System Dynamics and Innovation in Food Networks 2009

Proceedings of the 3rd International European Forum on System Dynamics and Innovation in Food Networks, organized by the International Center for Food Chain and Network Research, University of Bonn, Germany
February 16-20, 2009, Innsbruck-Igls, Austria
officially endorsed by

EAAE(European Association of Agricultural Economists)
IAMA (International Food and Agribusiness Management Association)
AIEA2 (Assoc. Intern. di Economia Alimentare e Agro-Industriale)
INFITA (Intern. Network for IT in Agric., Food and the Environment)

edited by

M. Fritz, U. Rickert, G. Schiefer

Sustainable Development and Food Chain Dynamics: A Question of the Ultimate Measure of Sustainability

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Abstract

This paper looks at the socio-environmental sustainability of agri-food systems and addresses the key issue of measuring 'sustainability'. The paper begins by providing an overview of the environmental impacts of the global agri-food systems especially focusing on the UK. The author generated a comprehensive analysis of the key hotspots within food systems in a previous paper presented at the 2nd International European Forum on Systems Dynamics and Innovation in Food Networks in 2008. This article takes the discussion further by looking at the key tools for supply chain environmental measurement and contributes establishing a new measure of sustainable production/consumption.

Introduction

Much of the recent management research is grounded in the works of the industrial systems thinkers (Ackoff, 1971). Recent management theories and models, such as Lean (Womack and Jones, 1996; Seddon 2003), Total Quality Management (Juran, 1988), Balanced Scorecard (Kaplan and Norton, 1993), Competitive Advantage (Porter, 1985), Business Process Re-engineering (Hammer and Champy, 1993), and Learning Organization (Senge, 1990) reflect the influence of the new age systems thinkers.

Moreover, the new management paradigms increasingly embrace the metaphor that the firm and its supply chain are a single organism living in a wider environment on which they depend for survival (Morgan, 1986). Nonetheless, this organism metaphor, so prevalent in the management literature, is often restricted to only the human factors of the organization and the human-related exchanges with the surrounding environment reflecting a general lack of focus on issues lying in the domain of sustainable development and sustainable industry in management literature. Galdwin *et al* (1995) refers to the problem as the shared unwritten rule of the management theory reflecting *'an overarching anthropocentric paradigm*' and call for a collective paradigm shift towards a *'sustaincentric paradigm'*. Similarly, David Ehrenfeld refers to this rather bold disassociation between human economic activities and the remainder of the natural world as the *'arrogance of humanism'* (Ehrenfeld, 1981). The paucity of attention to the fact that any economic organization is embedded in the context of the natural environment and the injudicious neglect of the ecosystem services (Costanza *et al*, 1997) is also cited, inter alia, by Robert (2002), Hawken *et al* (1999) and McDonough and Braungart (2002).

Amongst all sectors of our economy, the agri-food production and consumption system has a notably huge impact on natural environment contributing, depending on the economic area, anything between 20% to 50% of global warming potential (Garnett, 2007; Tukker *et al,* 2005) and more than 70% of the freshwater annually withdrawn by humans (Wood *et al,* 2000). This goes against the popular perception that the transportation and primary manufacturing industries are the most environmentally damaging human activities. A study by the World Resource

Institute (WRI) showed that 20-30% of the world's forest areas were converted to agriculture between 1990 and 2000 resulting in extensive species and habitat loss (Wood *et al,* 2000). Soil degradation, including nutrient depletion, erosion, and salination, is widespread. Salt accumulation in soils has damaged 45 million hectares of agricultural land, representing some 20% of the world's total irrigated land. At the same time, many water sources are being polluted by excessive use of fertilizers and pesticides whilst irrigation is draining more water than is being replenished by rainfall, causing water tables to fall (Wood *et al*, 2000). The planet faces the double challenge of increasing food production while continuing to provide much needed environmental goods and services.

Furthermore, in comparison to other sectors, the agri-food system has a disproportionately high socio-environmental footprint relative to its contribution to the overall economy. This relationship is distorted even further when considering the agricultural end of the food chain. For example, a recent European study shows that the food supply-consumption system accounts for 42% of the global warming potential (GWP) across the EU-25 countries (Tukker *et al*, 2005) while representing a much smaller part of EU's economy. In the UK, the agri-food system is estimated to contribute at least 19% of the total UK greenhouse gaseous emissions (Garnett, 2007) while accounting for just over 8% of the GDP or nearly £148 billion of consumer expenditure (DEFRA, 2006). The UK farming sector alone (agriculture and fisheries) contributes around 9% of the total UK global warming potential while representing a mere 0.7% of the GDP (Cabinet Office Strategy Unit, 2008; Garnett, 2007). Moreover, recent studies put the social impacts of the UK food chain, such as congestion and road accidents above its environmental footprint (Cabinet Office Strategy Unit, 2008).

The onus is on the agri-food industry to own up to its disproportionately high socio-environmental footprint. Also, the existing economic supply chain management and analysis toolbox needs to be enhanced to address the environmental effects of the agri-food chains. To begin with, it is essential to identify the key hotspots within the agri-food system for immediate action which in turn requires establishing the right measurement systems and effective diagnosis tools. For example it is important to understand the relative impacts of agricultures, fertilizer manufacturing, freezing and home cooking. The next section will provide a hotspot analysis of the agri-food system.

It is well understood within the management literature that the key driver for improvement is availability of knowledge in the form of measureable facts (Deming, 1982). It is an old adage in management that what cannot be measured cannot be improved. The power of able measurement systems has been long recognised in the arena of economic management (Kaplan and Norton, 1993). The emphasis in measurement systems literature is on developing all-encompassing and accurate yet simple and easy to communicate measures (Hammer, 2007). Nevertheless, the existing environmental measurement systems are far from mature and lack in the principles of inclusivity, accuracy and simplicity. In the UK, in 2005, the Department for Environment, Food and Rural Development (DEFRA) published 68 indicators for measuring sustainability of both domestic and business activities. Rather ironically the document was entitled "Sustainable Development Indicators in Your Pocket" (Defra, 2008). It is, clearly, impossible to effectively target and monitor improvement when 68 different indicators are involved. This paper offers a single measure of sustainability and deploys the proposed measure to compare agri-food systems with other major polluting sectors such as aviation and car transport.

An overview of the Environmental Impacts of Agri-food Systems: Identifying the Key Hotspots

Our economic and industrial practices are profoundly disturbing the ecological balance of the planet in many different ways at the same time that disparities are widening in human society. These socio-environmental challenges range from climate change to loss of bio-diversity to extreme poverty and acute social inequality. However, there is a general consensus amongst environmentalists that climate change is the most pressing environmental crisis of all and that Global Warming Potential (GWP) of human activities is the best measure forward (IPCC, 2007; Foster *et al*, 2006; Garnett, 2007). A seminal report published in 2006 demonstrates that the climate change – resulting from human activities – could shrink the global economy between 5 and 20% now and forever (Stern, 2006). This paper, therefore, focuses on climate change and more specifically on GWP measured in terms of total Green House Gas (GHG) emissions.

However, the new found popular interest in climate change is highly skewed towards areas that are politically visible, such as transport and in particular the evils of air travel. This situation is mirrored within the academic community with an explosion of articles on sustainable transport[1]. Nonetheless, globally only 14% of the GHG's actually result from transport, with as little as 2% coming from aviation, against 32% resulting from agriculture and land use (see Figure 1) a major part of which can be directly attributed to the food chain (Stern, 2006).

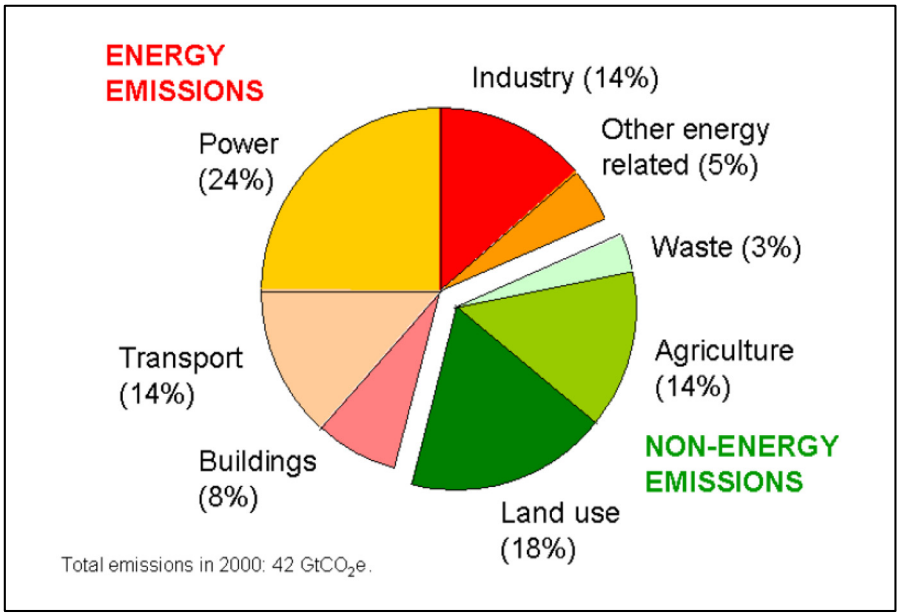

Figure 1. Global GHG Emissions Contribution
(Source: Stern, 2006)

A report published by the European Science and Technology Observatory entitled the Environmental Impact of Products (aka the EIPRO report) looked at the life cycle environmental impacts of all products within the EU-25 countries from the final consumption point of view covering both private and public sector consumers (Tukker *et al*, 2005). The report showed that a staggering 31.0% of the total EU GWP contribution is directly related to the agri-food system (Tukker *et al,* 2005). However, this figure neither includes home cooking and refrigeration nor

1. A literature search carried out in 2008 using the academic search engine 'EBSCO', yielded 552 academic references to Sustainable Transport while for example Sustainable Livestock only found 51.

emissions rising from the catering industry which respectively contribute 2.8% and 8.1%. This study is so far the most thorough review of the EU environmental impacts based on both literature review and extensive data generation. Animal foods such as meat, poultry and dairy products are singled out to contribute more than 50% of food related GHG's, i.e. 17.5% out of 31.0% (see Figure 2).

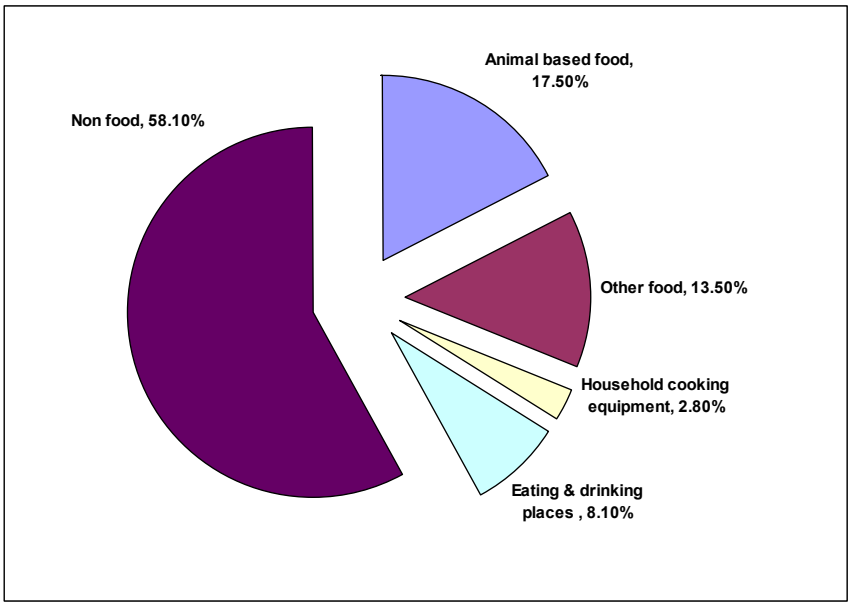

Figure 2. EU-25 GHG emission as per Reported in the EIPRO Study
Source: Tukker *et al,* 2005

This finding is consistent with the Dutch and British data. In Holland Kramer *et al* (1999) demonstrate that certain areas within the agri-food system such as the livestock production are particularly problematic with meat and dairy products contributing similarly over 50% of the total GHG's emitted. In the UK the GHG emissions attributed to meat and dairy consumption are about 8% of the total UK GWP or four times that of the GHG emissions generated from fruit and vegetable consumption (Garnett, 2007).
The authors believes that key agri-food environmental hotspot areas go largely unaddressed. While there are few recent studies drawing attention to the impacts of the biggest polluters in the food system such as primary livestock production (Steinfeld *et al*, 2006; Garnett, 2007 & 2008), there has been very limited input to policy makers and consumers. This is arguably down to a lack of a meaningful measure for sensible policy decisions.

Whereas the food miles issue has received much recent popular and academic debate, arguably the larger food production area goes largely unaddressed (Knowles, 2007). Where there is a focus, it tends to be recent in nature and within deep but disparate and rarely inter-connected narrow pockets. *"Over the next decade, the requirement is to ensure the costs generated by greenhouse gases across the economy are fully priced so that the polluter pays. That means greenhouse gases generated in producing food or in food miles need to be recognised in the same way as greenhouse gases generated in other industries"* (Miliband, 2007).

Therefore, the potential hotspots along the food chain can be summarized as the following (Foster *et al*, 2006; Garnett, 2007; Tukker *et al*, 2005):

- Animal food such as meat and dairy contribute well above 50% of the total agri-food global warming potential (Steinfeld *et al*, 2006; Kramer *et al,* 1999).
- Agricultural and fertilizer manufacturing accounting for nearly 45% of total food related emission (Garnett, 2008).
- Significance of transportation especially air freight in the food chain is reported by Foster *et al* (2006) who argue that – when viewed from a single product standpoint – the impacts of post retail transport (i.e. car based shopping) are greater than that of distribution to the retail point.
- Eating and drinking out have huge impacts within the overall system, i.e. estimated around 20% of the total food GHG's (Tukker *et al*, 2005).

Measuring the Environmental Performance of Agri-food Systems

This contribution so far touched upon the significant environmental impact of agri-food systems and provided an overview of the biggest problem areas within the industry. However, the question remains how to measure the impacts, communicate problems and target improvements? This section addresses the question of the ultimate measure of sustainability.

As mentioned earlier, since global warming is the most pressing environmental crisis of all, this contribution focuses on climate change measured by the total amount of GHG's. In the literature the environmental footprint of products (i.e. total GHG's associated with production and consumption of goods) are expressed in terms of 'CO_2 equivalent'. That is, different green house gases take on different impact factors against the global warming potential of a unit of CO_2. For example the global warming effect of the refrigerant gases are thousands of times greater than Carbon dioxide (CO_2) while Methane (CH_4) and Nitrous oxide (N_2O) GWP values respectively are 21 and 310 where CO_2 has a GWP value of 1 (IPCC, 2007).

Moreover, there are two fundamentally distinct approaches to measuring the environmental impact of products ($CO_{2\text{-eq.}}$): bottom-up and top-down. The bottom-up approach begins with an individual product and conducts a Life-Cycle Assessment (LCA) of it. The results for this particular product are then assumed to be representative for a wider range of products and are extrapolated to a larger family of products. Combined with other LCA's for representative products it is possible to put together a picture of the whole economy. A key weak point of the bottom-up approach, apart from the issue with extrapolation and generalisability, is that the LCA approach inevitably cuts across processes and therefore the researcher needs to make assumptions in terms of the coverage of environmental impacts.

On the contrary, the top-down approach begins with input-output tables at macro-level often produced by statistical agencies. These tables, in the form of matrices, describe production activities in terms of the purchases of each sector from all other sectors (i.e. input-output models). Available models have different degrees of aggregation (between several and several hundred sectors). When matrices also contain data about the emissions and resource use in each sector this information can be used to calculate the environmental impacts of products covering the entire supply chains. (Tukker *et al,* 2005)

The main weak point of the top-down approach is limited availability of suitable input-output tables including the required environmental information and that the products in available input-output tables are typically highly aggregated. For example, the EIPRO study and in many cases the Carbon Trust in the UK adopt a top-down input-output approach, while few other reports such as the so-called "Shopping Trolley" report (Foster *et al*, 2006) take a bottom-up LCA rou-

te. Top-down analysis is more appropriate when creating overview reports in terms of total impact of products or industry sectors. Nonetheless, the top-down approach is permissive in details, disconnected from the ground and non-interventionist. Therefore, the bottom-up approach is preferred in terms of intervention and when it comes to bringing change about.

The other difficulty in understanding the environmental impact of products is that it is often not easy to specify the right unit(s) of measurement, especially when comparing different products. Should emissions ($CO_{2\text{-eq.}}$) be studied per unit of weight or per calorie? For example, on average GHG emissions from a kilo of bread is 980 grams $CO_{2\text{-eq.}}$ (Anderson and Ohlsson, 1999) whereas a kilo of pork meat contributes 5000 grams $CO_{2\text{-eq.}}$ (Cederberg, 2003) and GWP for a kilo of conventional UK beef is estimated at 16 kg $CO_{2\text{-eq.}}$ (Williams *et al*, 2006). On the other hand, a more sophisticated comparison could be looking at emissions per unit of energy (e.g. calories) embodied in our food. However, fatty foods often have high calorific value but poor in nutrients.
It is debatable whether GHG's should be attributed by unit of weight, calorific value or amount of good nutrients? Comparison is extremely difficult if not impossible and the answers will vary depending on the researcher's perspective.

Currently, a number of IT tools have been developed to capture some of these complexities. Nevertheless, these complex computerized calculations are only part solutions. Considering that market price will play a dominant role in regulating the total consumption (and hence pollution), discussions around measurement by weight or calorific value could be a moot point. The aggregate levels of emissions depend of the aggregate levels of consumption which in turn largely depend on pricing. Also, pricing is the key policy leverage point, i.e. taxation against the aggregate level of GHG's or in simple terms 'making the polluter pay'.

The author argues that measuring GWP *per se* is not sufficient and other key parameters should equally be taken into consideration as will be discussed in the following. It is firstly important to understand how – economically – accessible a product is. For example it is clear that aviation is harmful for the environment. But the question is whether the current market value reflects the service cost for flying as well as the costs associated with the resulting pollution.

Actually, there is a school of thought arguing that the cost of flying is considerably cheaper than it should really be once accounting for the socio-environmental externalities. "*The demand for air transport might not be growing at the present rate if airlines and their customers had to face the costs of the damage they are causing to the environment*" (Royal Commission on Environmental Pollution, 1994). Global aviation generates nearly as much CO2 annually as that of all human activities in Africa (WWF-UK, 2006). Research undertaken by the Friends of Earth reveals that the European aviation sector received about £30 billion in subsidies in 2002, both directly through payments for expansions and surface access and indirectly through exemptions from fuel tax and VAT. Currently airlines pay no duty or VAT on aviation fuel, on airline tickets and on new aircrafts. Duty free sales, a tax payer subsidy, also provide up to 50% of airport revenue although all EU flights are now exempt from duty free sales. In the UK airlines would have to pay at least £5 billion a year if they were taxed at the same rate as motorists equal to more than £200 per UK household. Partly as a result of these (hidden) subsidies air travel was 42% cheaper in 2002 than it was in 1992 (Friends of Earth, 2002). It can, therefore, be concluded that aviation is grossly underpriced and '*too accessible*' when normalised for the socio-environmental externalities. By way of example the following looks at the socio-environmental impacts of air transport and animal food.

The neo-economics theory treats all environmental effects as externalities and while absolute GWP indicators are powerful means of measuring the 'external' impact of human industrial activities, a simple unified measure is required to 'internalise' such externalities. A measure that looks at products' global warming potential (GWP) in terms of $CO_{2\text{-eq.}}$ per unit of currency (e.g. $CO_{2\text{-eq.}}$ per £ spent). Using this measure the environmental impact of animal food in the UK is estimated to be 2.69 Kg $CO_{2\text{-eq.}}$ / £ whereas environmental footprint of aviation is estimated to be 2.65 Kg $CO_{2\text{-eq.}}$ / £ [*see* Appendix A for calculations]. This simply means that it is cheaper to pollute by consuming meat and dairy than it is by using air transportation.

It must be noted that the above measurement for animal food and aviation are based on aggregate data; however, it is equally possible to produce $CO_{2\text{-eq.}}$/£ measure based on LCA data for single product families. Whereas, using this measure at an aggregate level is suitable for input into policy decisions, using LCA level data is equally valuable for local intervention, e.g. comparing local produce with oversees products to sense-check custom and tax regimes.

Nonetheless, even $CO_{2\text{-eq.}}$/£ is a relative indicator since free market mechanisms are inherently inequitable. For example, tax policies could not treat food consumption for subsistence and transport for leisure as equals. There is an even more fundamental issue involved in measuring socio-economic sustainability linked into '*the need for the product being consumed*'. The ultimate measure of sustainability of products should, also, account for a third dimension which is the actual need for that product. The author proposes that consumer value should be *judged* against Maslow's hierarch. In this context the following diagram is proposed where the horizontal axis is global warming potential of products normalised against market price, i.e. GWP*(1+1/£). And the vertical axis represents Maslow's co-efficient (1 for physiological needs and 10 for self-actualisation).

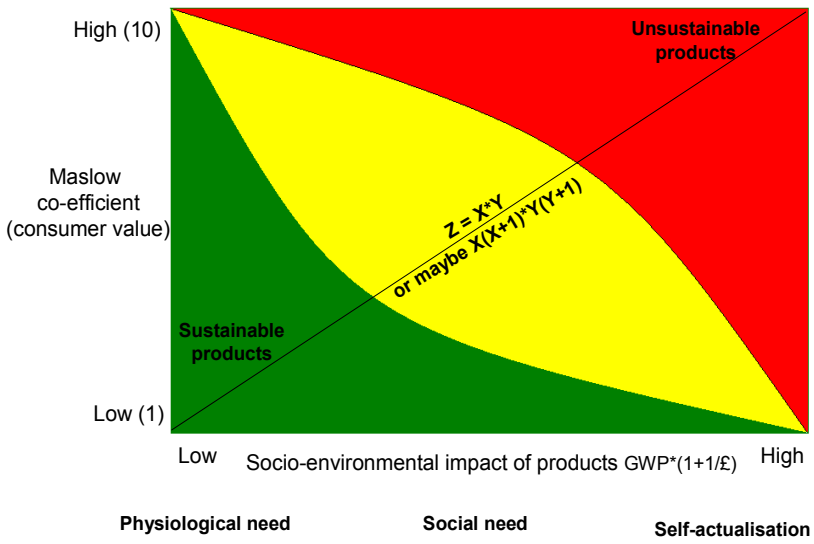

Figure 3. The 'Z' measure of Sustainability

As such it is possible to compare the true socio-environmental impact of products. Referring back to the comparison between air transport and animal food: the 'x' values on the horizontal axis, respectively for animal food and aviation, are 69.9 and 47.6 (GWP + GWP / £). The 'y' values on the vertical axis are assumed to be 4 for animal food and 8 for air travel. Although,

these could seem as arbitrary numbers the measure itself is extremely beneficial especially for policy making. The Maslow co-efficient needs to be established via consensus and by involving all potential stakeholders. Accordingly, the 'Z' measure of sustainability is 279.7 for animal foods and 381.2 for air travel. This means that the ultimate socio-environmental impact of air travel is more than animal foods by about 35% whereas the simple GWP impact of the aviation sector is actually 50% less than animal foods (consumption of animal foods emits 67.23 Million tonnes $CO_{2\text{-eq.}}$ while the GWP of the aviation industry is 45 Mt $CO_{2\text{-eq.}}$).

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Appendix A

GWP/£ for animal-based-foods (meat and dairy):
Based on the UK statistics for food consumption expenditure (DEFRA, 2006) – Meat and dairy expenditure amounts to an average of £7.41 per person per week out of a total food and drinks expenditure of £23.56, excluding eating-out. Hence, the total UK consumer expenditure on animal-based-foods is around £25[1] billion per annum. Data published in (DEFRA, 2006) can be verified by looking at the total estimate of food expenditure and comparing it with IGD figures. The total food expenditure is calculated as £79.6[2] billion based on DEFRA (2006) data which is consistent with IGD (2005) figure (i.e. £78 billion) in Table 1.

Table 1. UK Grocery Retail Sales by Category, 2005 value

Category sales at UK retailers	Sales	%
food and drink	£ 78 bn	65 %
tobacco	£ 12 bn	10 %
non-food grocery	£ 17 bn	14 %
non-grocery	£ 12 bn	10 %
Total retail sales through UK grocery outlets	**£ 120 bn**	

Moreover, according to Garnett (2007) the GWP contribution of meat and dairy is 8% of the total UK GWP or 67.23[3] Mt $CO_{2\text{-eq.}}$. Therefore GWP/£ is 2.69[4] $KgCO_{2\text{-eq.}}$ /£.

GWP/£ for aviation:

Some 85 million UK passengers fly every year (Dft, 2007; CAA, 2006). Here, 'UK passengers' refers the number of times that people who live (permanently or semi-permanently) in the UK using air travel. This ought not to be confused with the number of 'terminal passengers' which is related to, but not the same as, the number of trips by air to and from the UK. For example, a passenger making a direct, one way trip from the UK to an overseas destination would count as one terminal passenger, while a domestic direct one-way trip would count as two terminal passengers. It is assumed that on average the UK passengers spend £200 per flight. So the UK consumers' expenditure on aviation is estimated at £17 billion.

Moreover, the GWP of air travel is calculated for the UK based on data published by Carbon trust. Carbon Trust (2006) data shows that some 40 $MtCO_2$ is attributable to emission from fuel consumed by airlines registered in the UK (see the following diagram). Unfortunately, despite its national prominence, this calculation is surprisingly inaccurate. What about passengers travelling with non-UK registered airlines? Moreover the figure includes both freight and personal travel. Freight should be allocated to functional use such as food, industry, etc. Much worse, non CO_2 emissions are not included in the figure. The author estimates aviation's total GWP at 45 $MtCO_{2\text{-eq.}}$ Based on various assumptions. Therefore, GWP/£ for aviation equals 2.65 $KgCO_{2\text{-eq.}}$/£ which is lower than meat and dairy.

As a caveat it must be noted that Radiative Forcing Impact (RFI) has not been taken into account in calculations. At high altitudes, aviation's non CO_2 emissions such as NOx and contrail for-

1. That is, £7.41 x 52 x 65,000,000.
2. That is, £23.56 x 52 x 65,000,000. The total food expenditure is calculated as £79.6 billion.
3. That is, 8% of the total UK GHG emissions which is 229 MtC-eqv. Based on Garnett (2007).
4. 67.23 MtCO2-eqv. divided by £25 billion.

mation have an additional contribution to climate change above that of CO_2 alone. To account for this extra impact, an RFI factor of aviation at altitude needs to be applied which has been calculated between 1 and 4 in different sources (IPCC, 2007).

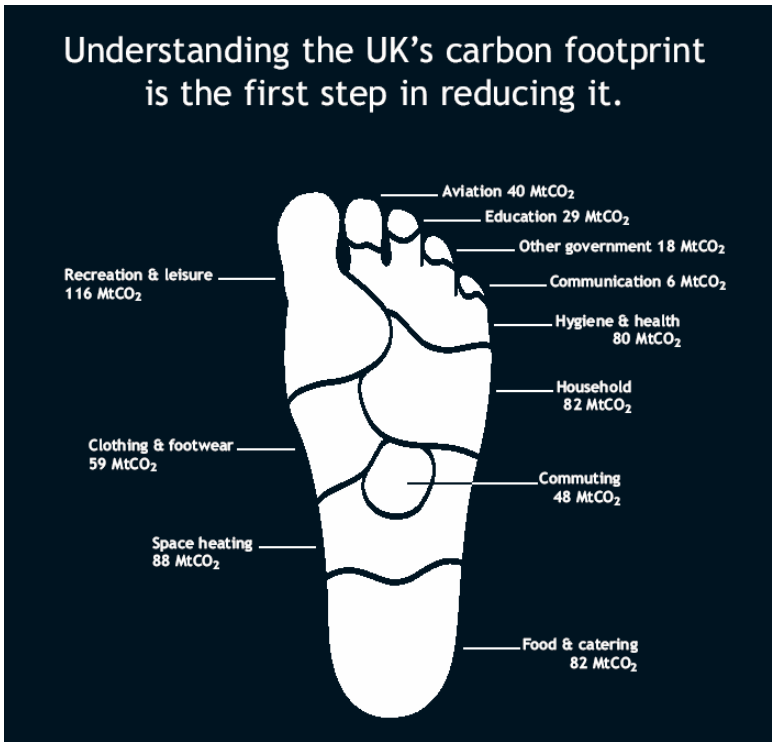

Figure 4. UK Consumers' Environmental Footprint
(Carbon Trust, 2006)