as demands for different kinds of foods and methods of obtaining them (e.g. from supermarkets and chain restaurants) change. The patterns are changing in different ways region by region: thus in rapidly industrialising countries, urbanisation and rising living standards leads to demands for more meat and for more processed and restaurant food; whilst in Western Europe and North America concerns over food safety and quality push up sales of ‘organic’ foods. The co-existence of different FCPS strategies means that achieving any notion of sustainability must take account of the essential feature of modern socio-economic systems based on competitive capitalisms, namely their variety-generating potential and the consequent continuous posing of alternative trajectories. Some would argue that the dynamic nature of the industrialised sector is its long-term strength: this dynamism needs to be preserved to ensure that the challenges of sustainability are matched by the same variety of innovative responses.

Given the importance of 'variety' both to ecosystems and to the innovative development of human economic and social endeavours, advocating single strategies for all countries/regions is counter-productive for the sustainability of natural and human systems. Nevertheless the 'tensions' between different strategies is worth further consideration and research, especially if we can envisage new 'combinations' that better meet the demands of sustainability and changing demand for food.
References
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Parrott N, Marsden T. 2001. “Organic and Agroecological Farming in the Developing World”, Department of City and Regional Planning, Cardiff University
Polanyi (1957)
Figure 1: Environmental Impacts of Food Consumption and Production Systems
ENDNOTES

1 Its symbolism might be illustrated by the dust-jacket of the recent book by Felipe Fernandez-Armesto, 2001. Fernando-Armesto is an Argentinian academic, who works in the US and Europe, and is especially critical of modern food consumption practices. His publisher has chosen to depict an opened pea-pod on the front of the book, despite the fact that the pea is only briefly mentioned in the book in Fernando-Armesto’s denunciation of frozen foods in general!

2 This section is based on a section of Green, Harvey and McMeekin (forthcoming)

3 See Lifset and Graedel (2002) for a justification for this.

4 For details of the elements of the Food System, see Tansey and Worsley, 1995; Millstone and Lang, 2003, present current information on global food production, trade and consumption in atlas form.

5 Derived from IHDP-IT, 1999

6 See Millstone and Lang, 2003, p66-67 for graphical presentations of data on ‘food miles’.

7 see Hall and Soskice (eds), 2001

8 This account is based on Pretty (1995), Pretty (2002); Haverkort and Hiemstra (eds), (1999); Parrott and Marsden, 2001

9 The arguments here are based on Brown et al., 2000; Soil Association, 2001; Wright and McCrae, 2000

10 At the moment, organic food is internationally-traded and sold through supermarkets, whose sales of such food is rising rapidly in the richer countries. This is unacceptable to many supporters of organic agriculture - notably those in the ‘organic movement’ - whose broader agenda is bioregionalist.

11 This is part of the growth of ‘alternative’ food supply chains (or ‘short food supply chains’), as opposed to ‘retailer-led’ supply chains; see Marsden et al., 2000

12 This account is based on Ford, 2000; Conway, 1997; Manning, 2000; Heasman and Melletin, 2001


14 The picture of the frozen pea system presented here has been developed by reference to a variety of published material supplemented by interviews with growers’ representatives, processors and a small number of other food industry sources. For discussion of Life Cycle Assessment, see “The Eco-indicator 99: A damage oriented method for Life Cycle Impact Assessment. Methodology Report” PRé Consultants B.V. 2000.

15 For example, industrial and domestic refrigeration is achieved through the compression of liquids and their expansion into gases, with the associated harnessing of the latent heat of vaporisation. So compressor technology is identified as a key input. This idea of studying the effects of complex, extended systems by concentrating on selected inputs and outputs was pioneered in the “ExternE” project which investigated the economic costs associated with environmental externalities of energy systems. In that case only physical flows of substances were considered: here we have also noted less concrete inputs and outputs. Indeed, we have used the term “input” rather loosely, counting the provision of transport infrastructure as an “input” to the system, although it is a good provided to society at large, not specifically the pea production system. Since our objective is not the compilation of a quantitative inventory of substance flows, this difference in usage is not expected to be of great consequence.

16 Research at this stage has not been sufficiently detailed to establish a percentage, but reports on the economics of the food industry stress the fact that individual consumers are a minority market for food ingredients whose share is falling as that of prepared-meal producers is rising. The following quote from The Economist’s “Survey of Biotechnology”; 27 March 2003, gives some idea of relative importance in the food sector: “…in the West, where most crops are used in processed foodstuffs rather than sold as raw ingredients. The retail market for raw ingredients is simply too small to justify spending money on the development & approval of [genetically] modified versions.”

17 Forum for the Future, op.cit.