Carbon governance from a systems perspective: an investigation of food production and consumption in the UK

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Abstract
This paper provides a critical analysis of the UK's current carbon and energy governance structure as applied to the food production and consumption system. A central tenet of UK climate change policy is the regulation of carbon through taxes as well as a cap and trade scheme. This conceptualises the economy as comprising mutually exclusive units of resource consumption (buildings, transport, industry, agriculture, etc.) such that different sectors are treated separately and each company has a site based responsibility to reduce its emissions. However, the reality is that the production of goods and services takes place across highly interconnected systems. Relationships between members of the system are primarily economic, but are mediated by influences such as policy and power. These relationships are not fully accounted for within current systems of carbon regulation. This paper explores the implications of this for systemic change to a low carbon economy. It is argued that this systems-based approach could be fruitful in gaining a better understanding of the issues involved in this transition.

The UK's food system is used as a case study to which these ideas can be applied and interrogated. Food is responsible for about a fifth of a 'developed' country's greenhouse gas emissions (mostly carbon dioxide through fossil energy use, but also methane and nitrous oxides from agriculture) and is currently regulated under the Climate Change Levy and Agreements and the EUETS. Additionally the diverse array of relationships between system members of different size, situation and influence, make it an ideal candidate through which to explore these ideas.

Introduction
Climate change has been described as 'the single most important issue that we face as a global community' (Blair 2004). As part of the UK's response to such a challenge, the 2003 Energy White Paper committed the UK to a reduction in CO_2 emissions by 60 % by 2050 relative to a 1990 baseline (DTI 2003). Since publication of the Energy White Paper there has been debate as to whether a 60 % reduction is sufficient, and ultimately up to an 80 % reduction in greenhouse gas emissions may be required in order to avoid dangerous climate change (HM Treasury 2006). Such a large reduction in our carbon footprint will require a sizable shift in the way that energy is produced and used in this country. Food production and consumption in the UK is thought to be responsible for about 22 % of total greenhouse gas emissions (HM Government 2005,p.62). A recent report by the Carbon Trust placed food third behind leisure and tourism and space heating in a list ranking carbon emitted from consumer services requirements (Carbon Trust 2006). This is a significant contribution and the food system will inevitably come under scrutiny for emissions reductions in this country's drive to 'decarbonise' the economy (Schellnhuber *et al.* 2006). Food production and consumption is a complex process imbued with cultural, historical, social, economic and technical diversity. Furthermore, the importance of food for our personal survival and its security and social welfare implications mean that it must be managed carefully.

In the UK the services associated with food – nutrition, health, enjoyment, culture to name a few – are in the main provided through a hybrid of state supported agriculture at the base of a free market food system. Production, trade and consumption for profit take place across highly interconnected systems. The availability of cheap, easily accessible fossil fuels has been integral to the development of the food system to its current form, that of a globalized network of producers and consumers heavily reliant on mechanisation to deliver food in increasingly diverse forms. Reducing the carbon intensity[1] of the UK's food system therefore presents a challenge. Achieving this challenge can be categorised into 5 broad approaches.

1. Increasing the efficiency of current production processes
2. Reducing the carbon intensity of fuels used in the production of food
3. Reducing wastage within the food production and consumption system
4. Eliminating or reducing carbon intensive processes/parts of the food chain
5. Reducing the consumption of carbon intensive foodstuffs

A combination of these is likely to be required if a 20-40 % food system is to be reached (i.e. producing 60-80 % less carbon equivalent emissions). The challenge comprises a significant increase in the energy efficiency of technologies used at a rate greater than population growth and future rises in energy service requirements. Better material efficiency across the entire food system to reduce embodied carbon lost through waste – which is thought to be 30% of all food purchased for the household alone (WRAP 2007). The elimination of processes or parts of the system that are particularly carbon intensive – in such a way as to not displace carbon intensive processes to elsewhere in the system, for example by reducing the proportion of people who shop by car and increasing food delivery systems. And finally, re-assessing our diets to determine what is both healthy *and* low carbon – such as reducing our meat, dairy and sweet processed food intake. All these approaches, but especially numbers 3-5 are likely to have systemic effects such that these changes need to be managed to make sure carbon is reduced overall.

It is argued here that current policy frameworks aimed at reducing the carbon intensity of food production and consumption do not take into account the systems-based aspects of this process and that if large scale reductions in carbon are to be made, this needs more attention.

This paper begins with a discussion of the systems aspects of food production and consumption, and the ramifications this could have for carbon emissions reductions. It then looks into how much energy the process of food production and consumption requires. This includes inputs to the farm through farming, processing, transport and retail, to consumption in the home and food service outlets – including food storage and preparation. Food waste is also discussed briefly. Finally, current approaches to carbon and energy governance within the food system are discussed and analysed with respect to the systems characteristics of food.

1. The amount of carbon emitted as a result of the sector as a whole.

As well as carbon emitted through fossil energy use, food production results in emissions of methane and nitrous oxides from ruminant rearing, animal waste management and fertilizer use, and HFCs and PFCs from refrigeration. Farm based methane and nitrous oxide emissions contribute 7.7 % of total UK greenhouse gas emissions and emissions of HFCs and PFCs contribute about 1.4 % (DEFRA 2005, DEFRA 2005), although not all of this is refrigeration based. These greenhouse gases contribute significantly to food's overall global warming impact. Although this paper is primarily concerned with carbon emissions from energy use, it is worth keeping in mind the role of other greenhouse gases, especially that arising from meat and dairy production.

Finally, this paper concentrates on carbon. However food production and consumption is intertwined with many other bio-physical cycles: water and nitrogen, phosphorous and potassium being particularly important, as well as land use and disease control. A call for more systemic thinking in carbon management must be seen in this greater context.

Food production and consumption as a system

The making and eating of food can be seen to occur within a system – that is, the consumption of edible and safe food is the outcome of multiple units of production linked by the movement of goods between them coupled by the circulation of information and money. The production and consumption of food also displays many systems characteristics such as emergent properties, interdependence and feedback. By taking a systems approach to a problem or issue it is as important to focus on the relationships between the units within the system, as it is to look at the units themselves (Open Systems Group 1981).

The systems characteristics of food production and consumption have implications for how best to reduce carbon emissions in two ways. Firstly the wider structural impacts of change need to be considered – a consequence of the structural interconnectedness of the system. Secondly, there may be systemic barriers to attaining large reductions in carbon emissions that arise from relationships within the system constraining change.

Food system interconnectedness is potentially very important from a structural perspective as change to one part of the system can lead to change in another, and the energy use or carbon ramifications of this can be unclear. A classic example of this is the relationship between packaging and waste – in some situations, reducing packaging of food products in an effort to reduce carbon emissions can lead to increased waste from damage, such as increased bruising on loose fruit compared to packaged fruit. Equally, the transition from many smaller abattoirs to fewer more centralised plants, as has occurred in the UK, requires the rest of the system to adapt to this. In this instance with larger lorries, longer distances, changing wholesale structures and altered waste management systems. This structural interconnectedness complicates determining how effective some demand reduction measures might be. As the food system becomes more carbon constrained, the wider implications of change will need to be closely monitored to ensure overall carbon savings.

The relationships between different parts of the food system have important implications for the ability of individual actors to reduce their own carbon footprints. The classification of sup-

Table 1. Sectoral comparison of secondary or delivered energy use and carbon emissions in the UK's food system including the percentage of total food energy/carbon this represents.

Sector	Sub-division	2° energy use (PJ) (%)	Carbon MtC (%)
Farming	Direct	37.4 (4.8)	0.92 (4.8)
	Indirect	96.6 (12.4)	1.70 (8.8)
Transport	Air	4.6 (0.6)	
	Road Haulage	119.3 (15.3)	2.64 (13.7)
	Home transport	14.5 (1.9)	
Processing		158 (20.2)	3.8 (19.6)
Packaging		58.8* (7.5)	1.3* (6.7)
Storage		4.1 (0.5)	0.15 (0.8)
Retail		21.4(2.8)	0.63 (3.3)
Home		165.3 (21.2)	5.55 (28.7)
Catering		100 (12.8)	2.65 (13.7)
Total		780	19.34
Total UK		7206	153

References: DEFRA (2006 a), MTPROG (2005), DEFRA and AEA Technology Environment (2005), DUKES 2006, Tremove (2005), Dutilh & Kramer (2000), Gerbens-Leens (2003), Jones (2001), DEFRA (2005 b), Select Committee (2005), Russell Layberry Pers. Comm BMT Model (13/09/06)

* Due to lack of data these figures exclude energy use and carbon emitted in the production of plastics.

ply chains into 'producer driven' or 'buyer driven' provides a good, if overly simplified, example of this (Gereffi and Korzeneiwicz 1994). Food has become increasingly buyer driven as food retailers have grown more powerful in relation to large food manufacturers and increasingly determine the structure, composition and production processes of entire supply chains. This in turn affects carbon emissions of individual sectors as their composition is defined by those who can provide goods according to retailer specifications and at least cost. Case studies of fresh vegetables and cut flowers illustrate the importance of retailers in restructuring supply chains from spot markets and auction houses respectively, to direct management and coordination of production from the field to the supermarket (Dolan and Humphrey 2004, Hughes 2000). In both cases this includes the development of specifications and control of production despite not having direct ownership of these processes.

There are also examples of producer driven supply chains, especially in areas like industrialised meat production. Boyd and Watts interrogation of the chicken industry in America shows the development of agri-industrial food complexes coordinated by 'integrators' (Boyd and Watts 1997). These integrators originated from large feed supply companies that contracted out the growing stage of chicken production to small farmers. Feed companies then grew to incorporate the processing stage too. A similar situation has arisen in industrial pig production (Watts 1994). In both cases integrators sell feed and young piglets or chicks to farmers who then fatten them and sell them back to the integrators at a predetermined weight related price.

Both these cases illustrate the variation in control between different parts of the food system as to how food is produced. This in turn limits the options that some parts of the food system have as to how and by how much carbon emissions can be reduced. Conversely it also highlights the opportunities for change if parts of the food system take the initiative. Thus, looking at both structural inter-connectedness and issues over control within the system, it is clear that to some extent it is the nature of the relationships between different players within the system that affect options for decarbonisation.

Energy, greenhouse gas emissions and the UK food system

The UK's food system has historically been increasing in carbon intensity as we have moved from animal power used in localised food systems through to a global, industrial agri-food system. One measure of food production efficiency is the input/output ratio, i.e. the energy needed to produce an item (excluding solar energy) relative to the energy contained in the food item (its calorific value). It is thought that pre-industrially this ratio was 1 : 100 – 1 calorie of input required for 100 calories of output for on farm energy use (Jones 2001). Between 1952 and 1972, Leach (1976) estimated that this ratio fell from 1 : 5.8 to 1 : 4.4, and now in some cases ratios can be as low as 1 : 2 to 1 : 0.002 for high input fruit and vegetable cultivation and winter greenhouse vegetables respectively (Weizsacker et al 1998). When considering whole chain energy consumption rather than just on-farm, it is estimated that the ratio is 1 calorie input required for 0.16 calories output (Open University 2001). Without having to return to pre-industrial conditions, this suggests that there is scope for improving the energy efficiency of our food production system, as well as achieving energy savings through altering what we eat. This is already happening in some parts of the food system: carbon emissions from the food manufacturing sector have been slowly declining since 1990 (DEFRA 2006), but in other areas, for example food transport, carbon emissions are increasing (DEFRA and AEA Technology Environment 2005).

Table 1 shows a sectoral break down of energy use across the UK's food system. The figures used come from a variety of sources and in some instances have been translated from secondary to primary energy use. These figures give a good estimate of the relative energy consumption of different sectors. As they are taken from a variety of sources, none of whom provide

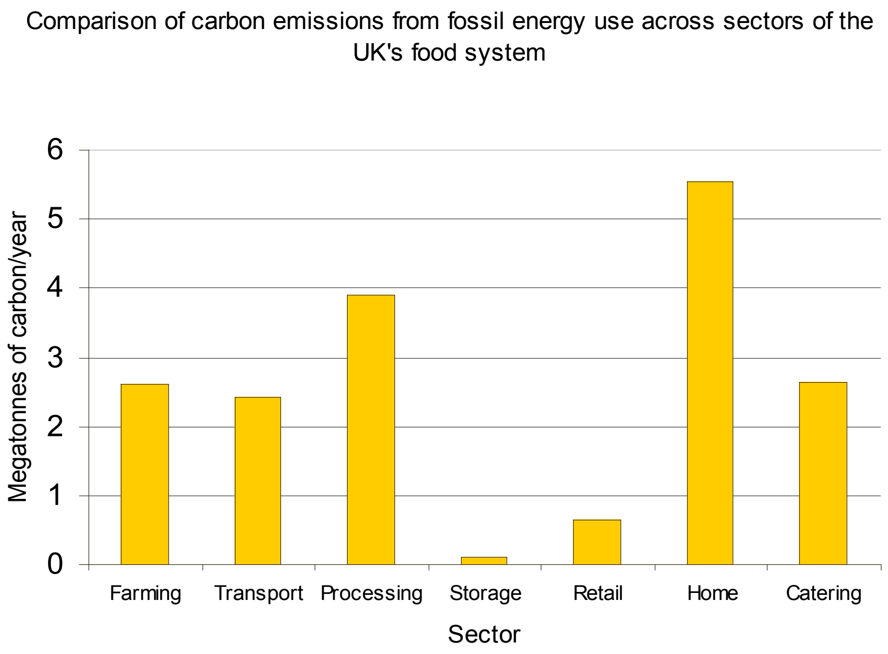

Figure 1. Carbon emissions from sectors of the UK's food system

error estimates, it is difficult to say what level of uncertainty surrounds these numbers.

As it stands, this equates to 10.8 % of the UK's delivered energy consumption, excluding the air freight contribution. Further omissions include: energy used in fishing, in the production of plastic packaging and the off-farm storage of fresh fruit and vegetables, often imported, that can be stored and ripened in temperature controlled environments for considerable periods. Food related waste management has also been excluded. There is also some uncertainty around the numbers, in particular the amount of energy used to store food. Because storage occurs at a number of different points in the food chain, it is often not clear how this is allocated sector-wise. There are also very varying estimates of energy use in the retail sector. The figure used here is taken from the Food Industry Sustainability Strategy (DEFRA 2006 [a]), however an estimate from the DEFRA food miles report, published a year earlier, gives an estimate of 97.9 PJ. This alters the percentage of total UK energy use that food is responsible for to 11.8 % and increases the fossil carbon impact from 19.2 MtC to 22.9 MtC. With all figures presented in Table 1 only direct energy use on site and in the production of inputs has been included rather than any embodied energy in machinery or vehicles, which is usually included in food life cycle analyses (LCA).

Households are clearly the greatest consumers of energy in the food system. Food related energy use in the home is split between cooking (48 %) – including the use of kettles and microwaves, refrigeration (33 %) and washing up (19 %). Other significant energy consumers are processing, catering (all food service institutions like restaurants, canteens and bars selling cooked food), transport and farming. Of course, were all greenhouse gases to be considered, the relative contribution of farming would be much more significant (see introduction). Figure 1 shows how energy use translates into carbon emissions between sectors. There is a greater impact in those sectors that consume a greater proportion of electricity.

Different sectors within the food system have very varying carbon emissions. However the ability of actors within each sector to influence their own emissions varies somewhat and is not proportional to their carbon impact. It could be argued that retailers have a disproportionate influence on emissions from other sectors – by creating strict produce specifications and providing product ranges that require a large and complex logistics system for example (of course this could also be seen as a consumer issue and is tied up with the grey area around consumer-retailer cause and effect). Equally, both the farming and catering sector comprise a huge variety of different sized farms and outlets many of which will not have the manpower or economic means to use best available technologies and monitor their carbon footprints (and it can again be argued that this is a result, at least in the case of farms, of the increasingly small margins on which they operate – a consequence of multiple factors many of which emanate from other parts of the food system).

UK carbon and energy governance structure

Currently carbon is regulated through a range of policies that conceptualise those governed as being individual units that emit carbon or use energy. It is not clear whether this approach is able to lead to a strategic move from a heavily carbon dependent nation, to one which is not. Taking a systems perspective could throw light on this issue.

The production and consumption of food is indirectly affected by a range of policies that emanate from the Department of the Environment, Food and Rural Affairs (DEFRA), the Department for Transport (DfT), the Department of Trade and Industry (DTI) and the Department of Health (DH). Some of these policies will have implications for energy use and greenhouse gas emissions associated with food, but the large number of them and the unclear overall effect they have on energy use means they will not be discussed specifically here.

Table 2. Binding policies currently directly affecting energy use and carbon emissions from companies in the UK food system

Policy	Mechanisms	Sectors Included	Achievements	How is it reducing carbon emissions?
EUETS/ UKETS	Cap and trade system	Large energy and CHP users within: poultry farming, dairy, horticulture, fertilizer production, food & beverage manufacturing/processing, paper mills, glass, aluminium, steel.	Emit 88.2% of their average annual emissions between 1998-2003 over phase 1 of the EUETS	Absolute reductions (assuming strong government)
CCA-CCL	Tax with discount linked to specified efficiency gains	CCL All – CCAs do not include arable, dairy, sheep and beef farming, haulage firms, independent retailers, homes.	2001-2005: 0.3% absolute reduction in carbon/year	Efficiency Two absolute CCAs
Various European Commission Directives	Obligatory labelling on some white goods, plus minimum standards	Domestic – does not include hobs and some kitchen appliances	Absolute reduction in household food related energy use by 2010 – annual savings of 4.4PJ/year	Efficiency plus minimum standards
The Producer Responsibility Obligations	Recovery and recycling of packaging in proportion to amount used/produced	Packaging producers Raw material manufacturers Convertors Packer/fillers Sellers (all must handle >50T packaging or turnover >£2m)	By 2008 those businesses eligible must have recovered an average of 60% of their throughput a year	Efficiency
Landfill Directive	Tradeable allowances for landfilling of biodegradeable waste	Households via local authorities	By 2010 biodegradable municipal waste going to landfill with be at 75% of 1995 levels	Absolute reductions of methane emissions

References: Market Transformation (2005), DEFRA (2006), DEFRA (2005)

However, it is important to note the potentially significant impact that some policies, not directly related to energy use/carbon can have on carbon emissions. For example planning laws have in the past encouraged and then latterly discouraged out of town supermarkets, free trading zones encourage long distance trade and health and safety laws have affected abattoir numbers and waste levels within the food system. The better regulation agenda (Cabinet Office 2006) from government should, theoretically, mean that environmental factors are considered with each new policy introduced. But how carbon impacts are evaluated and weighted compared to other variables is not clear.

The Common Agricultural Policy (CAP) is closely intertwined with energy use and greenhouse gas emissions from farms. Its relationship with these environmental impacts has not specifically been studied to date. CAP support based on direct payments (the old CAP support structure) has lead to agricultural intensification and over production, both of which will have lead to greater energy use and greenhouse gas emissions. However with the advent of decoupling, which is being phased in between 2005–2012, the carbon intensity of farming should decrease. The full impacts of this transition are yet to be fully understood or quantified. The reduction of government intervention in farming, and consequently the more tangible link between agriculture and the rest of the food system, should make this sector more open to system-based change.

Table 2 summarises some of the main legally binding carbon-based policies currently in force within the UK's food system. A number of these are not directly aimed at reducing energy use, but have an impact on material efficiency or methane emissions which overall contribute to reducing the food system's carbon footprint.

Binding policy that affects the production of food goods tends to be efficiency based which does not guarantee overall energy conservation (Boardman 2004), especially as many sectors are growing. An exception to this is the EU Emissions Trading Scheme (EUETS) which, assuming strong government and progressively lowered caps, should encourage overall reductions in carbon emissions from those involved. However, the emissions of food related companies currently included represent only 1.6 % of total fossil energy related carbon emissions from the food system (DEFRA 2005 and personal calculations). There is no binding policy that will lead to guaranteed absolute reductions in carbon emissions from homes, catering, farming and transport. These are all significant contributors to the impact that food has on UK carbon emissions.

Coupled with this, the regulatory tools used view companies/facilities as individual units – providing incentives only to reduce their own energy use: not rewarding energy conservation or efficiency investment in their supply base. It could be argued that the price of carbon will be passed on to buyers of products and in so doing, act to penalise those who produce excessive carbon through the system. However, this very much depends on the price of carbon and fuel in relation to product costs as well as competition in the system and elasticity to price changes. Furthermore, with the increasing levels of disposable income in the UK (Office of National Statistics 2003), coupled with food poverty issues, increasing food prices in response to increasing carbon prices may well not affect food purchasing decisions by some whilst worsening access to healthy nutritional food for others.

European Commission Directives (92/75, 92/42, 03/66, 96/5702/40 and 97/17) take a somewhat more systems based perspective by being part of a market transformation strategy

Table 3. Overview of non-binding carbon and energy related strategies focussed on or involving the food system.

Strategy	Mechanisms	Sectors Included	How is it reducing carbon emissions?
Sustainable Distribution Strategy	Sustainable Distribution Fund (Shifting from road to rail and water)	Distribution	Encouraging modal shift to less carbon intensive transport
Food Industry Sustainability Strategy (FISS)	Voluntary agreements and industry engagement via carbon trust	Manufacturing, retail and catering	Energy efficiency & promotion of best practice
Strategy for Sustainable Farming and Food (SSFF)	Voluntary agreements and industry engagement via carbon trust	Whole system but farm focussed	Refers to work of FISS
Hospitable Climates Voluntary Agreement	Voluntary agreements with members of the HCIMA	Catering	Efficiency and energy advice

for white goods in the home. Market transformation is a suite of policy measures that act to push the market towards providing goods of greater efficiency with minimum standards acting to prevent slippage in improvements made (Boardman et al 2005).

Table 3 summarises current strategies relating to the food system. These are more over-arching frameworks that guide environmental improvements within a sector or industry compared to the targeted policies of Table 2.

The Food Industry Sustainability Strategy (FISS) includes three sectors (manufacturing, retail and the food service sector). It does mention the need to take a whole life cycle approach to shifting food to a more sustainable production pathway (p.18 DEFRA 2006) and rhetorical commitments are made to pursuing research in this area and developing policy here. Consumers are also targeted via the proposed development of an 'Environment Direct' service that aims to communicate the impacts of consumer product choices (p.22 DEFRA 2006). If it is a well used and designed service, this has the potential to increase the share of more benign products but this is likely to remain a small part of the overall food market – reflecting the current minority of 'ethical' shoppers. However, FISS does not include farming, the domestic sector and personal transport: three considerable contributors to carbon in the food system (see figure 1). FISS also relies upon the CCL, CCA and EUETS to achieve reductions in carbon emissions from the sector, not more holistic tools in alignment with the broader reach of the strategy. The SSFF aims to include the entire food system, however when it comes to reducing carbon emissions it refers to the FISS – so leaving out agriculture and homes.

Current carbon related policies/strategies are shown here to be quite 'bitty' – dealing with one or some parts of the production-consumption chain, but not all. They also cater little for the two examples of food production and consumption's systemic characteristics as discussed in the second section of this paper. That is, both the structural linkages that make change in one part of the system likely to impact other parts, and the nature of relationships along supply chains acting to constrain or enhance adapting to a 'lower carbon' world. The EUETS and the CCL/CCA both concentrate on the company or farm as the arena for action. There is no policy that creates a framework within which the relationships and links emanating from these units can be managed, exploited or considered. Similarly the strategies incorporate multiple sectors, but focus on them individually rather than seeing the relationships between them as opportunities for action.

Future governments will need to take these systemic characteristics into consideration as carbon becomes increasingly constrained, and those in the agri-food system are expected to reduce their carbon footprints much more significantly than at present. Larger changes, such as in what we eat, how and where it is produced will have to be evaluated in terms of whole life cycle carbon impacts. Additionally, these larger changes will only be possible if suppliers and customers along the chain promote and enable alternative modes of production.

Policies and strategies currently used to manage carbon can also be evaluated with respect to the 5 approaches for change laid out in the introduction. The CCL and CCA are aimed at increasing efficiency (no.1) whilst the EUETS aims to increase efficiency and supports fuel switching (no.s 1 and 2), as caps become progressively lower it should also lead to energy/carbon intensive processes or parts of the chain being eliminated – number 4 (assuming this is manageable in a system with unequal power relations across production-consumption chains). Nowhere in the current suite of policies or strategies is there any move to push for a change in food types eaten (no. 5).

It is recommended here that new policy tools are developed that take a systems approach to reducing carbon emissions within the food system, whilst concurrently using a target based framework that looks to achieve stated reductions within a set time period. Current policy tools are either tax based and therefore do not lead to definite carbon reductions, or are cap and trade but applied too narrowly.

Conclusions

This paper has aimed to highlight the incongruence between the current approach to carbon governance as applied to agri-food sector and the nature of how food is made and consumed – through multiple businesses and individuals bound together in a system.

Food production and consumption has been portrayed as a system with very varied energy use and carbon emissions between sectors. The parts of the system with high carbon/energy intensity are not necessarily those that can most easily adapt to a carbon constrained world. The approach currently taken to regulating carbon in the UK does not consider these systemic characteristics of creating and consuming food.

The implications of not managing for relationships within systems are that constraints acting to maintain the status quo are missed, potentially making larger scale changes more difficult. Holding those directly responsible for carbon emissions culpable for their reduction also fails to take into consideration the complicated nature of power and responsibility along production-consumption chains.

There are positive opportunities in looking more closely at connections between players in the food system. Procurement criteria can be used to push for greater consideration of carbon and other environmental variables within the supply chain. This is especially the case in a system where retailers and consumers hold a lot of influence along the production chain.

System change can be brought about through a range of mechanisms. These include:

- Consumer demand for food goods and services that leads to the creation of a lower carbon food system due to market pull. Carbon labelling of food goods could help bring this about, as would including food in a personal carbon allowance scheme.
- A regulatory incentive structure that leads to whole systems realignment. For example making it relatively more attractive to buy carbon credits from within ones own supply base or product sector compared to outside it, and having minimum carbon standards for food goods
- Leverage of systems using players with influence within the supply chain (examples include retailers and public procurers). The Carbon Trust have recently extolled this approach in their publication Carbon footprints in the supply chain: the next step for business (Carbon Trust 2006). This opens up the possibility of more radical changes to how food is produced and consumed.

It is unlikely that a single policy is able to achieve systems change, a suite of compatible policies will be required. Some of the suggested approaches above require a much better understanding of how energy is used and greenhouse gases emitted in food production and consumption. Gaining a good understanding of this is a huge undertaking and may take many years to complete. Development and implementation of systems based policy tools that build on current knowledge will need to take place alongside further research based around Life Cycle Analysis and the interconnectedness of food related energy use.

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